Université de Lille

Ecole Doctorale des Sciences de l'Homme et de la Société

Laboratoire SCALab, UMR CNRS 9193

Promoting the acquisition of vocabulary in a foreign language: evidence for an early benefit of orthography on L2 spoken and written word learning in elementary-school children

Thesis work presented on December 14th 2021 for the degree of Doctor of Psychology

Florian Salomé

Committee :

Pr. Séverine Casalis, Université de Lille, France	Supervisor
Dr. Eva Commissaire, Université de Strasbourg, France	Co-supervisor
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Pr. Peter de Jong, University of Amsterdam, Netherlands	Rapporteur
Pr. Jon Andoni Duñabeitia, Universidad Nebrija, Spain	Rapporteur
Dr. Jessie Ricketts, Royal Holloway University London	Reviewer

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Remerciements

Je souhaiterais adresser mes plus sincères remerciements au Professeur Séverine Casalis, ma directrice de thèse, qui, par sa confiance, m'a permis de m'épanouir sur ce sujet de recherche. Savamment, vous avez su me sensibiliser à la recherche dans le champ du bilinguisme à mon retour de mobilité ERASMUS, il y a déjà sept ans, par l'intermédiaire d'un mémoire sur la morphologie décompositionnelle. Je vous suis particulièrement reconnaissant de m'avoir fait profiter de vos conseils avisés, de votre expertise, de votre bienveillance (sur le plan personnel et professionnel), mais également de m'avoir permis de profiter de l'autonomie dont j'avais besoin. Mes remerciements sont également adressés au Docteure Eva Commissaire pour son co-encadrement et son accueil lors d'un Indoc au sein du laboratoire LPC de l'Université de Strasbourg, mais également pour sa disponibilité, sa culture et rigueur scientifiques.

I am also very grateful to Pr. Fabienne Chetail, Pr. Peter de Jong, Pr. Jon Andoni Duñabeitia, and Dr. Jessie Ricketts for the time spent in the reviewing of this work. Thank you very much for accepting to be members of my PhD Thesis committee.

Je remercie également l'Agence Nationale de la Recherche pour avoir financé le projet APPREL2 dont fait partie ma thèse. Je remercie également le laboratoire SCALab, l'Université de Lille, ainsi que l'école doctorale Sciences de l'Homme et de la Société pour les aides financières et matérielles, ainsi que pour les formations, qui m'ont permis de mener à bien ce doctorat.

Cette thèse n'aurait pas été possible sans l'aide et la collaboration des inspecteurs de l'Education Nationale, des conseillers pédagogiques, des directeurs et directrices des établissements élémentaires, des enseignants et enseignantes, mais également des élèves. Je souhaitais adresser un remerciement particulier à Mr. Thierry Mercier, inspecteur de l'Education Nationale de Valenciennes centre, ainsi qu'à Mme Cécile Panczak, conseillère pédagogique pour l'intérêt que vous avez montré pour ce projet de recherche.

J'adresse également mes remerciements aux membres du projet APPREL2 pour la richesse de nos échanges tout au long de cette thèse. Professeure Heather Hilton, votre expertise dans la didactique des langues et nos discussions m'ont permis de prendre la mesure de la multifactorialité des difficultés associées à l'apprentissage des langues étrangères en milieu scolaire. Je vous remercie également pour votre intérêt scientifique pour mon sujet de thèse,

ainsi que pour vos encouragements, notamment dans les dernières semaines de rédaction : une fois de plus, vous aviez raison !

I would like to extend my thanks to Pr. Angèle Brunellière and to Pr. Dr. Pienie Zwitserlood for accepting to take part to my thesis follow-up committee, as well as for your implication and your scientific advises. Angèle, je souhaitais vous adresser un remerciement plus personnel pour avoir été présente dans les moments de doute et pour votre écoute.

Je tiens également à adresser mes remerciements au laboratoire SCALab, et plus particulièrement aux membres de l'équipe Langage pour la richesse des échanges, vos conseils et votre expertise. Un remerciement particulier adressé au Pr. Dominique Knutsen pour ses conseils en matière d'analyses statistiques, mais surtout pour sa bienveillance et sa bonne humeur. Emmanuelle, Sabine, vous êtes l'âme de ce laboratoire, toujours présentes et disponibles pour nous accompagner au quotidien dans la bonne humeur, un grand merci.

Mes remerciements sont également adressés à l'ensemble de mes collègues doctorants, à ceux qui m'ont précédé et ceux qui me suivront. Cécile, Cynthia, Gary, Marc, nos échanges ont vraiment contribué à faire de ces années de thèse une formidable aventure humaine.

Alicia et Camille, mes collègues et amies, passer ces années de thèse en votre compagnie a été particulièrement enrichissant, vous avez su être présentes dans les réussites et les moments plus difficiles. Beaucoup de rires, les soirées post-congrès, les vacances à Montréal, vous avez été (et êtes) les pilliers de ma vie de doctorant. Camille, beaucoup saluent ta rigueur, ton organisation, ton endurance professionnelle, toutes ces qualités qui font, que travailler à tes côtés est inspirant et un plaisir. Peu connaissent ta créativité, ton humour et ce petit grain de folie dont tu nous as fait profiter. Alicia, te côtoyer m'a permis de devenir bilingue français-Rassel : rien ne vaut l'immersion linguistique pour progresser rapidement. Merci pour ton soutien, pour ces nombreux cafés « décompression » et toutes ces anecdotes « Loup-phoque ». Participer au cabaret des sciences avec vous m'a laissé sans voix !

Pour conclure, mes remerciements les plus chaleureux sont adressés à ma (belle-) famille, mes amis, Charles, Marine et Marion pour votre présence, votre écoute et vos conseils. Un remerciement plus personnel encore à Pierre qui, par sa présence et ses attentions au quotidien m'a soutenu dans les moments de doute, de détresse, mais aussi d'avancées et de joie. Partager ces expériences avec toi, c'est ma définition du bonheur ! Merci à vous tous.

Sans votre présence, cette thèse n'aurait pas pu être menée à son terme. Je vous remercie toutes et tous d'avoir contribué de près ou de loin à rendre cette aventure aussi agréable au quotidien.

English summary

The contribution of orthography has been reported for learning of low-frequency words in native language (L1; Rosenthal & Ehri, 2008) and of pseudowords (Ricketts, Bishop, & Nation, 2009) by using a paired-associate learning paradigm (PAL). These studies cannot fully account for foreign language (L2) word learning, for which both L2 spoken and written forms have to be linked into a pre-existing concept, which in turn, is already connected to phonological and (sometimes) to an orthographic representation in L1. Besides, L2 learning confronts children to different challenges, such as incongruent letter/sound mapping with L1, due to the larger overlap on written than on spoken modality between languages (Marian et al., 2012). Therefore, this doctoral work aimed to explore the benefit of orthography on L2 word learning in children and to determine whether this advantage was modulated by L1 reading skills. We also sought to determine the moderating effect of incongruent letter/sound mappings with L1 on L2 learning. Using a PAL, we conducted three main L2 vocabulary learning studies by contrasting two learning methods, both simultaneous presentation of spoken and written (orthographic method) vs spoken forms only (non-orthographic method). As for learning phase, we made two groups of children (third vs. fifth graders) learn 16 (Study 1a) or 24 German words (Study 1b, Study 2). As for testing, we assessed learning performance with three main experimental tasks: a forced-choice picture recognition task (choose the correct image corresponding to the spoken form), a go/no-go spoken recognition task (discrimination between spoken German words and close phonological distractors) and an orthographic judgment task (select the correct German written form among three written distractors). We reported a consistent benefit of orthography on all three experimental tasks in both groups, supporting that children relied on written information at early steps of L2 learning. Still, contradictory results were reported for phonological learning in fifth graders, given that the benefit of orthography was only retrieved when increasing the learning load (Study 1b). Interestingly, although fifth

graders outperformed the third graders on all experimental tasks, we reported a comparable amplitude for the orthographic facilitation in both groups. Measures of L1 reading skills were not (consistently) correlated with L2 vocabulary learning, supporting that a minimal amount of orthographic knowledge was enough to trigger an orthographic facilitation. A moderating effect of incongruent letter/sound mappings with L1 was restricted to L2 phonological learning, with larger discriminative performance for congruent compared to incongruent L2 words immediately after learning (Study 2), but disappeared after a one-week delay, aiming for a differential time-course for the encoding of congruent and incongruent L2 words, an assumption that was discussed in regards to the ontogenetic model of L2 lexical representation (Bordag, Gor, & Opitz, 2021) and to the L2 lexical fuzziness (Kapnoula, 2021). Study 3 was conducted during an Indoc mobility and explored whether the bilingual advantage on L3 vocabulary learning might be extended to children attending a classroom-immersion to L2 and whether this advantage was reinforced by the cross-linguistic similarities conveyed by cognate words. We reported a generalized advantage and cognate facilitation was restricted to the learning of novel L3 written form. In light of these results, this doctoral work reinforced the need for developmental models of bilingualism to consider the lexical and sublexical processing at early steps of L2 acquisition.

Keywords: L2 vocabulary learning, orthographic facilitation, spoken and written word recognition, grapheme-to-phoneme incongruency, paired-associate word-learning paradigm

Résumé français

La contribution de l'orthographe a été rapportée pour l'apprentissage de mots de faible fréquence en langue maternelle (L1 ; Rosenthal & Ehri, 2008) et de pseudomots (Ricketts, Bishop, & Nation, 2009) en utilisant un paradigme d'apprentissage par paires associées (PAL). Ces études ne peuvent rendre compte de l'apprentissage de mots en langue seconde (L2), pour lequel les formes orales et écrites en L2 doivent être reliées à un concept préexistant, lui-même relié à une représentation phonologique et (parfois) orthographique en L1. En outre, l'apprentissage d'une L2 confronte les enfants à d'autres défis, notamment aux incongruences entre les lettres et les sons, en raison d'un chevauchement plus important entre les langues à l'écrit par rapport à l'oral (Marian et al., 2012). De ce fait, cette thèse a exploré le bénéfice de l'orthographe sur l'acquisition de mots en L2 chez l'enfant et si cet avantage était modulé par les compétences en lecture. Le rôle modérateur des incongruences lettres/sons sur l'apprentissage de la L2 a également été investigué. À l'aide du PAL, nous avons mené trois études d'apprentissage du vocabulaire en L2 en contrastant deux méthodes d'apprentissage, à savoir la présentation simultanée de formes orales et écrites (méthode orthographique) et les formes orales uniquement (méthode non orthographique). En ce qui concerne la phase d'apprentissage, nous avons exposé deux groupes d'enfants (CE2 vs. CM2) à 16 (étude 1a) ou 24 mots allemands (étude 1b, étude 2). Les performances d'apprentissage étaient évaluées à l'aide de trois épreuves : une tâche de reconnaissance d'images en choix forcé (choisir l'image correcte associée à la forme orale), une de reconnaissance orale en go/no-go (discriminer entre les mots allemands et les distracteurs phonologiquement proches) et une de jugement orthographique (choisir la forme correcte du mot écrit parmi trois distracteurs). L'avantage orthographique a été montré pour les trois tâches chez les enfants, suggérant qu'ils s'appuyaient sur l'orthographe dès les premières étapes de l'apprentissage de la L2. Cependant, des résultats contradictoires ont été rapportés pour l'acquisition de la forme phonologique chez les CM2,

sachant que l'avantage de l'orthographe n'était retrouvé qu'après avoir augmenté la charge d'apprentissage (étude 1b). Notons que, bien que les CM2 surpassaient les CE2 pour l'ensemble des tâches, l'amplitude de la facilitation orthographique était similaire entre les deux groupes. Les compétences en lecture n'étaient pas (systématiquement) corrélées à l'apprentissage du vocabulaire en L2, indiquant que la facilitation orthographique ne nécessitait qu'une faible connaissance de l'orthographe. L'effet modérateur des incongruences lettres/sons avec la L1 était limité à l'apprentissage de la forme orale en L2, avec de meilleures performances discriminatives pour les mots congruents par rapport aux incongruents immédiatement après l'apprentissage (étude 2). Il disparaissait toutefois après une semaine de délai, ce qui plaide pour un encodage différé des mots incongruents par rapport aux congruents, comme l'a postulé le modèle ontogénétique de la représentation lexicale en L2 (Bordag, Gor, & Opitz, 2021) et le lexical fuzziness (Kapnoula, 2021). L'étude 3, menée lors d'un Indoc, visait à déterminer si l'avantage bilingue sur l'apprentissage du vocabulaire en L3 pouvait être étendu aux enfants en immersion linguistique à la L2 en milieu scolaire, mais si cet avantage était renforcé par les similarités interlinguistiques en lien avec les mots cognates. Nous avons montré un avantage généralisé sur l'apprentissage de la L3, sachant que l'effet de facilitation cognate se limitait à l'apprentissage de la forme écrite. À la lumière de ces résultats, cette thèse a souligné la nécessité pour les modèles développementaux du bilinguisme de prendre en compte les traitements lexicaux et sub-lexicaux dès les premières étapes de l'acquisition de la L2.

Mots clefs: apprentissage du vocabulaire en langue seconde, facilitation orthographique, reconnaissance de mots à l'oral et à l'écrit, incongruence entre les graphèmes et les phonèmes, paradigme d'apprentissage par paires associées.

Résumé substantiel en français

Apprendre une langue étrangère, ainsi que les méthodes pédagogiques en lien avec cet apprentissage sont un des enjeux majeurs de ce siècle (Scott & Beadle, 2014), dans un monde où le bilinguisme est en passe de devenir la norme mondiale (Baker, 2001) et au sein duquel nous sommes exposés à une multitude de sources multilingues dans un contexte professionnel mais également personnel. Bien que le fait d'être bilingue favorise, dans l'imaginaire collectif, les opportunités professionnelles, il est important de souligner que la compétence en langue seconde reste particulièrement faible, notamment en France, avec de fortes différences entre les individus et les pays. En effet, une évaluation réalisée à la demande de la Commission Européenne et menée par Surveylang (2011) sur les compétences des élèves de troisième en langue seconde (compréhension orale et écrite, production, écrite) a mis en évidence que, parmi les 16 pays candidats (Allemagne, France, Italie, Malte, Roumanie, Suède, entre autres), il y en avait six au sein desquels plus de 20% des adolescents testés ne parvenaient pas à atteindre le niveau d'utilisateur élémentaire (A1). Il est à noter qu'en 2005, la Commission Européenne avait fixé pour objectif commun sur 15 ans que la plupart des citoyens européens devaient atteindre un niveau d'utilisateur indépendant (B1). En 2012, seuls 14% des adolescents français honoraient cet objectif.

En France, comme dans la plupart des pays européens, l'apprentissage de la langue étrangère se fait principalement dans un contexte académique, caractérisé par une faible exposition à la langue seconde, du fait des contraintes logistiques en lien avec ce type d'apprentissage. Par ailleurs, depuis la rentrée 2016, les élèves français sont exposés à une première langue étrangère dès le CP et à une seconde dès la 5ème. De plus, l'inclusion de la modalité écrite n'a lieu qu'à la fin du troisième cycle (CM1, CM2). Toutefois, l'exposition à l'écrit devient dominante à compter de l'entrée dans l'enseignement secondaire. L'apprentissage de la langue seconde se produit donc rarement par l'intermédiaire d'une présentation simultanée de la modalité écrite et orale alors qu'il est communément accepté que la maîtrise d'une langue repose sur des compétences en matière de communication écrite et orale.

A l'heure actuelle, alors que de nombreuses études ont mis en évidence les différents mécanismes impliqués dans l'apprentissage de la langue maternelle, ainsi que la contribution de certains facteurs sur ces apprentissages, nos connaissances restent particulièrement limitées lorsqu'il s'agit de l'apprentissage du vocabulaire en langue étrangère. En effet, le bilinguisme a été jusqu'à présent documenté soit par l'intermédiaire des modèles cognitifs bilingues de la reconnaissance écrite (BIA, BIA+) et orale de mots (BIMOLA), sachant que ceux-ci sont centrés sur une population d'adultes bilingues ayant un niveau de compétence relativement élevé au sein des deux langues ; soit par des modèles développementaux, postulant que l'accès au lexique de la langue seconde se ferait par médiation de la langue maternelle, par l'intermédiaire d'un lien lexical direct entre les deux lexiques (en L1 et en L2) pour le cas de bilingues séquentiels. Ces modèles, dans leur forme actuelle, ne permettent donc pas de rendre compte de la manière dont les représentations lexicales et sous-lexicales sont acquises lorsque la langue maternelle n'est pas encore totalement maitrisée.

L'apprentissage du vocabulaire en langue seconde peut confronter les enfants à des challenges différents de ceux rencontrés lors de l'acquisition de la langue maternelle. En effet, alors que l'apprentissage du vocabulaire en L1 repose sur l'association d'une forme orale à son concept et (accessoirement) à sa forme écrite dès lors que la lecture a été acquise, celui-ci nécessite en L2 que l'enfant encode and stocke de nouvelles formes orales et écrites, elles-mêmes associées à un concept préexistant, lui-même relié à une représentation phonologique et (parfois) orthographique en L1. En outre, l'apprentissage d'une L2 confronte les enfants à d'autres défis, notamment aux incongruences entre les lettres et les sons, en raison d'un chevauchement plus important entre les langues à l'écrit par rapport à l'oral (Marian et al., 2012). Ainsi, il nous est apparu important de déterminer si la présence de la forme écrite favorise l'apprentissage de mots dans une langue étrangère, et si c'est le cas, il est important de pouvoir le dissocier d'un avantage purement visuel. En effet, la présentation de la forme écrite pendant l'apprentissage apporte une source visuelle supplémentaire pouvant favoriser l'apprentissage du vocabulaire en L2. Ce sujet revêt un intérêt particulier, sachant qu'il permettra d'apporter une meilleure compréhension des mécanismes en jeu lors de l'apprentissage d'une langue étrangère et qui pourrait ainsi à terme donner lieu à des préconisations pédagogiques sur l'adaptation de nouvelles méthodes d'apprentissage de la langue étrangère.

Les études précédentes se sont particulièrement intéressées au bénéfice de l'orthographe, communément appelé facilitation orthographique, sur l'apprentissage de mots de faible fréquence en langue maternelle (Rosenthal & Ehri, 2008) ainsi que sur celui de pseudomots (Ricketts, Bishop, & Nation, 2009) pour lesquels les représentations sémantiques sont faiblement spécifiées. De ce fait, les conclusions en lien avec les études d'apprentissage du vocabulaire en L1 sont difficilement généralisables à l'apprentissage du vocabulaire dans une langue seconde. Toutefois, à l'heure actuelle, une seule étude a tenté de déterminer la contribution de l'orthographe sur l'apprentissage du vocabulaire en langue seconde (Hu, 2008). Bien que les résultats fussent prometteurs, cette étude incluait de multiples biais méthodologiques. Premièrement, les participants présentaient des différences importantes en ce qui concerne leur profil linguistique, étant donné qu'ils avaient été exposés à l'anglais pendant au moins deux ans avant l'étude et qu'il y avait une large variabilité de programmes pédagogiques en L2. Par ailleurs, les auteurs ne faisaient apprendre que six pseudomots, dont trois en présence de l'orthographe. De même, chacun de ces mots était présenté à de multiples reprises et de manière déséquilibrée entre les participants (d'une à dix présentations pendant l'apprentissage). A ce titre, les résultats de Hu (2008) doivent être interprétés avec prudence et d'autres études sont requises pour confirmer et étendre ces résultats préliminaires.

Le présent manuscrit de thèse, rédigé en vue de l'obtention du titre de docteur en psychologie est organisé de la manière suivante. Une revue de la littérature a été effectuée. Celle-ci est organisée en trois chapitres, abordant chacun une thématique permettant de comprendre le contexte théorique sur lequel s'inscrit notre contribution expérimentale. Dans le premier chapitre, nous avons ainsi abordé la contribution des connaissances en vocabulaire sur l'acquisition de la lecture et la maîtrise de l'écrit, ainsi que celle de l'orthographe sur l'apprentissage de mots en langue maternelle. Le second chapitre avait pour objectif de faire le lien entre les traitements langagiers en langue seconde et l'acquisition du vocabulaire en L2, mais également de faire un état des lieux des modèles cognitifs et développementaux du bilinguisme. Enfin, le troisième chapitre associé au contexte théorique avait pour objectif de faire le parallèle entre le bilinguisme et l'immersion linguistique à la langue seconde en présentant les études menées sur l'avantage du bilinguisme sur l'apprentissage du vocabulaire dans une seconde langue étrangère (L3). Après avoir fait l'état de l'art, le présent manuscrit consigne les différentes contributions empiriques de mon travail de recherche effectué au cours de mon doctorat, qui est réparti sous la forme de trois chapitres. La population d'intérêt était constituée d'enfants francophones natifs et scolarisés en classe de CE2 (Etude 1) et de CM2 (Etude 1 à 3), lesquels n'avaient pas de connaissances préalable en langue allemande en amont de l'étude (Etude 1 et 2) ou en anglais pour l'étude 3 menée auprès d'enfants en immersion linguistique à l'allemand dans un contexte scolaire. Pour l'ensemble de ces trois études, nous avons utilisé un paradigme d'apprentissage de mots par paires associées, ainsi que trois tâches expérimentales principales, à savoir une tâche de reconnaissance d'images en choix forcé (choisir l'image correcte associée à la forme orale), une tâche de reconnaissance auditive en go/no-go (discriminer entre les mots allemands et les distracteurs phonologiquement proches) et une tâche de jugement orthographique (choisir la forme correcte du mot écrit parmi trois distracteurs). Notons que les études d'apprentissage ont été menées en langue allemande pour deux raisons principales. Premièrement, du fait de la transparence orthographique de l'allemand, cela nous permettait de manipuler le degré de congruence entre les graphèmes et les phonèmes par rapport au français, tout en gardant une consistance des correspondances lettres/sons entre les mots allemands. Deuxièmement, nous avons également fait ce choix, étant donné la faible attractivité de l'allemand par rapport à la langue anglaise et à l'espagnol (voir le rapport MENJS-MESRI-DEPP, RERS 2020, qui montre que seuls 9 % des étudiants français ont fait le choix de l'allemand comme langue étrangère au cours de leur cursus, alors qu'ils étaient plus de 99 % à avoir choisi l'anglais et à 35 % pour l'apprentissage de l'espagnol). Cela nous assurait donc de la faible probabilité pour les enfants d'avoir acquis des connaissances préalables en allemand en amont de l'étude d'apprentissage.

Au sein du chapitre 4, nous avons dissocié notre étude dite princeps en trois sous-études. La première (étude 1a) visait à déterminer si la présence de la forme écrite favorisait l'apprentissage du vocabulaire en langue seconde, et ce, pour l'acquisition de la forme écrite et orale des mots allemands mais également pour la connexion réciproque entre la forme phonologique en L2 et la sémantique. Le niveau d'adéquation entre la forme écrite et sa représentation orthographique encodée a également été exploré. Cette étude visait également à déterminer si le bénéfice de l'orthographe était modulé par les compétences langagières et cognitives associées au niveau scolaire (effet du grade), mais également par le niveau de compétence en lecture. Pour ce faire, nous avons fait apprendre 16 mots allemands à des enfants de CE2 et de CM2 en contrastant deux méthodes d'apprentissage : une méthode orthographique, caractérisé par la présentation simultanée de la forme écrite et orale des mots en association avec leur concept, et une méthode non-orthographique, pour laquelle l'information écrite était remplacée par une série de symboles indéchiffrables (#####). La deuxième sous-étude (étude 1b) avait pour objectif de déterminer si l'augmentation de la charge d'apprentissage (passer de 16 à 24 mots allemands) modulait l'avantage orthographique rapporté pour l'étude 1a. Cet objectif permettait ainsi de répliquer les données expérimentales et de valider l'adéquation du paradigme expérimental avec les études d'apprentissage du vocabulaire en langue seconde. De plus, nous avons également exploré si le bénéfice de l'orthographe était modulé par le degré d'incongruence des correspondances entre les graphèmes et les phonèmes par rapport à la L1. La troisième sous-étude avait pour objectif de fixer les paramètres expérimentaux, notamment le le degré optimal d'exposition à la langue seconde permettant l'apprentissage de ces mots et ce, en fonction de la charge d'apprentissage (16 vs. 24 mots allemands). Les résultats à cette étude princeps montraient un effet consistent de l'orthographe sur l'apprentissage de la forme écrite et de la sémantique (connexion entre phonologie et sémantique) chez les CE2 et les CM2. Par ailleurs, bien que retrouvé auprès des CE2 indépendamment de la charge d'apprentissage, le bénéfice de l'orthographe n'était retrouvé pour la charge d'apprentissage la plus élevée (24 mots allemands), suggérant que jusqu'à un certain point, les participants étaient capables de réussir la tâche sans se reposer sur l'orthographe. Toutefois, lorsque la charge d'apprentissage dépassait ce point, alors les capacités cognitives des CM2 étaient « dépassées », raison pour laquelle la présence de l'orthographe favorisait l'apprentissage de nouvelles formes phonologique. Par ailleurs, le bénéfice de l'orthographe ne semblait pas modulé ni par le grade, ni par le niveau de compétence en lecture. Bien que surprenant au premier abord, ces résultats sont finalement consistants avec les précédentes études qui ont montré que l'avantage orthographique était retrouvé auprès d'enfants présentant des difficultés d'apprentissage (Ricketts et al., 2015) ou une dyslexie (Baron et al., 2018). Ces résultats suggèrent donc que le bénéfice de l'orthographe ne nécessite qu'un niveau minimal de connaissances de l'écrit pour pouvoir être observé. Nous avons de ce fait mis en évidence un effet facilitation de l'orthographe présent dès les premières étapes d'apprentissage de la langue seconde. Par ailleurs, il ne semblait pas y avoir de modulation de l'avantage orthographique par le degré de congruence des correspondances lettres/sons.

Le chapitre 5 incluait la deuxième étude, qui visait initialement à déterminer plus précisément l'effet modérateur de la congruence sur l'effet de facilitation orthographique sur l'apprentissage du vocabulaire en langue seconde. Pour ce faire, nous avions sélectionné des mots allemands qui présentaient soit un haut degré d'incongruence lettres/sons avec la L1, soit un haut niveau de congruence. A titre d'exemple, le mot allemand <Kamm> était considéré comme hautement congruent, étant donné qu'il était possible d'accéder à sa prononciation correcte (/kam/) en s'appuyant sur les CGP du français. A contrario, le mot allemand < Zaun,> était fortement incongruent avec les CGP françaises, sachant qu'en s'appuyant sur les CGP françaises (/zon/), les enfants devraient produire une prononciation éloignée de celle attendue en allemand (/tsao̯n/). Toutefois, du fait de la crise sanitaire, nous avons dû stopper les inclusions expérimentales précocement et seuls 19 participants ont été inclus dans l'étude (tous avaient pris part à un apprentissage du vocabulaire en présence de la forme écrite des mots). Les résultats préliminaires montraient une absence d'effet de la congruence sur deux des trois tâches expérimentales. Toutefois, pour la tâche de reconnaissance orale en go/no-go, nous avons mis en évidence de meilleures performances discriminatives pour les mots congruents par rapport aux mots incongruents immédiatement après apprentissage. Toutefois, ce « désavantage » pour les items incongruents disparaissait après une semaine de délai, suggérant un encodage différent pour les mots incongruents, en lien avec le postulat du modèle ontogénétique de la représentation lexicale en L2 (Bordag et al., 2021), mais également laissant penser à un effet bénéfique de la consolidation « offline » associée à un passage favorisée de la mémoire à court terme à l'intégration de la forme dans le lexique (Brown et al., 2012 ; Henderson et al., 2012). Toutefois, à l'heure actuelle, il apparaît difficile de déterminer si cet avantage est relié à l'orthographe per se, à la consolidation offline en lien avec le sommeil, ou à une contribution double de l'orthographe et de la consolidation offline. Des études futures sont donc nécessaires pour confirmer ces résultats, sachant qu'en l'état, il est nécessaire de prendre du recul par rapport à ces résultats préliminaires.

Le chapitre 6 incluait la troisième qui a été menée lors d'un Indoc au sein du laboratoire de Psychologie cognitive de l'Université de Strasbourg. Cette étude visait à déterminer si le fait de faire l'expérience d'une immersion linguistique à la langue seconde dans un contexte scolaire favorisait l'émergence de l'avantage bilingue sur l'apprentissage du vocabulaire en L3. Par ailleurs, nous nous demandions si les similarités cross-linguistiques portées par les mots cognates pouvaient accentuer plus encore cet avantage bilingue. Contrairement à nos attentes, l'avantage bilingue a été retrouvé pour deux des trois tâches indépendamment de la nature cognate ou non des mots entre la L2 et la L3, plaidant pour un avantage généralisé à l'ensemble des items. Toutefois, pour la tâche de jugement orthographique, l'avantage bilingue était limité aux mots cognates. Bien que limité, cet effet cognate plaide en faveur d'une activation de la langue seconde lors de l'apprentissage d'une L3, en accord avec le scaffolding account (Bartolotti et al., 2018).

Ces différentes études ont été discutées en appuyant sur la nature de l'avantage orthographique, sur la forte interaction entre l'écrit et l'oral en lien avec le recodage phonologique, mais ont également permis de mettre en avant la nécessité pour les modèles développementaux du bilinguisme d'inclure un niveau de traitement lexical et sublexical précoce pour rendre compte des dynamiques d'apprentissage en langue seconde dès les premières étapes d'exposition à la langue seconde. Cette thèse, aussi modestement que possible, a permis d'ouvrir la porte à des recherches futures afin de mieux comprendre le bénéfice de l'orthographe.

Sommaire

LIST OF THE TABLES

LIST OF FIGURES

LIST OF APPENDICES

Foreword

The present doctoral work is part of the APPREL2 project, which aimed to account for the learning and the development of lexicon in a foreign language (L2) at the early steps of classroom instruction. This academic learning is characterized by a weak exposure to foreign language (around 1.5 hour/week) and for which the written modality is included from Grade 4.

With this doctoral work, we wanted to explore the acquisition of L2 vocabulary and to determine the contribution of orthography on L2 word learning. More precisely, this thesis work aimed to assess whether the presence of written information promoted the acquisition and memorization of L2 words, especially for the learning of L2 spoken and written forms as well as the (reciprocal) L2 phonology to semantics connection. In addition, we also supposed that the contribution of orthography on L2 vocabulary learning may be modulated by several factors, especially the cross-linguistic dissimilarities (incongruent letter/sound mappings) and similarities (cognateness), as well as L1 linguistic skills, i.e., degree of reading automatization and vocabulary size.

The general objectives of this doctoral work were a) to determine whether the presence of written form helped children (fifth vs. third graders) to learn L2 vocabulary at initial steps of foreign language learning, b) to identify whether this learning advantage was modulated by the degree of reading automatization, c) or by the degree of grapheme/phoneme congruency with L1, d) to set the best experimental parameters (size of the learning list vs. degree of exposure to each L2 word) to conduct reliable L2 vocabulary learning studies by using a paired-associate word-learning paradigm. An additional objective came from the opportunity to take part to an Indoc research mobility at the Cognitive psychology lab of the University of Strasbourg by investigating L2/L3 word learning among two groups of fifth graders, including children attending a linguistic immersion to foreign language and monolingual children who learned L2 in a traditional school context.

Therefore, this doctoral work proposed a first assessment of the contribution of orthography on the learning of L2 vocabulary by using a paired-associate word-learning paradigm among fifth and third graders from a large variability of French elementary schools.

General introduction

Since the creation of the European Union in the 20th century and the free movement of people across countries, multilingualism has become a basic element in our culture, through Internet, publicity, social media, videogames and cultural and sports events in a global scale, but also through multiliterate immigration. According to Baker (2001), two-thirds of the worldwide population would be at least bilingual. Interestingly, in society's imaginary, being able to communicate in and to understand a foreign language is associated with a success factor, given that it may provide large professional opportunities.

According to 84 % of Europeans, everyone should have acquired enough proficiency to communicate at least in one language other than their native language (European Commission, 2012). However, at European level, an objective investigation of proficiency in foreign languages has been conducted at the end of secondary school among adolescents from 14 European countries, revealed large differences in L2 proficiency across European countries (see European Survey on Language Competence, ESCL, 2012). Indeed, the proportion of adolescents who reached a level of L2 proficiency equivalent to an independent linguistic user (B1 level according to the Common European Framework of Reference, CEFR) was about 82% in Malta but restricted to 14% in France. It is however important to mention that the comparisons between different educational systems was not completely possible due to variability in age of testing, learning conditions and previous experience with foreign language, as well as to external (cultural) factors, i.e., multilinguistic vs. monolingual environments, and thus, these results have to be taken with caution.

In addition, the ESCL confirmed that English remained the most widely spoken foreign language at the European level, i.e., 38 % of the European citizens. In France, 99 % of French high-school students have chosen English as one of their two foreign languages compared to 16.3 % of them for German (see the MENJS-MESRI-DEPP, RERS 2020). Therefore, given that German suffers from a low attractiveness, we conducted L2 (German) vocabulary learning studies in this doctoral work to ensure that a large proportion of children had no prior experience with this foreign language before learning.

Although France's low ranking for the L2 proficiency at the European level was not surprising, it should be mentioned that, since the start of the school year 2016, foreign language learning starts from Grade 1 in most elementary schools, and that the teaching of a second foreign language is included from Grade 7. Thus, France is now one of the European countries that provides the largest amount of teaching hours in a foreign language. Furthermore, the inclusion of the written modality only starts from Grade 4 and becomes more and more prominent in the following teaching years because of the practicalities of L2 learning in an academic context. Thus, the exposure to the foreign language remains quite limited and written supports become predominant – which is not propitious for the development of communication skills -. Additionally, it is commonly supported that becoming proficient in a foreign language requires to master both spoken and written communication skills. In light of these observations, it remains uncertain whether the presence of orthography may help children in acquiring and memorizing L2 vocabulary and, if so, at whether this advantage may be retrieved at early steps of L2 learning.

This doctoral work will be divided in two main parts: the theoretical and the experimental parts. After a detailed presentation of the theoretical context, we will address our research questions as well as our hypotheses, with regard to the existing literature toward: a) the vocabulary knowledge and the contribution of orthographic information on vocabulary learning in native language; b) second language processing and L2 vocabulary learning; c) linguistic immersion in foreign language and bilingual advantage in learning vocabulary in a third language.

THEORETICAL SECTION

Chapter I. Vocabulary knowledge and contribution of orthography to word-learning in native language

Preamble:

Vocabulary building through word-learning is a lifelong process which starts very early during infancy. Many studies have documented the initial processes involved in early word-learning in infants by using a habituation paradigm to focus on (early) speech perception and word segmentation (e.g., Nazzi & Ramus, 2003; Nazzi, Paterson, & Karmiloff-Smith, 2009) on the lexical consonant bias (e.g., Poltrock & Nazzi, 2015), as well as on the contribution of phonetic specificity (Nazzi et al., 2003). Other studies used a fast-mapping paradigm to explore children's word-learning abilities prior to reading acquisition (Aravind et al., 2018; Coutanche & Koch, 2017; Heibeck & Markman, 1985; Spiegel & Halberda, 2011). This paradigm assumes that a minimal exposure is required to learn a novel concept if it is contrasted with another concept, which is already known by children, due to the mutual exclusivity constraint. Some of them contrasted accurate word retention between monolingual and early bilingual children, and reported a monolingual advantage over bilinguals (e.g., Kalashnikova, Escudero, Kidd, 2018; Weatherhead, Arredondo, Nácar Garcia & Werker, 2021). Nonetheless, in this thesis, we focus on the word-learning mechanisms that occur once learning to read has started. In the early stages of reading development, children are exposed to the written transcription of familiar concepts and forms and their orthographic representations need to be connected to the corresponding pre-existing vocabulary knowledge, which only include phonological and semantic representation (and their connections) stored in memory. With reading automatization, the written language modality becomes dominant for the acquisition of novel words (especially for foreign language learning in secondary school) and vocabulary learning processes have to be redesigned by moving from an exclusively spoken-mediated word-learning one to a written-mediated one. Word pronunciation is then accessed from its written form by decoding, for which children have to learn the correspondences between graphemes and phonemes, but they also have to deal with inconsistent letter/sound mappings. Given the enhanced exposure to written language and its interplay with the spoken language, there is a strong scientific interest in the contribution of the written modality on vocabulary learning and in the interaction between vocabulary knowledge and linguistic processing associated with orthography. In this first chapter, we first introduce the literature about vocabulary knowledge and learning regarding the lexical quality hypothesis (Perfetti & Hart, 2002). Then, we address the contribution of vocabulary on written word recognition and reading by relying on the main cognitive models, i.e., the Dual-Route Cascaded model (DRC; Coltheart et al., 2001) and the connectionist triangle framework (Harm & Seidenberg, 2004). We then explore whether orthography plays a role in vocabulary learning by referring to studies that use a paired-associate learning paradigm. Finally, we focus on the linguistic and non-linguistic variables that may modulate the benefit of orthography on word-learning.

I. 1. Vocabulary knowledge and lexical quality hypothesis

In this section, we use the term ‘vocabulary knowledge’ to refer to the pre-existing association between a spoken form and its associated meaning, which are already stored in the lexicon prior to reading acquisition (Gupta et al., 2009). Word-learning refers to the acquisition of its formal dimensions, i.e., spoken and written forms (as well as semantics). Vocabulary knowledge plays a crucial role in spoken communication including both speech production and comprehension, but also in learning and mastering written language as well as for academic success. Vocabulary learning is a lifelong endeavour that starts during early infancy; novel words are acquired and related to the other lexical representations stored in the lexicon to which they are associated. In L1, word-learning requires acquiring word-pronunciation, which is stored in a phonological representation, and its related meaning, i.e., semantic representation, and building connections between phonology and semantics, i.e., phonological-semantic connection. Thus, exposure to an already-known spoken word will automatically activate its related meaning. Most words are learned incidentally through environmental stimulations, such as television, conversations, rather than through explicit instruction (see Henderson, Devine, Weighall, & Gaskell, 2015; Houston-Price, Howe, & Lintern, 2014). Once children start learning to read, the orthographic word form, i.e., written form/spelling, has to be integrated into the lexicon and connected to the pre-existing phonological-semantic lexical representation stored in memory for already known words. According to the lexical quality hypothesis (Perfetti & Hart, 2002), the interplay between orthography, phonology and semantics contributes to form a strong lexical representation, with reciprocal excitatory connections between each representation. Each re-exposure to one of the three constituents of the lexical representation tends to reinforce the connection between the three constituents. Thus, for high-quality representations, the presentation of the written form simultaneously activates its associated meaning and pronunciation. However, it is still unclear which mechanisms underpin the building of high-quality representations. In line with the lexical quality hypothesis, previous vocabulary knowledge also plays a large role in word-decoding.

I. 2. Influence of vocabulary knowledge on written word-recognition and word-naming

I. 2. 1. Overview of the main cognitive models of word-reading and written word-naming

In the following section, we focus on two main models that are specific to L1 written word-naming and recognition, i.e., the Dual-Route-Cascaded model (Coltheart et al., 2001) and the Triangle model (Harm & Seidenberg, 2004) to account for reading strategies in children/adults. Two main differences between the two models may be underlined. First, due to its computational nature, the Triangle model (Harm & Seidenberg, 2004) includes sets of sub-symbolic codes to represent lexical attributes, whereas the Dual-Route-Cascaded model assumes lexical levels for orthography, phonology and semantics. The second main difference concerns the contribution of semantics in reading.

The Dual-Route Cascaded model has been invoked to account for written word-recognition and reading in L1. Two complementary reading/recognition procedures have been modeled: a lexical procedure, i.e., orthographic route, and a sublexical one, i.e., phonological route. Both procedures are co-activated during reading aloud. The sublexical procedure accounts for the reading of novel (or unfamiliar) words with regular letter/sound correspondences as well as pseudowords by decoding the written form into its spoken one by using the grapheme-phoneme correspondence rules. Importantly, the sublexical procedure does not rely on (previous) lexical knowledge. During the first steps of reading acquisition, children rely preferentially on this sublexical route to access the phonological form of words. Contrary to the sublexical procedure, the lexical one relies rather on (pre-existing) vocabulary knowledge. With reading automatization and increased vocabulary knowledge, expert readers rely preferentially on the lexical procedure to gain access to the global wordform (if stored in the lexicon) rather than on decoding, which has a higher cognitive cost. Using the lexical procedure is highly recommended in expert readers, given that there is a lower cognitive cost to gain access to the global wordform than to decode it. The lexical procedure thus relies on an interactive-activation procedure, with reciprocal excitatory and inhibitory connections across the phonological and orthographic lexicon as well as with semantics. Reading irregular words is also achieved preferentially through this lexical procedure rather than through the sublexical one, due to grapheme/phoneme inconsistencies. Nevertheless, decoding irregular words could still lead to the correct pronunciation of the word, but only if its spoken form is already stored in the phonological lexicon (prior lexical knowledge) and if this spoken pronunciation can be recognized through this misleading spelling (see Elbro & de Jong, 2017). Once the lexical procedure is involved in word-reading, the written input leads to the retrieval of its orthographic representation in the orthographic lexicon. Then, the access to the phonological lexicon is either direct from the orthographic lexicon or mediated by semantics. Thus, the DRC model postulates that reading an item does not necessary require the activation of the semantics associated with the word.

However, this assumption is not supported by the connectionist triangle framework model by Harm and Seidenberg (2004), for which access to semantics is required especially for irregular word-reading. In this model, lexical knowledge is represented by a pattern of activated units which are distributed between the three codes, i.e., orthography, phonology, and semantic codes. All three codes are interconnected through layers of hidden units. Consistent with the DRC model, the connectionist triangle framework postulates that, while reading, orthography sends activation signals to phonology either through a direct connection or through an indirect one via semantics. Although the direct pathway has a lower cognitive cost due to the fewer steps between orthography and phonology, it should be underlined that the indirect (semantic) pathway is activated in parallel. According to the authors, the semantic pathway may become preferential if the direct access to phonology is compromised due to inconsistent grapheme-to-phoneme correspondences included in irregular words.

In view of these two models, it is still debated whether the indirect pathway (orthography to semantics) facilitates the access to phonology, given that the connections between orthography and semantics are more arbitrary than ortho-phonological ones. Nevertheless, both models include a reciprocal connection between the semantic and orthographic representations, supporting the contribution of previous vocabulary knowledge to the acquisition of reading/literacy.

I. 2. 2. On the (reciprocal) contribution of vocabulary knowledge on reading (and spelling) skills

As demonstrated above, the DRC model and the triangle model include orthographic, phonological and semantic representations, as well as mappings between them modelled by reciprocal excitatory and inhibitory links. This is also the case with the lexical quality hypothesis (Perfetti & Hart, 2002). In the literature, there are lines of evidence for a specific influence of vocabulary knowledge (pronunciation and meaning) on reading and visual word-recognition, especially during the initial steps of reading acquisition. Importantly, early vocabulary knowledge has been identified as a strong predictor for future successful reading (see Nation & Snowling, 1998; Roth, Speece, & Cooper, 2002; Snow, Burns, & Griffin, 1998; Stanovitch, 1986). Further studies also reported a reciprocal association between vocabulary knowledge and enhanced reading abilities (Ouellette, 2006; Perfetti, 2007; Ricketts, Bishop, & Nation, 2007), consistent with the lexical quality hypothesis (Perfetti & Hart, 2002). Indeed, high quality lexical representation is associated with higher reading skills. Nevertheless, it seems important to disentangle the relationships between prior phonological knowledge and reading, on the one hand, and between semantic knowledge and orthographic learning (reading and spelling), on the other. Thus, in the following sections, we provide a short overview of the specific contribution of phonological and semantic knowledge to the development of reading skills, and, by extension to the acquisition of word-specific orthographic representations, i.e., to orthographic learning.

The contribution of lexical phonology, which refers to a child's familiarity with a word's phonological representation, to reading acquisition has been consistently reported in cross-sectional (e.g., Nation & Cocksey, 2009a; Nation & Snowling, 2004;) and longitudinal studies (Duff & Hulme, 2012; Lee, 2011; McKague, Pratt, & Johnson, 2001). Castle and Nation (2006) proposed that the oral vocabulary contributes to building word-specific orthographic representations, i.e., orthographic learning. Indeed, prior to exposure to the written word forms, children have already acquired many words in their oral vocabulary. At the first steps of reading acquisition, children have to learn and rely on grapheme-phoneme correspondences, which guide them in decoding the written form into its constitutive sounds, a phenomenon known as phonological recoding. In line with phonological recoding (Share, 1995, 1999), initial partial decoding attempts are guided by the oral vocabulary, once the word phonological form is already stored in the lexicon. If they do not match, the knowledge of the phonological lexical form may help children to modify their previous decoding attempt to fit with a pre-existing phonologically similar word stored in the lexicon. The contribution of phonological recoding on the building and storage of word-specific orthographic representations in the lexicon have been well documented in the literature (Ehri, 1995; Share, 1995; Sprenger-Charolles, Siegel, & Béchennec, 1997), and retrieved both for languages with transparent (see de Jong & Share, 2007; Share, 1999, for Hebrew;) and opaque orthographies (see Bosse, Chaves, Largy, & Valdois, 2015, for French; Cunningham et al., 2002 for English;). For irregular wordforms, children cannot rely on a strict decoding strategy, so knowing the pronunciation of these written forms should facilitate reading. This assumption is consistent with studies that reported a relationship between phonological knowledge and successful reading attempts (McKague et al., 2001; Nation & Cocksey, 2009a). Using an auditory lexical decision task, Nation and Cocksey (2009) investigated whether (regular vs. irregular) written word-recognition was influenced by its lexical phonology (familiarity with the phonological form of the word) in seven-year-old children. They reported an association between lexical phonology and better reading aloud, which was even stronger for words with irregular grapheme-to-phoneme correspondences.

Interestingly, phonological knowledge could also assist the building of word-specific orthographic representation, prior to initial exposure to the written form. Stuart and Coltheart (1988) suggested that, with experience with spoken language and early knowledge of sound-letter mappings, children might be able to anticipate a word's spelling. These (partial) expectations are referred to as the "orthographic skeleton hypothesis". The hypothesis posits that initial exposure to the word's written form should lead to its facilitated decoding, especially if it only contains regular grapheme-to-phoneme correspondences. Wegener et al. (2018) tested this hypothesis, and referred to it as the "orthographic skeleton hypothesis" in a training study. They exposed Grade 4 children to a set of spoken pseudowords embedded in a contextual spoken sentence associated with an unfamiliar picture, i.e., "A nesh which is used to shuffle cards". Importantly, no written information was provided during the oral vocabulary training. Using a naming task, the authors ensured that the spoken forms had been efficiently learned.

Pseudoword spellings were then presented embedded in a contextual sentence, i.e., “Nick picked up the cards and put them into the nesh to shuffle them”. Half of the associated spellings were predictable from their spoken form (nesh, /neʃ/) whereas the remaining ones were not (koyb, / /kɔɪb/). Reading times were compared between the trained pseudowords (exposure to the spoken form) and the untrained ones. Authors reported an interaction between familiarity with the spoken form (trained vs untrained set) and spellings’ predictability, with a larger benefit of spoken familiarity for predictable spellings compared to unpredictable ones. Thus, children were able to form initial word expectations about spoken words, even before prior exposure to them.

Investigating the contribution of semantic knowledge to orthographic learning, both for accurate reading and spelling, has yielded mixed results. In the literature, there is a lack of consensus whether semantic knowledge contributes to an efficient reading of irregular words, once the phonological knowledge has been controlled (see Duff & Hulme, 2012; McKague, et al., 2001; Nation & Cocksey, 2009a; for an absence of semantic facilitation, but see Ricketts et al., 2015 for a facilitation of semantic knowledge on L1 irregular word-reading). Nonetheless, several studies also reported that knowing a word’s meaning helped children in its decoding, especially for irregular grapheme-phoneme mapping. (e.g., Ouelette, 2006; see Taylor, Duff, Woollams, Monaghan, & Ricketts, 2015 for a review), but also for its spelling (e.g., Wang, Nickels, Nation, & Castles, 2013).

Overall, there is a strong association between vocabulary knowledge and reading acquisition, which is even reinforced with irregular word forms. This relationship between vocabulary and reading is reciprocal, as documented by the Matthew effect between vocabulary and reading skills (Stanovitch, 1986). As reported above, vocabulary knowledge promotes the ability of children to decode irregular words (Nation & Cocksey, 2009a). Conversely, enhanced decoding skills leads to extend vocabulary knowledge by promoting a richer exposure to novel words and their storage in the lexicon (Swanborn, & de Glopper, 2002). Strong correlations between language and reading skills were also documented in a longitudinal study in children aged 19 months to 16 years (see Suggate, Schaughency, McAnally, & Reese, 2018). Importantly, when children start learning to read, their exposure to written language increases and vocabulary learning is more mediated by reading. Hence, through this enriched experience with the written language, there should be a relatively consistent contribution of orthography to novel word-learning.

I. 3. Influence of orthographic information on L1 vocabulary learning

As presented earlier, the self-teaching hypothesis assumes that orthographic learning occurs through phonological recoding of phonological entry in vocabulary knowledge, by using it as a self-teaching mechanism to encode an orthographic representation for a specific word (Share, 1995; see also Ehri, 1995 for a comparable assumption). To test this hypothesis, Share (1999) designed a self-teaching paradigm, which explored the orthographic learning by presenting novel wordforms embedded in short texts and asking children to read them aloud. Orthographic learning was assessed by an orthographic choice task, for which the target spelling was presented alongside a homophonic one (in two other distractors). The correct spelling was recognized, named or spelled more accurately than the homophonic one in Grade 2 children. The self-teaching paradigm has been mostly used for orthographic learning, although Ricketts, Bishop, Pimperton, and Nation (2011) adapted it for both orthographic and semantic learning. For vocabulary learning, however, the paired-associate learning paradigm is more commonly used to assess word-learning abilities.

I. 3. 1. Paired associate learning paradigm (PAL)

The paired-associate learning paradigm (PAL) measures the ability to learn the association between two sources of information (provided simultaneously), which is often arbitrary. For example, when children start learning grapheme-to-phoneme correspondences, they have to associate each letter/bigram to its related phoneme. These associations can be either unimodal, i.e., verbal-verbal vs visual-visual paired associate learning, or bimodal/cross-modal, i.e., verbal-visual one. Often, the presentation of an item of visual information is associated with its pronunciation/production by participants. This learning paradigm has been especially used to measure reading, given that decoding may be related to a kind of PAL. Hulme, Goetz, Gooch, Adams, and Snowling (2007) compared the learning between three kinds of PAL in children aged between seven and 11 years. The first two were unimodal PALs, i.e., a visual-visual paired associate learning, for which they presented two abstract shapes, i.e., forms associated with no conceptual representation, and a verbal-verbal PAL, through an association between two spoken pseudowords, whereas the third one was a bimodal paired-associate learning paradigm with the simultaneous presentation of a visual-verbal association (non-word associated with an abstract shape). For each of these PAL, children had to learn five associations between two stimuli (visual-visual vs. visual-verbal vs. verbal-verbal), which were presented five times during "learning" (a total of 25 test/learning trials). At each trial, participants were presented with one of the stimuli and had to retrieve (the associated form in the visual-visual PAL) or to produce the missing one (i.e., pronunciation of the associated pseudoword in the visual-verbal and verbal-verbal PALs). Interestingly, although children exhibited the greater accurate learning association with the visual-visual and for the visual-verbal PALs (but a lower one for verbal-verbal PAL), the strongest correlations between PAL and reading skills were observed only with the visual-verbal PAL, consistent with the orthographic mapping of phonological information (e.g., Ehri, 2014). In addition, the visual-verbal paired associate learning paradigm has been used to access reading, spelling, and vocabulary learning. Importantly, in the field of vocabulary learning, further studies adapted the PAL to explore the contribution of orthographic information to word-learning in L1. Ricketts, Bishop and Nation (2009) used an adaptation of the PAL[1] to contrast an orthographic learning method, characterized by a simultaneous presentation of the written form associated

[1] Usually, the paired-associate learning paradigm is characterized by the simultaneous exposure to two sources of information for which participants have to learn their (arbitrary) association. During learning, one is provided and the second has to be produced or retrieved. Ricketts et al., (2009) added an additional item of written information to a visual-verbal paired-associated learning paradigm, i.e., picture-spoken form, for the orthographic learning method.

with its pronunciation and related picture, with a non-orthographic one, for which no written information was provided.

The rationale behind the paired-associate learning paradigm is based on the dual-coding during learning, especially for the cross-modal PAL. According to the dual-coding theory (Paivio, 1975; Paivio & Lambert, 1981; Sadoski, 2005) which was first designed for reading, written and spoken forms are encoded through a different sensorial modality, i.e., visual encoding for the written form but auditory-motor encoding for its pronunciation, but are also associated with each other. Thus, this multimodal association may strengthen the memorization of a word (and its lexical representation), explaining the higher learning performance in visual-verbal (orthography-phonology) paired-associate learning than in the verbal-verbal modality[2]. The dual-coding theory is consistent with the lexical quality hypothesis (Perfetti & Hart, 2002).

In this thesis, we opted for an adapted visual-verbal paired associate learning paradigm that was comparable to the one used by Ricketts et al. (2009), except that we added a series of non-decodable symbols for the non-orthographic learning method as a visual control. This aimed to prevent any orthographic facilitation from being confounded with a pure visual advantage.

I. 3. 2. Orthography's benefit on L1 word-learning: a systematic review

In this section, the contribution of orthography on L1 vocabulary learning is explored. We use the term "orthographic facilitation" to refer to the increased learning performance associated with the presence of written information during learning.

In a recent systematic review, Colenbrander, Miles and Ricketts (2019) explored whether the presence of written wordforms during learning facilitated vocabulary learning in L1, and more specifically by distinguishing its contribution on orthographic, phonological and

[2] The greater learning advantage in visual-visual paired associated learning may be explained by perceptual differences between visual and auditory language, given that the latter is more transient over time.

semantic learning. Several studies explored and documented orthographic facilitation on vocabulary learning in (typical) adults (Han & Choi, 2016; Miles, Ehri, & Lauterbach, 2016; Saletta, Goffman, & Brentari, 2016), in children with learning disabilities (e.g., Baron et al., 2018; Ricketts, Dockell, Patel, Charman, & Lindsay, 2015), in children with Down's syndrome (e.g., Mengoni, Nash, & Hulme, 2013), and in children with diagnoses of autism spectrum disorder (e.g., Lucas & Norbury, 2014; Ricketts et al., 2015) or with visual impairment (e.g., Savaiano, Compton, Hatton, & Lloyd, 2015). We focus here on the studies conducted in children with typical development (e.g., Chambré, Ehri, & Ness, 2017; Ehri & Wilce, 1979; Jubenville, Senechal, & Malette, 2014; Li, Zhang, Ehri, Chen, Ruang, & Dong, 2016; Ricketts, Bishop, & Nation, 2009; Rosenthal & Ehri, 2008; Valentini, Ricketts, Pye, & Houston-Price, 2018.

Orthographic learning:

As defined by Share (1999), orthographic learning refers to the acquisition, i.e., encoding and storage, of novel word-specific orthographic forms. Although the contribution of orthography to learning the spelling of novel wordforms may be intuitive, it is particularly interesting to ensure that participants are sensitive to the presence of orthography during learning. Consistent orthographic facilitation was indeed demonstrated for orthographic learning in the literature. Most studies used spelling to dictation (e.g., Chambré, Ehri, & Ness, 2017, 2020; Jubenville, Senechal, & Malette, 2014; Ricketts, Bishop, & Nation, 2009; Rosenthal & Ehri, 2008) and orthographic choice tasks (see Valentini, Ricketts, Pye, & Houston-Price, 2018) to assess orthographic learning. Nevertheless, they differed in the specific learning paradigm they used. In their study on grade 3 children, Valentini et al. (2018) taught eight low-frequency wordforms embedded in sentences/a story by contrasting two unimodal learning methods, i.e., visual (reading stories) vs. auditory only (listening to stories), and a cross-modal one, i.e., visual-auditory (combined) learning method (both listening to and reading stories). Importantly, children were assigned to one of the learning groups. Following comprehension tasks, an orthographic-choice took place in which two written versions of a target word (palisade, /palɪseɪd/ – palisaid, /palɪsɑːd/) were displayed on the screen. The orthographic foil (palisaid) was the most common misspelling of a target word committed by adults in a preliminary study. Better accurate spelling recognition was reported in children in the combined and reading only groups compared to those in the listening only group. However, there was no significant difference in spelling recognition between the combined and reading group. This supported the view that exposure to written information was sufficient for children to recognize the correct spelling form. Consistently, Rosenthal and Ehri (2008) also reported an orthographic advantage in Grade 2 and Grade 5 children but in a productive task, i.e., through a spelling task. In their study, children had to learn the association between a spoken form embedded in a sentence and a picture. The presence of the written form was manipulated as a within-participant variable. Thus, half of the items were associated with their spelling, presented underneath the picture, while the remaining were not. The second graders learned 12 low-frequency words, including six with orthography and fifth graders 20 words (including 10 in written form). During learning phases, participants first saw the written form associated with a picture and heard its pronunciation, which they had to produce for each trial. Then, the written form was embedded in a sentence that they heard and were asked to repeat. In the spelling task, although fifth graders outperformed the second graders, spelling performance was more accurate on items learned in association with orthography compared to those that were not. Thus, incident exposure to the written form led to a facilitation effect in orthographic learning.

Phonological learning:

Despite an obvious orthographic facilitation for learning novel spellings, whether this written advantage is observed when learning novel phonological forms appears more challenging at first sight. Indeed, if observed, the orthographic facilitation may reflect the strong relationship between orthographic and phonological lexicons, associated with orthographic mapping (see Ehri, 2014). Phonological learning refers to the acquisition and storage of novel spoken forms in the lexicon. It has been principally explored by asking participants to produce a spoken form, especially by using a (word/picture) naming task (e.g., Chambré et al., 2017; Jubenville et al., 2014; Li et al., 2016; Ricketts et al., 2009; Rosenthal & Ehri, 2008) and consistently led to the finding of orthographic facilitation in phonological learning (but see, Valentini et al., 2018 for a lack of facilitation when using a forced-choice spoken recognition task).. For example, Ricketts et al. (2009) made Grade 3 children learn 12 monosyllabic pseudowords using a paired-association learning paradigm. For half of the items, the subjects were exposed to both written and spoken wordforms with their associated picture, whereas no written information was provided for the remaining items during the training phase (randomized for items across participants). Training comprised three repetitions and three production blocks. During the production blocks, a picture-naming task was performed to assess (ongoing) phonological learning[3] in participants. Feedback was also provided after each pronunciation trial. Interestingly, the benefit of orthography was retrieved from the second (out of three) production block, with larger accurate pseudoword-recognition and pronunciation for items learned with orthography compared to those that were not. The lack of immediate orthographic facilitation on phonological learning (for the first production block) could be attributed to the neutralization between an orthographic advantage and disadvantage according to degree of letter/sound consistency (this will be discussed in Chapter I-3.4.1.1). Nonetheless, this facilitated phonological learning was not reported when using a forced-choice spoken recognition task in third graders (see, Valentini et al., 2018). During the phonological forced-choice task, children were exposed to two phonological versions of a (learned) word, i.e., the target and its most frequent mispronunciation as a phonological foil (palɪseɪd vs. /palɪsɑːd/) and had to recognize the target word. Surprisingly, phonological learning did not differ across the three groups, i.e., reading vs. listening only, vs. reading and listening, suggesting that the exposure to orthography did not support enhanced phonological recognition. These

[3] The picture naming task is regularly used as a measure of semantic learning as well as of phonological learning, given that it requires to access a word meaning through its pronunciation.

contradictory results may be explained by the nature of the experimental task. Indeed, contrary to the forced-choice spoken recognition task, picture-naming tasks do not rely on a pure phonological measure, but rather on both phonological-semantic one, given that participants had to access meaning associated with the picture and to pronounce it. In addition, given that phonological recognition is assumed to be less cognitively demanding than production, i.e., naming task, the forced-choice spoken recognition task may be successfully completed whether or not orthography was displayed during learning. Furthermore, Valentini et al. (2018) also suggested that the forced-choice task might be sensible to wordlikeliness, given that phonological foils may have been less word-like compared to the targets. There is thus a need for further studies to determine whether the orthographic facilitation would emerge for a pure spoken recognition task, once wordlikeliness has been controlled. As a summary, in addition to an orthographic facilitation on orthographic learning, there was also a robust orthographic advantage on learning (and retention of) novel phonological information.

Semantic learning:

As we have seen previously, orthographic and phonological learning refer to the acquisition of one particular formal dimension. For semantic learning however, in addition to the acquisition of a word meaning, it also requires connecting the orthographic and/or the phonological representation to their associated semantic representation. Due to the acquisition of these mappings, it may be difficult to disentangle between phonological and orthographic contribution when exploring whether the presence of written information helped the semantic learning. Furthermore, despite a rather consistent orthographic advantage on learning the spoken and written word forms, its contribution on semantic learning is more contrasted across studies and relative to the experimental tasks. Semantic learning was commonly assessed through a word-picture matching task (e.g., Jubenville et al., 2014; Li et al., 2016; Ricketts et al., 2009), word-sentence matching task (e.g., Rosenthal & Ehri, 2008) and verbal/written definition task in children (Chambré et al., 2017; Rosenthal & Ehri, 2008; Valentini et al., 2018 for a written definition choice as one in the three semantic post-tests). Still, using a picture-naming tasks provided a measure of semantic learning, by investigating the building of phono-semantic links (see, Chambré et al., 2017; Jubenville et al., 2014; Li et al., 2016; Ricketts et al., 2009; Rosenthal & Ehri, 2008). Most studies included several experimental tasks to measure semantic learning. For example, Rosenthal and Ehri (2008) used a picture-naming task and reported that (second and fifth grade) children exhibited higher scores for words prompted by pictures for those that were learned with orthography compared to those that were not. Additionally, they also measured semantic through two supplementary post-test tasks, i.e., a forced-choice recognition task and one for which they had to recall the definition of the target words. For both tasks, learning performance were not impacted by the learning method; thus, the presence of spelling did not facilitate the acquisition of novel concepts. However, this could be explained by performance at ceiling level. Similarly, Chambré et al. (2017) found no evidence of orthographic facilitation when semantic learning was assessed through a definition task, given that first graders performed at ceiling level. Thus, mixed evidence of an orthographic advantage has been documented for semantic learning. This might be attributed to methodological challenges, such as the large variability of learning parameters (number of items, repeated exposure to items) as well as the nature of the learning associations, i.e., from isolated word-learning to contextual word-learning embedded in sentences/texts. We will address some of these challenges in Section 3.2.2.

More consistent evidence for an orthographic advantage on the acquisition of novel (pseudo)word meaning has been reported when semantic learning is assessed through a picture-naming task. In this task, a picture is presented to the participants, who had to retrieve the associated word in the lexicon and to pronounce it. Nevertheless, due to the ambiguous nature of the picture-naming task, it remains difficult to disentangle whether orthography plays a direct contribution on the acquisition of novel word meaning or whether this facilitation is mediated through phonology. The locus of the benefit of orthographic on semantic access will thus be explored in the following sections.

I. 3. 3. Locus for the benefit of orthography on semantic access

In the following section, we will address the locus of the orthographic advantage on semantic learning. This explorative approach can be view as a gateway to understand which are the underlying mechanisms that may explain the beneficial contribution of orthography on vocabulary learning. Three main accounts have been documented in the literature. Orthography may play a direct advantage on semantic learning, through the building of ortho-semantic connections. An indirect advantage of orthography may also be conceivable. Then, the contribution of orthography on semantic learning may be mediated by phonology. The last possible hypothesis refers to the lack of direct or indirect contribution of orthography on the acquisition of word meaning.

The direct contribution of orthography on the semantic learning is consistent with connectionist models, including the connectionist triangle framework (Harm & Seidenberg, 2004). Indeed, the authors assumed that once a word is well-known, then, exposure to its written form may directly activate its meaning in the lexicon, without passing by the phonological level to assess the semantic one. This assumption is consistent with the lexical quality hypothesis (Perfetti & Hart, 2002) for which a lexical representation should be considered as one of high quality, if the presentation of the spelling leads to the retrieval of all its constituents, and more especially to the word's meaning. Despite these theoretical supports, little experimental evidence to this "direct" view has been provided in regard to the ceiling effect reported when semantic learning was assessed with word-picture matching tasks, but also to the ambiguous nature of the picture-naming task, which assess the semantic-phonological connection (see Colenbrander et al., 2018 for a review).

In line with this contrasting experimental evidence, another approach suggested that orthography plays an indirect effect on the acquisition of a word meaning through its benefit on phonological learning. Given that spoken language is more transient than the written one, phonology may be so strongly associated/attached to orthography that the expression "anchoring device" and "glue" are commonly used to define the tight connection between the written and the spoken form. Orthography may thus reinforce the phonological representation stored in memory, by mapping the written form with its pronunciation (see, e.g., Ehri, 1998; 2005; 2014). Therefore, the presence of orthography led to a deeper encoding of the phonological form in the lexicon, as well as an accelerated acquisition of the spoken form (Chambré et al., 2017). In turn, in light to this early phonological learning, connections between phonology and semantics may also be established in an accelerated manner, supporting the indirect contribution of orthography on the acquisition of a word meaning.

Nonetheless, it should be mentioned that contrary to the tight connection between orthography and phonology, strengthened by reading experience and thus, by repeated phonological recoding, the links between semantics and orthography, as well as those between semantics and phonology are rather arbitrary. Indeed, there is no reason why graphemes or phonemes may help in directly/indirectly assess a word meaning. Therefore, a third possibility rely on the absence of direct or indirect contribution of orthography on semantic learning. According to this view, orthography may have a contribution of the acquisition of the spoken form only.

I. 3. 4. Modulation of the orthographic facilitation by linguistic and non-linguistic factors

Despite a growing research interest towards the contribution of orthography on L1 vocabulary learning, only few were conducted in children. In addition, these results reported mixed results, some of which could be attributed to methodological limitations, i.e., restricted number of items per condition, lack of consensus on the required exposure to novel words.

Therefore, future studies are required to confirm the orthographic facilitation on vocabulary learning, and to determine whether it may be retrieved for L2 word-learning as well.

In this sub-section, we will focus on the linguistic and non-linguistic factors that were reported/or may play a moderating effect on the orthographic facilitation.

I. 3. 4. 1. The benefit of orthography is modulated by linguistic factors

I. 3. 4. 1. 1. Spelling to sound relationships: consistency vs inconsistency

Further evidence of an orthographic facilitation mediated by phonology has been provided by studies that explore the moderating effect of grapheme-to-phoneme (in)consistency on the orthographic facilitation (e.g., Jubenville et al., 2014; Ricketts et al., 2009). Grapheme-to-phoneme correspondences are either consistent or inconsistent within a given language. For example, English language contains a large amount of inconsistent grapheme-to-phoneme correspondences, meaning that one grapheme can be associated with more than one phoneme. Indeed, in English, the grapheme <i> is associated with the phonemes /ɪ/ (ship, /ʃɪp/) and /aɪ/ (fire /faɪɚ/). In French however, although the mappings between graphemes and phonemes are relatively stable for reading, with an average of 87.4% of consistent mapping between grapheme and phoneme (Ziegler, Jacobs, & Stones, 1996). Note that there are multiple occurrences of silent final consonant (chiot, /ʃjo/). The moderating effect of letter/sound inconsistency on orthographic facilitation has been documented in children (Jubenville et al., 2014; Ricketts et al., 2009). Jubenville et al. (2014) assigned Grade 3 French monolingual children to one of the three learning conditions: consistent print condition, inconsistent print condition and no-print condition. For the first two conditions, children were exposed simultaneously to the written and spoken information associated with their picture for each of the six pseudowords. The sole difference relied on the degree of grapheme/phoneme consistency, given that children were exposed to a set of pseudowords with either consistent L1 (French) GPC or inconsistent mapping between letter and sounds, that was characterized by a silent final consonant. Importantly, the authors ensured that the grapheme/phoneme correspondences were stable across pseudowords. In the third condition, no written form was provided during learning and children only had to learn the set of consistent nonwords. At testing, learning performance were assessed through a picture-naming task and a word-picture matching task. The latter led to performance near to ceiling for two out of the three learning condition (print consistent vs. print inconsistent, but not for the no print condition). Interestingly, for the picture-naming task, although exposure to print led to a facilitated acquisition and recall of expressive vocabulary, children in the consistent print condition outperformed their peers assigned to the inconsistent one. This supported the idea that the orthographic facilitation may be mediated by phonology for semantic learning. On the contrary, Ricketts et al., (2009) found an increased orthographic facilitation associated with the inconsistent (vowel and consonant) phoneme-to-grapheme correspondences, that was however restricted to the spelling to dictation task. Thus, when exposed to orthography during learning, children performance for spelling inconsistent pseudoword reached those reported from the consistent ones. Therefore, given that the written form associated with the pronunciation was unpredictable when using L1 sound-to-letter correspondences, the presence of orthography helped children to disambiguate the relationship between phonology and orthography, through the encoding of pseudoword-specific orthographic representation (see, Share, 1995 for the self-teaching hypothesis). These results are also consistent with the orthographic mapping of phonological information (Ehri, 2014). Nonetheless, some caution must be taken with these observations, given that Ricketts et al. (2009) manipulated both learning method (with vs. without orthography) and consistency as within-participant variables. In their study, third graders were exposed to 12 pseudowords, but only half of them were learned with orthography (these six items were assigned to one of the three consistency condition, with two pseudowords per condition: consistent, inconsistent consonant, inconsistent vowel). Future studies are needed to determine whether orthography plays a benefit or not in learning novel items that include inconsistent GPC, for which (partial) decoding attempts may result in producing an altered phonological form (if unknown). In the next section, we will thus focus on the moderating effect of reading skills on the orthographic advantage.

II. 3. 4. 1. 2. Reading skills

The contribution of reading skills on the orthographic advantage has been explored in typically developing children (e.g., Chambré et al., 2017; Ricketts et al., 2009; Rosenthal & Ehri, 2008; Valentini et al., 2018) but also in children with developmental language disorder (Ricketts, Dockrell, Patel, Charman, & Lindsay, 2015) and children with dyslexia (Baron et al., 2018). Mixed results have been reported in the literature. Although several studies reported strong correlations between reading skills and vocabulary learning, i.e., orthographic and phonological learning (e.g., Chambré et al., 2017; Ricketts et al., 2009; Rosenthal & Ehri, 2008), only one found that the benefit of orthography was larger in better compared to less-skilled readers for an orthographic learning task (Ricketts et al., 2009). The opposite direction was however found by Chambré et al. (2017), with stronger correlation between nonword-reading skills and phonological recall in first grade children that were not exposed to orthography compared to those who were. In addition, several other studies did not report any impact of reading abilities on the orthographic advantage (e.g., Ricketts et al., 2015; Valentini et al., 2018). In a nutshell, the interplay between the orthographic facilitation and reading skills remains unclear. Further studies are thus required to shed light on the contribution of reading skills on the orthographic advantage, which could be investigated by exploring learning performance in two groups of children with a different degree of reading automatization. Beyond L1 linguistic skills, the benefit of orthography may also be modulated by non-linguistic factors, such as the modality of exposure to written form, i.e., explicit or incident exposure to written forms

I. 3. 4. 2. The benefit of orthography is modulated by non-linguistic factors

I. 3. 4. 2. 1. Nature of the exposure to orthography: explicit vs incident learning

Most studies explored the contribution of orthography by using an implicit exposure to written information. In these studies, children were not informed to pay attention to the print during learning. To our knowledge, only three studies exposed explicitly children with orthography (Chambré et al., 2017; Chambré, Ehri, & Ness, 2020; Vadasy & Sanders, 2015). The aim of these two studies was to determine whether explicit exposure to orthography, by driving children's attention to the written form, enhanced the learning advantage well-documented for L1 word-learning. In their study, Chambré et al. (2017) contrasted an implicit exposure to orthography to an explicit one, for which first graders had to point to and to read aloud the words. Interestingly, a comparable orthographic advantage was reported regardless of whether children had to pay attention to orthography or not. Thus, simple exposure to print, i.e., without driving attention to orthography, was sufficient for mapping the grapheme/phoneme into memory. Furthermore, there was no additional benefit for learning the meaning, supporting the absence of a grapho-semantic mapping system that was comparable to the grapho-phonemic one. In a following study, Chambré et al. (2020) investigated whether forcing participants to decode novel wordforms during learning may extent the orthographic advantage compared to an incident exposure to print. Contrary to the previous study (Chambré et al., 2017), they made first graders spell and sound out the words during learning. There, they observed a particular advantage of explicit decoding on vocabulary learning, given that the orthographic advantage was larger compared to an incident orthographic learning method. Nevertheless, this extended orthographic facilitation already started to decline one day and one week after learning. The authors suggested that the presence of orthography speeded the memorization of word-pronunciations through grapho-phonemic connections (mapping the graphemes to the phonemes). Thus, it appears more adequate to use an incident exposure to orthography for investigating the contribution of orthography on L2 vocabulary learning.

I. 3. 4. 2. 2. Sleep-offline consolidation

The influence of offline sleep-consolidation on word-learning has been mostly investigated in adults, by contrasting between lexical configuration and lexical engagement (see, Dumay & Gaskell, 2003; Leach & Samuel, 2007). The lexical configuration refers to the encoding of a word form (spelling and pronunciation) as well as its meaning. The lexical engagement accounts for the lexical integration of these encoded information by connecting them with the pre-existing entries stored in the lexicon. This dual dissociation relies on the Complementary Learning System theory (CLS; McClelland, McNaughton, & O'Reilly, 1995; O'Reilly & Norman, 2002), according to which, the initial steps of learning is associated with the encoding of novel information in the hippocampus (Warren & Duff, 2014). Repeated reactivation of this representation enabled it to become gradually integrated with pre-existing vocabulary knowledge stored in the neocortex, and, thus, by decreasing the degree of hippocampal dependence (Davis, Di Betta, Macdonald, & Gaskell, 2009). This switch from the hippocampal to the neocortical memory network is an offline process, which is facilitated by sleep as evidenced in adults (Dumay & Gaskell) as well as in children (Brown, Weighall, Henderson, & Gaskell, 2012; Henderson, Weighall, Brown, & Gaskell, 2012). Previous studies identified that the specific communication between hippocampal and neocortical memory systems occurred during the slow wave sleep phase (SWS; Diekelmann & Born, 2010), which duration has been identified as a predictor of lexical integration (Smith et al., 2017; Tamminen, Payne, Stickgold, Wamsley, & Gaskell, 2010). Interestingly, contrary to adults, children exhibit larger offline-sleep consolidation (James et al., 2017; Wilhelm et al., 2012), as highlighted by large SWS (Ohayon, Carskadon, Guilleminault, & Vitiello, 2004; Wilhelm et al., 2013). Consistent evidence for offline-sleep consolidation in children aged between seven and nine years has been provided by James, Gaskell and Henderson (2019), who reported enhanced word recall performance in children after a one-day as well as a one-week delay.

I. 3. 4. 2. 3. Experimental parameters: number of items and degree of exposure to word during learning

The benefit of orthography on L1 vocabulary learning has been documented in most studies using a paired-associate word-learning paradigm for at least one experimental measure, i.e., orthographic, phonological, and semantic learning. However, there was no complete consensus across studies, which could be explained by the large variability of experimental methodology and post-tests used to assess L1 learning performance. In addition, several studies failed to find an orthographic advantage on semantic learning (for at least one or all measures) due to performance at ceiling level (see Chambré et al., 2017; Jubenville et al., 2014; Rosenthal & Ehri, 2008; Valentini et al., 2018). These ceiling effects may be explained by the restricted number of items included in the learning list as well as by the (highly variable) degree of exposure to the learning material during learning (and testing) sessions. Setting these parameters may be particularly challenging.

Indeed, defining the number of items included in a study relies on a balance between the experimental purpose, i.e. detecting differences between groups, and its feasibility, i.e., including a reasonable number of items in order not to overcome participants' learning abilities. Learning abilities are variable across children. For example, a vocabulary gap of 3000 words has been estimated between third graders whose vocabulary skills are located on the highest quartile compared to those in the lowest one (e.g., Biemiller & Slonim, 2001). Unfortunately, this gap tends to persist or even expand in time (e.g., Biemiller, 2003) and cannot be catch up by school-instruction (Biemiller & Boote, 2006). Still there is no consensus in the literature for studies using a PAL, with studies including between six (consistent or inconsistent) pseudowords (see Jubenville et al., 2014) and 20 novel words (see Rosenthal & Ehri, 2008, Experiment 2).

Although there is no particular standard to define word-learning abilities during childhood, due to inter-individual differences and developmental changes, word-learning abilities has been estimated to up to 20 novel words a day at the end of elementary school in line with school emulation (Anglin and Miller; 2000). This assumption may be taken with caution, given that learning abilities are strongly impacted by the developmental changes from early childhood to Grade 5 children (see, Fenson et al., 1994 for parental estimations; Anglin, 1993 for Grade 1 to Grade 5).

Ceiling effects observed in previous studies may also be (partially) attributed to the limited/restricted number of items, which is even weakened by the manipulation of the learning condition as a within-participant variable (e.g., Hu, 2008; Jubenville et al., 2014; Rosenthal & Ehri, 2008). Indeed, as an illustration, Rosenthal and Ehri (2008) made third graders learn six novel word with the presence of orthography and six words with no spelling. Through repeated exposure to these items, it may not be surprising that children overlearned the learning material, leading thus to the ceiling effects observed for two out the three semantic post-tests.

In addition to the limited number of words included in L1 vocabulary learning studies, there is still no consensus for the degree of exposure to novel words to promote their storage in the lexicon. According to Beck, McKeown, and Kucan (2002), 12 to 15 exposures to novel words are required in an ecological context (in a non-academic learning context) to promote their storage in the lexicon associated with prior vocabulary knowledge. Still, the repeated exposure to novel words may be necessary impacted by word-learning paradigm. In studies using a contextual word-learning paradigm, the required number of word encounters varied as a function of the size of the text passages, with one to four repetitions required for a word embedded in a single sentence to between eight and 12 encounters when embedded in long continuous texts (see Horst et al., 1998; Waring & Takaki, 2003). When using a paired-associate learning paradigm, Chambré and colleagues (Chambré et al., 2017; Chambré et al., 2020) reported that once children had to decode (or passively saw) spellings, they were able to pronounce correctly five out of the six low frequent words after six repetitions (still, there was no more learning improvement after nine exposure). Thus, orthographic mapping led to a substantial decrease in the required exposure to novel words for learning them. Conversely, the learning load associated with the size of the learning list may impact the memorizing strategies.

Setting the required exposure to learning material is although dependent on the number of items to learn, in order to define the correct balance between a sufficient number of items and the optimal exposure to the learning material during learning. This aims to prevent ceiling effects during word-learning studies. For example, Jubenville et al. (2014) made children learn six (consistent or inconsistent) pseudowords that were presented for at least for six learning cycles, i.e., 12 item repetitions (and a maximum of nine cycles, i.e., 18 item repetitions). Each learning cycle included a repetition and a production for each item; feedback was provided for each unsuccessful repetition or production. Hence, it was not surprising that performance on the word-picture matching task were near ceiling. Future studies should pay attention to setting these parameters in order to replicate the consistent orthographic facilitation documented in L1 vocabulary learning studies.

I. 4. Summary

In this chapter, we have focused on the main steps involved in L1 vocabulary learning prior to and after exposure to the written language, with reference to the two main cognitive models dedicated to word-reading and recognition, i.e., the Dual-Route cascaded model (DRC; Coltheart et al., 2001) and the connectionist triangle framework (Harm & Seidenberg, 2004), but also with reference to the lexical quality hypothesis (Perfetti & Hart, 2002). Although we documented how prior vocabulary knowledge promoted the acquisition of written forms, we then focused more particularly on the contribution of orthography on L1 vocabulary learning, which has been relatively well documented in studies using a paired-associate learning paradigm. Orthography has a relative consistent facilitation effect on learning the written and spoken form of novel words. However, the contribution of orthography to semantic learning has led to more contrasted observations that could be attributed to ceiling effects. Indeed, these effects seem to reflect some methodological challenges, especially regarding the setting of the learning parameters, i.e. number of items to be learned and amount of exposure to the learning material.

Although orthographic facilitation was found to be relatively consistent on L1 vocabulary learning, its learning benefit was rather modulated by the degree of consistency in letter to sound mappings. Importantly, learning vocabulary in a foreign language requires acquiring novel mappings between letter and sounds, some of which may conflict with the pre-existing GPC rules specific to L1. In addition, vocabulary learning may not involve the same mechanisms in L1 and L2, especially when foreign-language learning takes place once children have accumulated experience with L1. Therefore, it appears important to explore the specificities of second language processing and learning, especially during the initial steps of foreign language learning.

Chapter II. Second language processing and L2 vocabulary learning

Although the benefit of orthography has been relatively well-documented in L1, its benefit on L2 vocabulary learning has received less attention. However, whether orthographic facilitation also occurs in L2 vocabulary learning is of particular interest, especially for a better understanding of the mechanisms associated with L2 learning, as highlighted previously (see, e.g., Scott & Beadle, 2014). Foreign language learning mostly occurs in an academic context, after reading acquisition (the issue of foreign language immersion is also explored in Chapter III). When learning a foreign language, children are faced with different challenges compared to learning L1. First, they have to store novel phonological and orthographic representations linked to a pre-existing meaning, even though there are some gaps in conceptual representations across languages. Second, academic learning of foreign languages takes place late in childhood, once children have already gathered a relatively large experience of their native language. This might lead to an unbalanced proficiency between L1 and L2, and lead to L1 interfering in L2 vocabulary learning. Third, it confronts children with a problem of congruency. Although graphemes are relatively shared across (alphabetic) languages, their associated phonemes are more language-specific and thus less stable across languages. Therefore, L2 learners have to learn novel grapheme-to-phoneme correspondences, some of which include conflicting features due to incongruent grapheme-to-phoneme correspondences with L1. For example, the grapheme "u" is shared in both German and French, but they are associated with distinct phonemes, i.e. /u/ in German and /y/ in French. Thus, the incongruent German word <Schuh>, /ʃu/ would be pronounced /ʃy/when using French letter-to-sound conversion rules. In this context, it is still unclear whether the orthographic facilitation reported for L1 word-learning also intervenes in L2 vocabulary learning.

II. 1. Overview of the main cognitive models of language processing in bilinguals

Before exploring the impact of cross-linguistic similarities and dissimilarities in L2 vocabulary learning, we first present a brief, non-exhaustive overview of the main cognitive models that have been proposed to account for the specific aspects of bilingual processing, especially for bilingual spoken/visual word-recognition (e.g., BIMOLA; Bilingual Model of Lexical Access, Grosjean, 1988; BIA+; the Bilingual Interactive Activation Plus model, Dijkstra & van Heuven, 2002) and word production and translation (RHM; Revised Hierarchical model, Kroll & Stewart, 1994). Importantly, these models of bilingual processing presented below are adapted from pre-existing monolingual models, following the adage that "no model should be left behind" exposed by Kroll, van Hell, Tokowicz, and Green (2010). Despite some differences in the organization of the lexicon (integrated vs. independent lexicon according to language) and to its access (selective vs. non-selective) in bilinguals, linguistic processing is thought to depend on a similar architecture in both monolinguals and bilinguals. For example, both BIMOLA and BIA/BIA+ models belong to the interactive activation models and are a bilingual adaptation of the TRACE model (McClelland & Elman, 1986) and of the Interaction Activation model, respectively (McClelland & Rumelhart, 1981). In addition, two of the main models of bilingualism refer to previous conceptualized bilingual models. The BIAd (Grainger et al., 2010) is a developmental proposition which includes the BIA+ and RHM models, whereas MULTILINK (Dijkstra, Wahl, Buytenhuijs, Halem, Al-Jibouri, De Korte, & Rekké, 2018) relies on the pre-existing architecture of the BIA+.

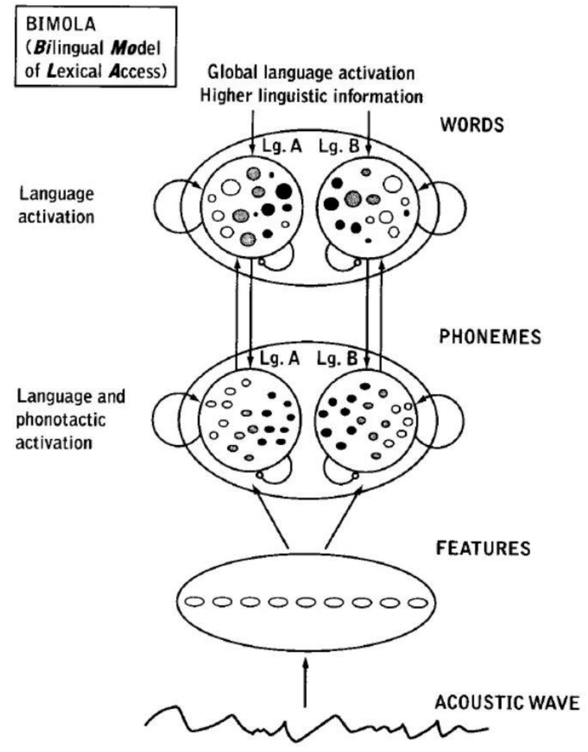
In the following section, we present these models of bilingual access to the lexicon and highlight those which include a developmental view of bilingualism. Importantly, none of them are specific to the early acquisition of vocabulary in a foreign language. Thus, our presentation starts with models of spoken and written word-recognition in bilingual experts, and then goes on to discuss other models which could account for the developmental view of bilingualism.

II. 1. 1. Bilingual Model of Lexical Access (BIMOLA; Grosjean, 1988)

Our review of the main cognitive models of bilingualism starts with the Bilingual Model of Lexical Access (BIMOLA), a model of spoken word-recognition for unbalanced and late bilinguals, which assumes two separate phonological lexicons, one for the native language (L1) and one for the foreign language (L2). In addition, the model also postulates a selective access to each language. Thus, the access to the L2 spoken lexicon is not mediated by L1. This is particularly informative when extending our focus to L2 vocabulary learning, given that, according to BIMOLA, the acquisition of novel spoken forms in L2 should not be overly impacted by L1. The rationale behind this postulate is that languages are more distant in phonology than in orthography. Thus, due to the weak interlinguistic phonological overlap, phonemic and lexical representations are not shared in the spoken modality. In addition to the independent language network, the BIMOLA also assumes an interconnected network to account for the active interference of the non-relevant language in monolingual speech.

The architecture of the BIMOLA model is presented in Figure 1. It has three main levels of processing, i.e. a feature, a phoneme and a word level. In the BIMOLA, the feature level is shared in both languages whereas both phoneme and word levels are different between them. Connexions between the feature and the phoneme levels are unidirectional whereas they are bidirectional between phoneme and word level. At the phoneme level, the joint activation of units in both languages is dependent on their degree of similarity across the languages. The activation of phonemes that are specific to one language only results in an increased activation of its overall language network, as well as a faster recognition of words in that language. Similarly, the activation of a word that is specific to one language only leads to a spreading activation along its language network, as well as to a faster activation of words belonging to that language. On the contrary, when a word shares phonological similarities in both languages, then the recognition of the related words in the guest language is slowed down, except if these words are particularly frequent (accounting for word frequency effects) or share a large phonetic overlap with the input (language phonetic effect). Interestingly, there are no explicit language nodes in the BIMOLA model to explain outline code-switching between native and foreign languages. According to the author, a metalinguistic statement about the nature of the acoustic wave is as informative as a language node to recognize and identify the language from the spoken signal.

Figure 1. *Bimodal model of lexical access (BIMOLA, Grosjean, 1888).*

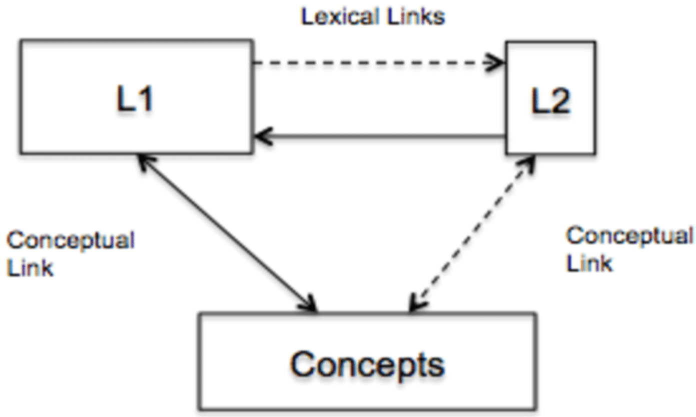


Unlike the BIMOLA, most models of bilingual visual word-recognition rely on a language non-selective access to lexical representation (an issue still debated in the literature) which are stored in a common integrated lexicon for both languages (e.g., BIA + model, Dijkstra & van Heuven, 2002; see Chapter I-1.3 for the detailed presentation of the model). Experimental evidence in favour of this lexical organization has been provided by studies on cognate word facilitation in written modality (e.g., De Groot & Nas, 1991; Dijkstra, Grainger, & Van Heuven, 1999; Dijkstra, Grainger, & Van Heuven, 1999; Dijkstra, Van Jaarsveld, & Ten Brinke, 1998; Dufour & Kroll, 1995; Lemhöfer et al., 2008; Lavaur & Font, 1998; Schwartz, Kroll, & Diaz, 2007; Voga & Grainger, 2007). These differences in lexical organization between spoken and visual word-recognition may be explained by the reduced spoken overlap across languages compared to the written one.

II. 1. 2. The Revised Hierarchical Model (RHM; Kroll & Stewart, 1994)

The Revised Hierarchical Model (RHM) (Kroll & Stewart, 1994) is a developmental model of word production and translation adapted to late foreign language learners, although it could also account for simultaneous L1 and L2 learning. The architecture of the RHM is presented in Figure 2. It was designed to account for production in both languages through backward, i.e., from foreign language to native language, and forward translations, i.e., from L1 to L2. Given that foreign language learners are exposed late to L2, an asymmetry in lexical development between the native and foreign language is postulated, as well as separate lexicons in each language. Thus, lexical representation in each language are stored in separate lexicons. However, the semantic representations are considered common in both languages. Two types of links are postulated: lexical and conceptual links. Both the L1 and L2 lexicons are connected by these bi-directional lexical links, although they are stronger in the L2-L1 direction until L2 is mastered. Both languages are related to the conceptual level by direct bi-directional conceptual links. These conceptual links are asymmetric in strength between the native and foreign language, given that L2 learners have a larger experience with their L1 prior to exposure to L2. Thus, conceptual links between L1 lexical representations and the conceptual level are considered to be stronger. The strength of the other links is dependent on the degree of language proficiency.

__Figure 2.__ The Revised Hierarchical Model (RHM; Kroll & Stewart, 1994).



During the initial steps of foreign language learning, access to the conceptual level from the L2 lexical level is mediated by native language through the L2-L1 lexical link. With growing L2 proficiency, a direct conceptual link between the L2 lexical level and conceptual level is progressively built, allowing a direct access to word meaning without mediation from L1. Importantly, this does not mean that the lexical link between L2 and L1 disappears, but that, with increasing L2 proficiency, lexical mediation by L1 is not as essential to access meaning from L2. Thus, expert bilinguals are able to directly access meaning through conceptual links between the L2 lexical level and the conceptual level, whereas late foreign language learners can only access word meaning through backward translation. However, the RHM is subject to several types of criticism.

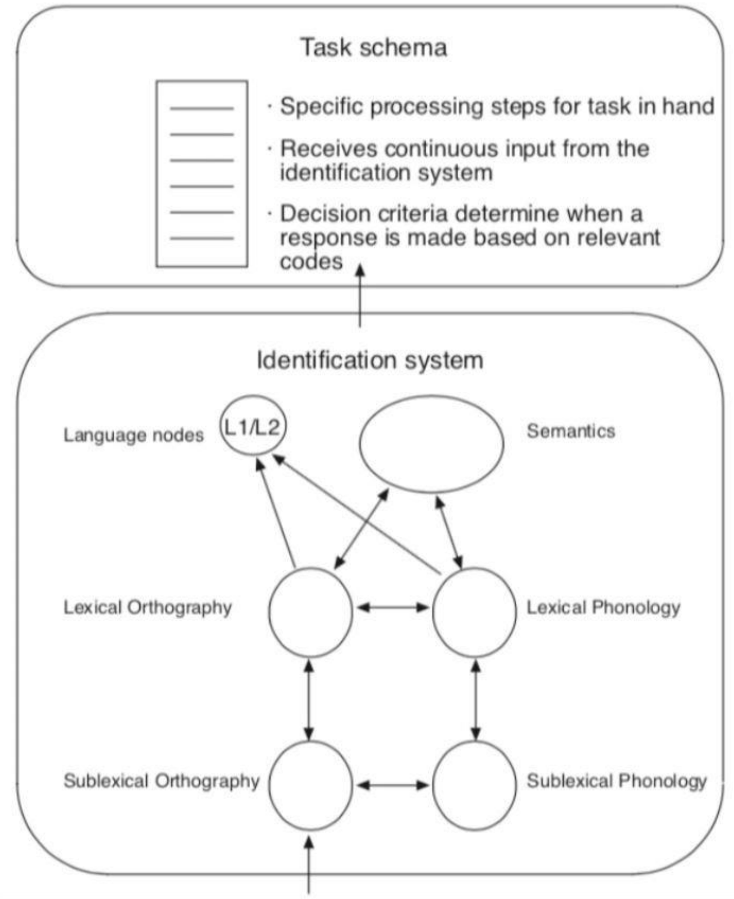
Brysbaert and Duyck (2010) identified five points of criticism that counteract the assumptions made by the RHM. **First**, little experimental evidence for separate lexicons has been found in the literature. **Second**, the hypothesis of selective access to language is also questioned. Interestingly, previous studies provided evidence against language selective access both for spoken (Spivey and Marian, 1999) and visual word-recognition (see. Dijkstra, 2005, for a review). However, the RHM does not explicitly postulate a language selective access, as acknowledged by Brysbaert and Duyck (2010) and by Kroll, Van Hell, Tokowicz et Green (2010). Furthermore, experimental evidence so far is in favour of a language non-selective access rather than against the assumption of separate lexicons, which could be activated in parallel by the sensory input. Thus, it is difficult to disentangle experimentally a unified lexicon and separate lexicons, since both have parallel access. Using interlinguistic orthographic neighbourhood effects, van Heuven et al. (1998) provided evidence against the assumption of two lexicons in visual modality. Dutch-English bilingual adults performed an L2 visual word-recognition task in which English target words had orthographic neighbours of higher frequency within-language or across-language only. They exhibited a cross-language lexical competition that was comparable to the one highlighted within a language, suggesting that orthographic neighbours in both languages were activated when participants performed a monolingual visual word-recognition task. **Third**, the RHM overestimates the strength of lexical links between L2 and L1 words, as evidenced by masked priming lexical decision tasks (see Schoonbaert et al., 2009 for a review). **Fourth**, the RHM also underestimates the lexical-semantic links in L2 by overestimating the lexical mediation between L2 and L1. Nevertheless, this assumption has been questioned in the literature with multiple lexical-semantic tasks, i.e., backward (L2 to L1) and forward (L1 to L2) translation tasks (e.g., Duyck & Brysbaert, 2004), translation judgment tasks (e.g., Altarriba & Mathis, 1997; Sunderman & Kroll, 2006; Poarch, Van Hell & Kroll, 2015; but see. Talamas, Kroll & Dufour, 1999 for contradictory results), and semantic categorization tasks (e.g., Dufour & Kroll, 1995). **Fifth**, in its current form, the RHM does not make any distinction between semantic representations that are shared across languages (language-independent), especially for most concrete words that are shared across cultures, from those that are language-specific, i.e., for abstract words. Furthermore, although most semantic features are shared across languages, there is still no complete semantic overlap between them, as exemplified by the distinction between the French translation equivalents "balle" and "ballon" for the English word "ball" (see. Dijkstra et al., 2018).

The RHM model has been relatively influential over the past two decades and several cognitive models also stem from its "basic" architecture to account for the shared-but not complete-semantics between languages (e.g., SAM, Shared Asymmetrical Model, Dong, Gui, & Macwhinney, 2005). However, Kroll and Stewart (1994) did not specify the modality on which the RHM relies (written vs spoken modality). In addition, no further evidence was provided regarding the early acquisition and storage of both L2 orthographic and phonological (lexical and sublexical) representations.

II. 1. 3. Bilingual Interactive Activation (Plus) Model (BIA, Dijkstra & Van Heuven, 1998; BIA+, Dijkstra & Van Heuven, 2002)

The Bilingual Interactive Activation Plus (BIA+) model is an updated version of the initial bilingual interactive activation (BIA) model (Dijkstra & Van Heuven, 1998; Van Heuven, Dijkstra & Grainger, 1998) and its architecture is presented in Figure 3. Both are models of bilingual visual word-recognition in native and highly proficient bilinguals, although a developmental version of the BIA model has been proposed (BIA-d; Grainger, Midgley, & Holcomb, 2010). They are based on the monolingual IA model (McClelland & Rumelheart, 1981). Consistent with the IA model, they include three levels, i.e., feature, letter and word levels, that share interactive (excitatory and inhibitory) links. Thus, the (pre-)activation of a word candidate in the lexicon occurs through a cascade of excitation/inhibition from the bottom levels: the features included in the visual input excite letters that include these features and inhibit those that do not, and, next, activated letters send excitation to the word candidates that include these letters. In addition to these three levels, a language level, i.e., language nodes for L1 and L2, was implemented to refer to the language membership of words: each word in the lexicon is thus supposed to be associated with its belonging language node. Importantly, these language nodes were conceived so that they could receive bottom-up activation from the word level, i.e., word A activates language node A, and sends top-down inhibition to the word level for those that are not included in a specific language node, i.e., language node A inhibits the activation of word B whereas language node B sends inhibition to word A. In the initial version of the BIA model, language nodes were considered to fulfil four complementary functions in visual word-recognition. First, they played a role of language tags, by linking each word to the language they belong to. Second, they are thought to collect the global lexical activation associated with the process of visual word-recognition, which is also language-specific and could explain language-switch costs. Interestingly, the authors reported that this function would fail particularly in bilingual beginners (L2-learners) given that it stems from vocabulary size (L2 vocabulary size is smaller than L1 one in L2-learners) as well as from the subjective frequency of the pre-activated word candidates (larger frequency for L1 candidates compared to L2 ones due to a restricted/limited exposure to foreign language in L2 learners). Third, these language nodes were considered to act as "language filters" to modulate the relative activation of each language, and thus to smooth the switch from one language to another. Fourth, these language nodes were thought to collect non-linguistic contextual activation, leading to the pre-activation of a specific language node as well as its connected word representations that are consistent with individual and contextual expectations. These two latter functions are no longer supported by the language nodes in the BIA+ model, but by the level of task and parameter specifications.

Figure 3. *Bilingual Interactive Activation plus (Dijkstra & Van Heuven, 1998 ; Van Heuven, Dijkstra & Grainger, 1998).*



The BIA model was the first one to account for the mechanisms in play during bilingual visual word-recognition but also to postulate (and simulate) both an integrated lexicon as well as a language non-specific access to the lexicon. Indeed, at word level, all the word candidates are represented within the same lexicon, regardless of the language to which they belong. Furthermore, during visual word-recognition, word candidates receive excitation from the bottom levels (features and letter levels), irrespective of their associated language, as evidenced by studies investigating neighbourhood density effects between languages (see Bijeljac-Babic et al., 1997; van Heuven et al., 1998; Dijkstra et al., 1998). Despite its major contribution to bilingual visual word-recognition, the BIA model has several limitations that led to the development of the BIA+ model (Dijkstra & van Heuven, 2002).

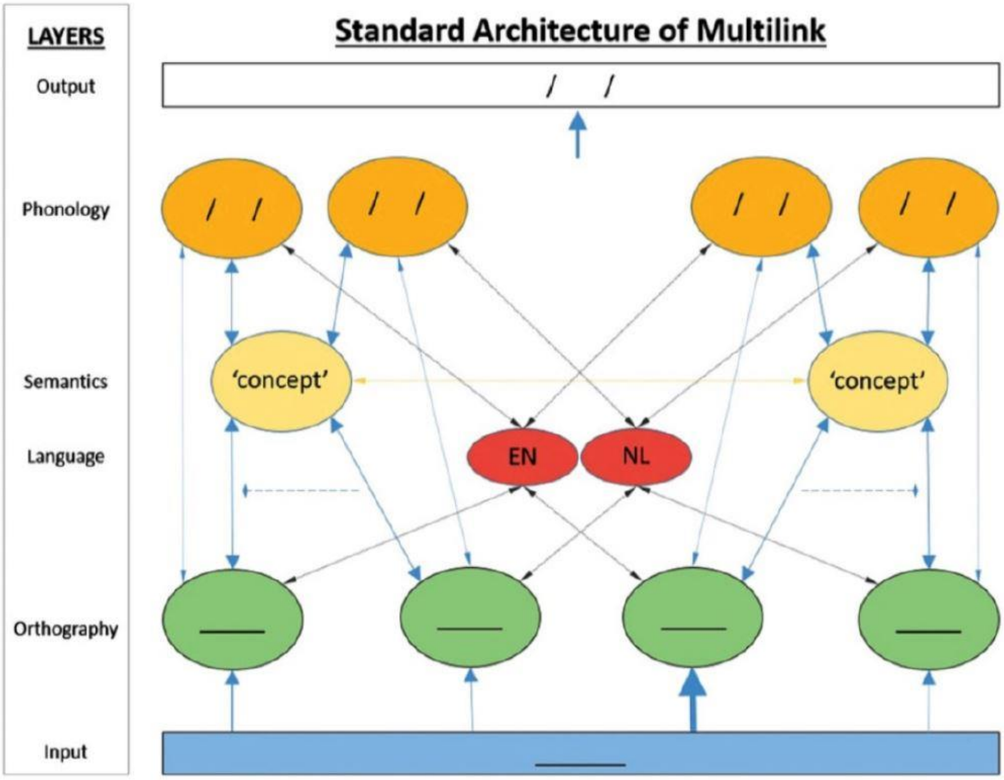
The BIA+ model includes a sublexical and lexical phonological level as well as a semantic level in addition to the pre-existing BIA model. Intermediate sublexical orthographic and phonological levels were postulated to model the mapping between graphemes and phonemes through an Onset-Nucleus-Coda scheme for written and spoken modality. Still this is not implemented in the current version of the BIA+ model. Thus, in its current state, the BIA+ model cannot provide any account for the processing of grapheme-to-phoneme conversion rules, especially for those that are incongruent with L1. Importantly, as for orthographic representations, a language non-selective access to the lexicon (as well as the integrated lexicon) was extended to semantic and phonological representations. In addition, the authors assumed that there should be delayed access to semantic and phonological representations in a foreign language compared to L1, which they attributed to a lower subjective frequency in L2 than in L1. Consequently, cross-linguistic effects were expected to be larger in the forward direction (L1 to L2) than in the backward one (L2 to L1). Nonetheless, contradictory evidence emerged from the literature (see Jared & Kroll, 2001 for interference of language dominance in cross-language phonological priming; Van Wijnendaele & Brysbaert, 2002, for comparable phonological priming effects regardless of the primes in Dutch-English unbalanced bilinguals). Thus, BIA+ underestimates the impact of phonology in L2 processing, as argued by Brysbaert, Van Wijpendaele, and Duyck (2002).

A major contribution of the BIA+ model is its theoretical account of the processing of interlingual homographs and cognates as well as their specification in the lexicon. It assumes that (identical vs. non-identical) cognate words are represented twice in the orthographic lexical level, but only once in the semantic one, given that the meaning is (relatively) shared across languages. For example, for the French-English non-identical cognate pair (violon – violin), the visual presentation of the word “violon” may activate both stored orthographic lexical representations for “violon” and for “violin”. Both L1 and L2 orthographic candidates may send (bottom-up) activation to the semantic level for the shared meaning of “violin”. The co-activated semantic representation may also send activation back to the orthographic lexical level through a top-down excitatory link, leading to a resonance between the lexical and semantic levels. This is considered to account for the cognate facilitation effects reported in the literature (please see Chap II-2 for an exhaustive review). Nevertheless, the lexical-semantic representations are not specified in the current version of the BIA+ model, an issue that was overcome by the MULTILINK model.

II. 1. 4. Multilink (Dijkstra et al., 2018)

The MULTILINK model (Dijkstra et al., 2018) is a computational model designed to account for (spoken and written) word form and meaning retrieval in word-recognition and production tasks. Based on an algorithm, the MULTILINK model contains a series of computations and simulations of previous theoretical data. In its current version, it includes 1295 Dutch-English translation pairs; each English word was selected from the English Lexicon Project (ELP; Balota et al., 2007) and from the Free Association Database (Nelson, McEvoy, & Schreiber, 1998) and was paired with a Dutch translation from the Dutch Lexicon Project (DLP; Keuleers, Diependaele, & Brysbaert, 2010). Each selected word was between three and eight letters long. The architecture of MULTILINK, whose symbolic lexical network is presented in Figure 4, results from a combination between the RHM and BIA+ (in others). Interestingly, sublexical processing is not represented in the core architecture of the MULTILINK model but is considered by using the normalized Levenshtein distance, which simulates the activation of cross-linguistic orthographic and phonological neighbours. According to the authors, using the Levenshtein distance captures the influence of between-word similarity relatively well, regardless of word length. In addition, it also overcomes the problem of letter-position coding (see Dijkstra et al., 2005) in simulations, thus, providing a relative flexibility in coding letter-position in words to account for letter-transposition effects. The architecture of the model is based on a localist-connectionist network to account for a range of bilingual language processing specifically associated with linguistic properties, i.e., cross-linguistic similarities, word length, or subjective frequency, with task demands, as well as with intra-individual characteristics, i.e., L1/L2 symmetrical (and asymmetrical) proficiency.

Figure 4. Multilink (Dijkstra et al., 2018).



First, the MULTILINK model used a lexical-semantic representation to account for the processing of cross-linguistic similarities conveyed by cognate words. Through multiple simulations, MULTILINK replicated the main effects of cognate facilitation documented in the literature, although these simulations were restricted to Dutch and English.

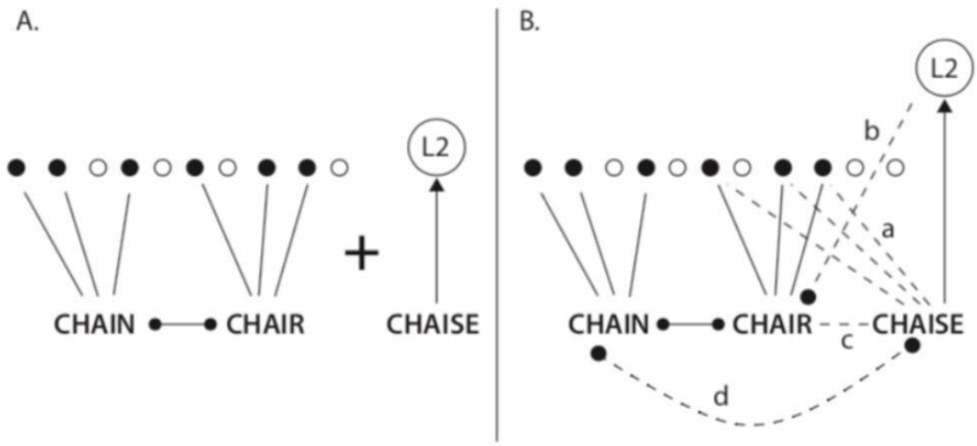
Second, like the BIA+ model, MULTILINK also uses a task/decision system, which makes it possible to simulate word processing in a wide variety of tasks, such as lexical decision tasks, word-naming, word translation and production.

Third, the MULTILINK's lexicon and parameter settings can be modulated by L2-proficiency to simulate the differences in lexical access between high- and low-proficient bilingual adults. Although it was not designed to account for the development of a bilingual lexicon, it is possible to simulate unbalanced access to L2 lexicon by decreasing the native's frequency in L2 by a defined factor. According to the authors, this may simulate/explain the difference in word level activation between L1 and L2. However, it cannot provide a full account of the initial steps of foreign language learning, given that it postulates that L2 words were already integrated in the lexicon, even for unbalanced bilinguals. A first proposal of developmental model will be detailed in the next section.

II. 1. 5. Bilingual Interactive Activation-Developmental (BIA-d, Grainger, Midgley & Holcomb, 2010)

The BIA-d model is a theoretical proposal developed by Grainger, Midgley, and Holcomb (2010) et al. (2010) to link BIA/BIA+, i.e., models of visual word-recognition in expert/balanced bilinguals, to late acquisition of L2 vocabulary in an academic context, for which the initial cross-linguistic dynamics are considered in the RHM. The architecture of BIA-d is presented in Figure 5. The BIA-d contrasts two phases of L2 vocabulary acquisition: an initial supervised vs. an unsupervised learning phase. During the supervised learning phase, a teacher explicitly links an L2 word to its L1 translation equivalent. Thus, access to the meaning may initially be mediated by the L1-L2 lexical link, consistent with the RHM. Once L2 learners have acquired sufficient experience with the foreign language, the unsupervised learning phase progressively overcomes and replaces the supervised one. Then, direct L2 lexical-semantic links may progressively be built, leading to decreased activation of the L2-L1 lexical links. The language node in L2, which was initially built in the supervised phase, progressively sends top-down inhibition to the lexical level for L1 words. With increasing activation of the L2 language node, the inhibitory top-down links become even stronger, leading to the creation of inhibitory links for L1 and L2 orthographic neighbours as well as moving from two separate lexicons to an integrated one in both L1 and L2, thus moving from an RHM-architecture to a BIA-one. This transition is also marked by a relative switch due to an increase in proficiency in bilinguals, who generally report facilitated production and comprehension in L2.

Figure 5. *Bilingual Interactive Activation-Developmental (Grainger, Midgley & Holcomb, 2010).*



Despite the promising account of BIA-d for the developmental vision of L2 word-learning, the switch from two separate lexicons (one in each language) to an integrated lexicon to which access is language non-selective remains unspecified. Furthermore, the BIA-d mostly accounts for how the lexical-orthographic and semantic representations are progressively linked together to increase L2 proficiency, which is particularly important for L2 vocabulary acquisition. However, it does not include any evidence of lower levels of lexical and sublexical orthographic and phonological representations. Thus, in its current form, the BIA-d does not provide any clues to the acquisition of the specific grapheme-to-phoneme correspondences specific to L2, an issue which is particularly important in accounting for L2 vocabulary learning.

II. 1. 6. Summary of the bilingual models of language processing in regard to the challenges associated with L2 vocabulary learning

In the previous section, we presented the main cognitive models in the field of bilingualism. Although each of these models focuses on specific linguistic processing, such as spoken/visual word-recognition (BIMOLA, BIA/BIA+), word production and translation (RHM), or on both visual/spoken word-recognition and word production (MULTILINK), only two models, namely the RHM and BIA+, contain a developmental dimension to account for the initial steps of foreign language learning. Nevertheless, the contribution of orthography to foreign language learning remains underspecified in these models, especially during the first steps of L2 vocabulary learning. Previous studies conducted in L1 reported a reliable orthographic facilitation on novel word-learning (see. Colenbrander et al., 2020 for review), that contributed to the acquisition of meaning, as well as its written and spoken form. However, whether this learning advantage extends to L2 vocabulary learning is still unclear, given that evidence is lacking about how an L2 written form is processed while it has never previously been read. Indeed, contrary to L1, academic learning of a foreign language requires children to acquire both written and spoken code spontaneously. The developmental models of bilingualism cannot provide any account for these learning dynamics, given that they do not account for the sublexical orthographic and phonological dimensions of this process.

II. 2. Cross-linguistic dynamics associated with L2 word-learning

Learning vocabulary in a foreign language also requires children to acquire the grapheme-to-phoneme correspondences that are specific to the foreign language. Nevertheless, despite several cross-linguistic similarities in alphabetic languages (see Schepens et al., 2013), it is highly possible that interference from the L1 might arise if letter/sound conversion rules differ between L1 and L2, i.e., lack of congruence. Cross-linguistic similarities, i.e., formal similarities conveyed by cognate words, may also facilitate the learning of L2 words. In addition to their shared semantic representation, L1/L2 cognate words already have an L1 orthographic representation stored in the lexicon which shares a large orthographic overlap with the L2 written form.

Intuitively, cognate words are commonly thought to be easier to learn. In a recent study, Otwinowska and Szewczyk (2017) tested this intuition by exploring lexical knowledge of Polish-English cognate words and English non-cognate words in adult monolinguals. In their study, participants started learning English as a foreign language at school, and their L2 proficiency was estimated between B1 and B2 level according to the CEFR (Common European

Framework of Reference). Cognate and non-cognate words were matched on their frequencies, increasing the likelihood that encountering these words was comparable for both cognates and non-cognates. Participants had to translate a sample of 105 English words into L1 Polish, as well as to report their confidence with the translation provided on a 4-point scale. This task was used to determine the English words they already knew. Unsurprisingly, participants' lexical knowledge was higher for Polish-English cognate words compared to non-cognate ones, suggesting the relative ease of learning cognates, although their results were prone to a bias of cognate-guessing (estimated between 10 and 25%). In addition, cognateness was also identified as a significant predictor of L2 vocabulary learning in adults (Willis & Ohashi, 2012). In the next section, we thus focus on the contribution of cognateness to L2 vocabulary learning.

II. 2. 1. Contribution of cross-linguistic similarities to L2 vocabulary learning

II. 2. 1. 1. Distinction between identical and non-identical cognate words

Due to historical, societal and linguistic factors, several wordforms are shared across languages. Thus, exposure to a foreign language confronts L2 learners with these cross-linguistic similarities when acquiring vocabulary. Importantly, these cross-linguistic similarities are mostly conveyed by cognate words, which are commonly defined as interlinguistic translation equivalents sharing a partial-to-complete orthographic overlap as well as a partial phonological overlap between two languages. Thus, a common distinction is made between identical cognate words (piano in French-English) and non-identical cognates (règne-reign in French-English). However, there is no clear criterion to determine to what extent a word can be considered as a cognate one or not, although cross-linguistic distance can be objectively measured by (normalized) orthographic and phonological Levenshtein distance (e.g., Heeringa, 2004; Kessler, 2005; Levenshtein, 1966; Schepens, Dijkstra, & Grootjen, 2012). Defining the cognate status of a word relies mostly on subjective cross-linguistic similarity judgments. According to the language pairs, there is also a difference in tolerance toward the orthographic overlap. Based on a similar Levenshtein distance (respectively, 2.65

vs 2.72), Otwinowska, Forys-Nogala, Kobosko, and Szewczyk (2020) considered the English-Polish word pair (hurricane - huragan) as a cognate one, whereas they did not for the word pair (complaint- skarga). On the contrary, Tonzar, Lotto, and Job (2009) considered the Italian-English word pair (flauto-flute) as non-cognate, although their orthographic and phonological overlap between L1 and L2 was larger than in those used by Otwinowska et al. (2020).

II. 2. 1. 2. Cognate facilitation effects on L2 vocabulary learning

A cognate facilitation effect is well-documented in the literature for visual/auditory-word-recognition (e.g., Dijkstra, Miwa, Brummelhuis, Sappelli, & Baayen, 2010; Dijkstra, Grainger, & Van Heuven, 1999; Dijkstra, Van Jaarsveld, & Ten Brinke, 1998), backward (L2 to L1) and forward (L1 to L2) translation (De Groot, 1992; De Groot, Dannenburg, & Van Hell, 1994; Kroll & Stewart, 1994). It is characterized by faster response times as well as more accurate recognition of cognate items than of non-cognate ones.

The cognate facilitation effect is modulated by the degree of cross-linguistic spoken and written form overlap. Dijkstra et al. (2010) conducted an English lexical decision task in Dutch-English bilingual adults (they were exposed to English as a foreign-language for eight years on average), in which the English words had a varying degree of form overlap with the Dutch ones, i.e., from English non-cognate words (song- lied), English-Dutch non-identical cognates (crown-kroon) to English-Dutch identical cognates (lamp-lamp). They observed a discontinuous cognate advantage with faster response times and more accurate responses for both identical and non-identical cognate words than for non-cognate words. However, the cognate facilitation effect increased with growing written form overlap; the largest advantage was reported for non-identical cognate pairs that shared the largest form overlap (also incomplete). These observations are consistent with the language non-selective access to lexical representation in the BIA+ (BIA+; Dijkstra & van Heuven, 2002) as well as with a localist-connectionist account (see. Dijkstra et al., 2010), where facilitated visual recognition was attributed to the overlap between orthographic and semantic representations. Interestingly, identical cognates had a more discontinuous facilitation pattern, which was attributed to a varying degree of phonological similarity, with a larger interference effect in dissimilar phonological pairs. This L1 interference could be attributed to letter/sound incongruences with L1 grapheme-to-phoneme correspondence pairs (please see. Chap II- 2).

Second, this cognate facilitation effect was also impacted by task demands. In their second study, Dijkstra et al. (2010) conducted a language-decision task in which Dutch-English bilingual adults had to determine whether a word displayed on a computer belonged to the Dutch or English language as quickly as possible. Unsurprisingly, a cognate inhibition effect occurred, characterized by faster response times and more accurate responses for non-cognate words compared to (non-identical) cognates. This could be explained by lexical competition between the Dutch competitor (which received strong activation from language nodes) and the English one (whose activation came from L2 nodes).

Thus, the representation of cognate words in the lexicon is still a matter of debate. Although some authors suggested a common or a unique orthographic representation for cognate words in the lexicon, this cannot explain the cognate facilitation effect reported for non-identical cognate words, for which two orthographic representations are required. Importantly, due to the transient nature of phonology across languages, two phonological representations should be assumed. Evidence for semantic-to-orthographic feedback has been proposed to account for the differential cognate facilitation effects reported in bilingual adults (see, Lemhöfer & Dijkstra, 2004; Dijkstra et al., 2010).

In light of previous studies, the learning of cognate words might be facilitated compared to the learning of non-cognate items, due to the large cross-linguistic overlap in both the written and (to a lesser-extent) spoken forms, in addition to a shared conceptual representation. This cognate facilitation effect on L2 vocabulary learning has been documented in adults (de Groot

& Keijzer, 2000; Valente et al., 2018; Rogers, Webb & Nakata, 2015; Lotto & De Groot, 1998; Van Hell & Mahn, 1997), as well as in children (Tonzar, Lotto & Job, 2009; Comesaña, Soares, Sánchez-Casas & Lima, 2012b; Comesaña, Moreira, Valente, Hernández-Cabrera & Soares, 2019).

In their study, Tonzar et al. (2009) compared learning performance for Italian-English (and Italian-German) cognate and non-cognate words in two groups of Italian monolingual children, i.e., a group of fourth graders and one of eight graders. Fourth graders had no previous academic experience with English language prior to the study, although this assumption should be taken with caution, given that it underestimates the impact of out-of-school exposure to English prior to formal instruction at school (e.g., Kuppens, 2010; Lefever, 2010; De Wilde, Brysbaert & Eyckmans, 2019). Two learning methods were contrasted: a picture-based learning method, for which the L2 English (or German) word was displayed along with its corresponding picture, and a word-based learning method, characterized by the simultaneous presentation of both L2 and L1 written forms. No spoken information was provided during the learning phase. Each pair, i.e., picture + word form vs L1 written form + L2 written form, was presented three times during the learning phase. Testing phase took place immediately and one week after learning using a spelling task as a recall measure by presenting either the L1 written form (forward translation task) or pictures, depending on the learning method used. The authors reported a cognate facilitation effect in L2 English (and German) word-learning, and word-learning performance was impacted by several variables.

First, the cognate facilitation effect was modulated by the learning method. Indeed, despite a larger learning benefit with the picture-based method compared to the L2 word-based one, the authors observed that the cognate facilitation effect was comparable for both learning methods, whereas more non-cognate words were learned with the picture-based learning method compared to the word-based one, consistent with Comesaña et al. (2009). Interestingly, these results are not in line with the prediction of the RHM, i.e. the L1-L2 word-based learning method should have facilitated the learning of cognate words through the creation of L1-L2 lexical links. There is, however, a lack of consensus on these results in the literature that relates to the composition of the learning lists. Comesaña et al. (2012) failed to find any learning advantage for non-cognate words by using a picture-based method when the learning list included both cognate and non-cognate words. They concluded that the word-learning advantage stemmed from orthographic (and phonological) cross-linguistic similarities (lexical mediation) rather than from semantic connections. Thus, access to semantic representations might depend on lexical mediation. However, the separate learning of cognate and non-cognate words did not lead to a specific learning advantage with the picture-based method (Comesaña et al., 2019).

Second, cognate facilitation was modulated by linguistic familiarity with the foreign language (especially for English-language), given that Tonzar and colleagues (2009) observed that the effect size for cognate facilitation was larger in fourth graders than in eighth graders. The authors thus suggested that repeated exposure to a foreign language contributes to reducing the learning differences between cognate and non-cognate words. In addition, they also reported that cognate facilitation was evident only in the immediate session, suggesting that cognate words are learned faster due to their formal similarity. However, with repeated exposure to learning material, this cognate facilitation effect tended to disappear with comparable performance with cognate and non-cognate words. From an educational point of view, this supports the importance of a learning method that focuses on non-cognate words.

II. 2. 1. 3. Modulation of cognate facilitation effects by the degree of cross-linguistic phonological overlap

Although previous studies reported a cognate facilitation effect in L2 vocabulary learning, whether cognate acquisition was modulated by L1-L2 phonological overlap remained to be determined. Importantly, as reported above, the facilitated acquisition of cognate words has been explored by using (exclusively) visual-written learning methods, which cannot disentangle the interplay between orthographic and phonological overlap, especially for non-identical cognate words, in their early acquisition. Valente et al. (2018) explored whether the learning advantage observed for cognate words might be modulated by both orthographic and phonological overlap in Spanish monolingual fifth graders as well as in adults. To do so, they contrasted learning performance for non-cognate Catalan words with cognate Spanish-Catalan words that were subdivided in three categories, according to the degree of orthographic and phonological overlap between Spanish and Catalan. The first category of non-identical cognate words included those that shared both a large orthographic and phonological overlap between languages (O+P+; e.g., *blusa-brusa* [blouse]), whereas the second one only comprised those with a scarce (written and spoken) form overlap (O-P-; e.g., *fêmea-femella* [female]). The third one included Spanish-Catalan cognate words with a scarce orthographic but a large phonological overlap (O-P+; e.g., *piedade-pietat* [piety]). The methodological orthogonality could not be fulfilled, given that the authors reported a lack of existing items for cognate words with a large orthographic but a scarce phonological overlap between Spanish and Catalan (O+P-). Learning performance was assessed using both a go/no-go lexical decision task as well as an auditive recognition task. Contrary to the generalized cognate facilitation effect observed in adults, the amplitude of the cognate learning benefit was affected by the degree of overlap between orthography and phonology in children. The effect remained as children had faster and more accurate responses for cognates compared to non-cognates in both experimental tasks. Interestingly, given that both groups were matched on their L2 skills prior to the study, the authors suggested that children were more sensitive to and reliant on written similarities during learning than adults. Support for this assumption comes from the L1 literature on visual word-recognition (e.g., Castles et al., 2003; Duñabeitia & Vidal-Abarca, 2008; Perea & Estévez, 2008).

Interestingly, a facilitatory compensation of phonology was reported once the cross-linguistic orthographic overlap was scarce for the auditory lexical decision task. Indeed, the larger the phonological overlap, the better the children's performance on the auditory lexical decision task. This observation is incongruent with previous studies using a written lexical decision task, which reported an inhibitory contribution of phonology in such a context (Comesaña et al., 2015; Dijkstra et al., 2010). Thus, the contribution of phonology is thought to be task-dependent, consistent with the BIA+ model (Dijkstra et van Heuven, 2002), which includes a task-dependent (temporal) access to phonological or orthographic representations during L2-visual word-recognition in addition to co-activation of the different codes (orthography, phonology, semantic).

II. 2. 2. Overview of the modulation of grapheme-to-phoneme incongruences on word-learning in L2

As reported above, cross-linguistic similarities conveyed by cognates are associated with a benefit in L2 written word-recognition (Dijkstra et al., 2010), as well as with L2 word-learning (Comesaña et al., 2012). Nonetheless, the so-called cognate facilitation effect was also found to be modulated by the degree of phonological overlap between L1 and L2, with a decreasing facilitation as its phonological overlap decreased (see. Valente et al., 2018). Indeed, given that orthography is commonly less transient than phonology across languages with an alphabetic writing system, learning a foreign language also requires L2 learners to acquire grapheme-to-phoneme correspondence rules that are specific to L2. These associations could either be congruent with the L1 grapheme-to-phoneme correspondences rules, leading to a one-to-one letter/sound association in both L1 and L2, or incongruent, e.g., one grapheme associated with a different familiar phoneme between L1 and L2.

So far, the contribution of orthography on second language learning has been mostly investigated by focusing either on cross-linguistic similarities conveyed by cognate words (see above, Chapter II, section 2.1.3) or on letter-to-sound correspondences that are shared across languages or not. In this thesis work, we use the term "congruency" to refer to the interlinguistic code conveyed by grapheme-to-phoneme and phoneme-to-grapheme correspondence rules. Thus, a foreign-language word will be considered as congruent, once its decoding, i.e., the association of each grapheme to its associated phoneme shared between L1 and L2 leads to the production of its correct phonological form or of its spelling, as soon as we rely on the grapheme-to-phoneme correspondences that are specific to L1. On the contrary, an incongruent word includes at least one grapheme-to-phoneme incongruency with L1, leading to a mispronunciation of its spoken form. For example, the grapheme <u> is associated with the phoneme /uː/ in German, but with the phoneme /y/ in French.

In the literature, the importance of orthographic congruence on learning phonological novel contrasts or novel phonological forms has been exclusively documented in adults (see Showalter & Barrios, 2021, for review). Surprisingly, so far, only two studies have documented the contribution of congruency in children, by exploring its impact on visual word-recognition using a letter-detection paradigm (see. Commissaire, Dunca, & Casalis, 2014 for French children learning English as a foreign-language; Hevia-Tuero, Insera, & Suárez-Coalla, 2021 for Spanish-English sequential – and simultaneous biliterate – bilingual children). Both studies reported a congruency effect as a trend, characterized by a faster letter-detection with the congruent items than with the incongruent ones, supporting a parallel automatic activation of phonology for a pure orthographic task, consistent with previous studies (Gross, Treiman, & Inman, 2000; Lange, 2002). However, this congruency effect was rather restricted to Grade 2 Spanish-English biliterate children in Hevia-Tuero et al. (2021), whereas cross-linguistic interference only emerged in Grade 8 children in Commissaire et al. (2014). According to Hevia-Tuero et al. (2021), these contrasted results could be attributed to an enhanced L1 interference as a matter of L1 orthographic depth, with larger interference from deep than shallow orthography. Unlike Hevia-Tuero et al. (2021), Erdener and Burnham (2005) found a larger proportion of incongruent production from L1-shallow orthography to L2-deep ones than from L1-deep orthography to both L2-deep and L2-shallow orthographies in adults.

In adult-focused studies, the contribution of orthography on phonological learning has been quite largely investigated through L2 spoken recognition using an auditory picture-word matching task (e.g., Escudero, Hayes-Harb, & Mitterer, 2008; Escudero & Wanrooij, 2010; Escudero, Simon, & Mulak, 2014; Escudero, 2015; Hayes-Harb, Nichol, & Berker, 2010; Showalter & Hayes-Harb, 2015; Showalter, 2018) or through L2 spoken production using a naming task (e.g., Bürki, Welby, Clément, & Spinelli, 2019; Erdener & Burnham, 2005; Hayes-Harb, Brown, & Smith, 2017). Most of these studies focused on learning L2 novel phonological contrasts, i.e., which are not pre-existing in native language. Nonetheless, few studies investigated whether the contribution of orthography to learning phonological contrasts and full-phonological forms was modulated by L1-L2 grapheme-to-phoneme congruency, for which graphemes and phonemes are familiar in L1.

Several of these studies reported a beneficial influence of orthography on learning novel phonological contrasts. Escudero and colleagues (2008) explored whether the presence of written information played a benefit in learning an English-specific (and perceptually difficult) phonological contrast, i.e., /æ - ɛ/, in L1-Dutch monolingual adults. Importantly, this phonological contrast could be disambiguated in the written modality, given that they are associated with two different graphemes, i.e., <a> and <e>. During the learning phase, 20 English-like pseudowords were presented in their spoken modality along with their associated picture. For half of the participants, the learning material was also presented with their written form in addition to the spoken form. Using an eye-tracker, learning performance were assessed through an auditory picture-word matching task, for which two pictures were simultaneously presented on the computer screen while the pronunciation of one of the English-like pseudowords was displayed. Half of the trials were considered as mismatched trials, i.e., including the perceptually difficult contrast, whereas the remaining trials, i.e., matching trials, included only one of the two phonemes. Interestingly, in the mismatched trials, participants who were not exposed to orthography were unable to discriminate efficiently between /æ/ and /ɛ/, by looking in an undifferentiated manner at both pictures. On the contrary, the presence of the phoneme /ɛ/ triggered fixation directed only on the English-like pseudoword containing the corresponding phoneme, whereas the phoneme /æ/ triggered fixation on pictures whose English-like pseudowords included either /æ/ or / ɛ/. Thus, the explicit learning of a graphemic contrast between <a> and <e>, two graphemes that are familiar for Dutch native speakers, facilitated the encoding of perceptual difficult phonemes, an observation that is consistent with the dual-coding theory (Sadoski, 2005). The benefit of orthography in this study can be attributed to the relative congruency between English and Dutch thanks to their grapheme-to-phoneme correspondences.

In a follow-up study, Escudero, Simon and Mulak (2014) suggested that the contribution of the written form on learning L2 novel contrasts was dependent on the relationship between grapheme-to-phoneme correspondences across the L1 and L2. They hypothesized that exposure to the written form during learning of L1-L2 incongruent grapheme-to-phoneme correspondences would hinder learning performance. On the contrary, an orthographic advantage was expected for congruent grapheme-to-phoneme correspondences. To test their expectations, they made 73 Spanish listeners (naïve Dutch listeners vs Dutch learners) learn Dutch-like pseudowords, which included one of the six Dutch vowels. Here again, the authors contrasted an orthographic learning method (spoken form presented along with its meaning as well as its written form) with a non-orthographic one, for which no written form was provided. Learning performance were assessed by an auditory picture-word matching task, in which several trials included a perceptual minimal pair, i.e., target and its distractive picture differed on one vowel contrast (e.g., /a/ vs /ɑ/), while the remaining trials were non-minimal pairs, i.e., target and its distractive picture differing on more than one contrast. In the minimal pairs, a distinction was made between those that were perceptually difficult to discriminate in Spanish speakers to those that were not, i.e., perceptually easy minimal pairs. In addition, the difficult minimal pairs were also categorized as including congruent or incongruent grapheme-to-phoneme correspondences with L1-Spanish. Interestingly, the exposure to orthography during training facilitated the spoken discrimination of minimal pairs with congruent orthography, but hindered performance on minimal pairs with incongruent orthography. L1 grapheme-to-phoneme correspondences were unable to preserve the phonological contrast, so orthography had a deleterious influence on phonological learning. Importantly, a comparable pattern of results was found in English native speakers confronted with the same Dutch-like pseudowords (Escudero, 2015), suggesting that the deleterious impact of incongruent orthography on phonological learning was not modulated by L1 orthographic depth (Spanish as an example of language with a shallow orthography vs English as a language with deep orthography). These results are, however, inconsistent with Erdener and Burnham (2005). Although they reported an overall orthographic advantage on the production of L2 novel forms, this facilitation effect was restricted to transparent L2 orthography in Turkish native speakers, i.e., transparent language, whereas it was retrieved for both Spanish and English in Irish native speakers, i.e., opaque language.

Further studies also documented this deleterious impact of orthography on phonological learning, as long as the written form was not consistent with the L1 spelling conventions. Hayes-Harb, Nicol, and Barker (2010) reported that the presence of orthography led to an erroneous encoding of novel phonological forms for incongruent-wrong-letter items, i.e., those for which there was a mismatch between one grapheme and one phoneme. Consistent with Hayes-Harb et al. (2010), the confusing contribution of orthography on L2 phonological learning was also observed for production, once there was a mismatch between written and spoken form located on a consonant (see Hayes-Harb, Brown, & Smith, 2017; Barrios & Hayes-Harb, 2020 for German final consonant devoicing; Bassetti, 2017; Bassetti, Sokolovic-Perovic, Mairano, & Cerni, 2018; Cerni, Bassetti, & Masterson, 2019 for the production of English short and long consonants by Italian native speakers).

Interestingly, several studies found no effect or a limited effect of orthography on L2 phonological learning. Showalter (2015) investigated whether the contribution of written information on learning L2 phonological contrasts was dependent on graphemic familiarity. For this purpose, they made 30 English native speakers learn Arabic-like pseudowords that included the minimal phonological pair /k-q/ at word-initial position. Contrary to Arabic, English has only one phoneme /k/ associated with both graphemes <k> and <q>. They contrasted two learning methods, a non-orthographic (audio + picture) and an orthographic learning method (audio + picture + written form). In the orthographic learning method, the written form was provided in an unfamiliar writing system, i.e., abjad. Using an auditory picture-word matching task, the authors found comparable performance in both groups, suggesting that orthography did not facilitate the learning of unfamiliar graphemes. In a follow-up experiment, the authors used alphabetic written transcription for the Arabic-like pseudowords. Again, orthographic information did not play any further contribution on learning novel phonological contrasts, a finding attributed to the perceptual complexity of the contrast /k-q/ that would have alleviated any potential orthographic facilitation.

In a following study, Showalter (2018) explored the cumulative influence of both graphemic familiarity and congruency by teaching English native speakers 20 Russian-like pseudowords, which included either graphemes shared across languages, i.e., familiar graphemes, or specific ones from the Cyrillic writing system, i.e., unfamiliar graphemes (e.g., <ФИЛ>-[fil]). Familiar written forms belonged either to the familiar-congruent condition (e.g., <KOM>-[kom]) or to the familiar-incongruent one (e.g., <PAT>-[rɑt]). Testing required participants to associate the spoken form with its corresponding picture. Performance was striking on the mismatched trials, i.e., for which the target and the distractive picture were different only on one phonological contrast. Participants assigned to the non-orthographic learning method performed at ceiling for all items, whereas those in the orthographic group performed less efficiently on the familiar-incongruent items. Importantly, this pattern of results highlights the interference effects of L1-L2 incongruent grapheme-to-phoneme correspondences, whose resolution is particularly challenging in L2 phonological learning.

To summarize, although it is not clear whether orthographic congruence modulates the encoding of correct L2 novel phonological forms, most studies reported that exposure to written information during learning led to enhanced learning performances, regardless of the congruency. For example, Bürki et al. (2021) made French-native speakers with a limited experience of English learn 20 English-like monosyllabic pseudowords. Contrary to the studies conducted by Escudero and colleagues (see, Escudero, Hayes-Harb, & Mitterer, 2008; Escudero & Wanrooij, 2010; Escudero, Simon, & Mulak, 2014; Escudero, 2015), the pseudowords included no minimal pairs and each consonant phoneme was retrieved in L1-French as well as in L2-English. Thus, there was a partial GPC overlap between L1 and L2 carried by consonants. Half of these pseudowords presented an incongruent grapheme-to-phoneme correspondence with L1-French that was located on the vowel, while the remaining ones were congruent between L1 and L2. They contrasted an orthographic learning method with a non-orthographic one. Semantic and phonological learning were assessed using a naming task. Interestingly, larger accurate naming was provided by the participants in the orthographic group than in the non-orthographic one. Furthermore, they also committed fewer errors when they were exposed to orthography during learning. Nonetheless, an analysis of formants showed that the pronunciation was more (L1) French-like than (L2) English-like once written information was provided, suggesting that the spoken production of L2 phonological forms was confronted with an interference from L1. Thus, although orthography facilitated the learning of novel phonological forms, it also contributed to the phonological recoding of L2 spoken forms using L1 grapheme/phoneme correspondences, a mechanism that has been reported in L1 in reading acquisition studies (see, Ehri, 2020 for review). For L1-L2 incongruent items, this should contribute to encoding "mispronounced" phonological forms, which would lead to misremembered spoken items and, thus, hinder the recognition of previously learned L1-L2 incongruent spoken forms (e.g., Escudero et al., 2014; Hayes-Harb et al., 2010; Showalter, 2018) as well as to misleading L1 spelling strategies when reading L2 words (Figueredo, 2006).

II. 3. Summary

In this chapter, we first presented an overview of the main cognitive models of bilingual written/spoken word-recognition and comprehension. We have seen that, in these models, only two, namely the RHM (Kroll & Stewart, 1994) and BIA-d (Grainger et al., 2010), include a developmental approach to account for the initial steps of foreign language learning. Nevertheless, in their current framework, they cannot provide any clue whether orthographic facilitation is retrieved in vocabulary learning in a foreign language, given that sublexical (and lexical) processing is not yet specified. As we was in the following section, learning vocabulary in a foreign language poses novel challenges to children, especially when dealing with conflicting features, as identified by incongruent mapping between graphemes and phonemes compared to the letter/sound correspondences that are specific to L1. This interference from L1 grapho-phonemic rules may be particularly challenging when learning novel words in L2. To our knowledge, only one study explored whether the contribution of orthography on learning L2 vocabulary was comparable to the one documented in L1 word-learning. Nevertheless, due to methodological challenges (low number of items) and ceiling effects observed for measures of semantic learning, further studies are required to generalize these results. Furthermore, that study was conducted in Chinese-speaking English language learners, so it provided little evidence whether this orthographic facilitation is also retrieved in alphabetic languages, in which children are particularly confronted with GPC incongruences.

With increasing experience of a foreign language, the interference from L1 should become more controlled, with children being accustomed to dealing with two languages. Thus, learning a third language, i.e., second foreign language, might be facilitated in bilinguals. In the next chapter, we focus on the literature that documented a bilingual advantage in L3 vocabulary learning. This advantage is put into perspective with the degree of exposure to a foreign language, and particularly by contrasting early exposure to both languages in a natural context with (academic) dual-language immersion in a foreign language at school.

Chapter III. Linguistic immersion in foreign language and bilingual advantage in learning vocabulary in a third language

We have described so far that the contribution of orthography to vocabulary learning has been consistently reported in L1 and for learning pseudowords. Nonetheless, a previous study reported a different contribution of orthography between monolingual and bilingual children, suggesting that being a bilingual modulates how novel vocabulary is acquired (see. Jubenville et al., 2014, Study 2).

In this chapter, after a brief presentation of the variety of bilingual profiles, we review this bilingual advantage in L3 vocabulary learning by discussing cognitive and linguistic variables that may modulate this learning advantage, such as enhanced short-term phonological memory, enhanced management of L1 interference, enhanced phonological discrimination abilities in bilinguals, and cross-linguistic similarities conveyed by cognate words between L1 and L3, as well as between L2 and L3.

Before exploring the bilingual advantage in L3 vocabulary learning, we first discuss academic exposure to foreign language through traditional and linguistic immersion in foreign languages, for which it is important to determine whether the bilingual advantage associated with enhanced cognitive and linguistic skills arises and if so, after how much exposure to the foreign language.

III. 1. Linguistic immersion in a foreign language

Although learning a foreign language at school relies more often on traditional instruction characterized by weak exposure to the language (no exposure to L2 written language before Grade 4 in France, but then the written modality becomes dominant), several foreign language classroom-immersion programs have been implemented over the last fifty years.

Initial classroom-immersion programs appeared in Canada during the late 60s, encouraged by a growing advantage of being bilingual for professional opportunities, and especially for anglophones also to be proficient in French, while not compromising any of their English competence (Genesee & Lindholm-Leary, 2007). Although initially restricted to one specific school in Quebec, these dual-language immersion programs were generalized across Canada (and then worldwide), as soon as several studies reported that children (from kindergarten to Grade 3) considerably improved their language skills in French (Genesee & Lindholm-Leary, 2007; Ouelett, 1990).

These dual-language immersion programs are characterized by a large amount of exposure to the foreign language in an academic context compared to traditional instruction at school. They differed according to the ratio of exposure between L1 and L2. For example, the Madison dual-language immersion program, which is particularly prevalent in the USA, involves an initial asymmetrical exposure between L2 and L1. Indeed, 90% of instruction time is provided in L2 (Spanish) and the remaining time in L1 (English) in kindergarten. Each school year, there is a 10% increase in instruction time provided in L1, until the 50:50 balanced ratio is achieved from Grade 3 to Grade 5. On the contrary, other linguistic-immersion programs, such as the one proposed in Strasburg elementary schools (L1-L2 French-German), include a balanced instruction time in both languages (50%-50% L2-L1 ratio). Nonetheless, both immersion programs expect children to be relatively proficient in reading and speaking in both L1 and L2 at the end of elementary school. Interestingly, this dual-language exposure to two spoken and written languages may help children to establish a dual-system of letter/sound mapping as well as lexical entry in both languages, i.e., a bilingual lexicon. Nonetheless, to our knowledge, there is no experimental evidence to account for this assumption. To date, however, previous studies reported that children attending a linguistic-immersion program in L2 achieved higher L1 reading and metalinguistic skills compared to their monolingual peers (Reder, Daigle, & Demont, 2012; Reder, Marec-Breton, Gombert, & Demont, 2013).

Attending a dual-language immersion program is not dependent on academic performance but rather on parents' wishes. The three main reasons associated with their wishes have been well documented in the (US) literature (see for more exhaustive listing, Gerena 2011; Giacchino-Baker and Piller 2006; López 2013; Ramos 2007; Schmidt 2017). The foremost reason for parents to choose linguistic immersion for their children is for them to develop bilingual and biliterate abilities. The second is related to the professional opportunities associated with bilingual instruction. The third involves the preservation of cultural and language inheritance. Still, to our knowledge, it seems rather difficult to estimate whether attending a linguistic immersion at school is sufficient for a child to become as proficient in both languages as a "real" bilingual. If so, when referring to classroom-immersion children, it is interesting to determine at which point of the program an L2 learner may be considered as a bilingual.

III. 2. Overview on bilingualism and its related advantage on cognition and metalinguistic skills

III. 2. 1. Profiles of bilingualism

Discriminating between the different profiles of bilinguals is a thorny problem, given that it is dependent on trends. The maximalist position (Christophersen, 1948) assumes that an individual may be considered as bilingual as soon as their linguistic skills are considered as quasi-equivalent in both languages (also assumed as balanced bilinguals) and if their language proficiency may be considered as comparable to that of a monolingual. On the contrary, the minimalist position is more flexible, because it assumes that a person may be considered as bilingual once they have acquired a minimal amount of L2 proficiency (on one of the four linguistic dimensions, i.e., language comprehension, reading, speaking and writing). Between these two positions, there is a large continuum of bilingual profiles, according to variations in L2 proficiency as well as age of acquisition in others.

However, these classifications are purely indicative, given that there is no consensus on the definition of bilingualism. In general, people are considered as bilinguals according to several criteria, such as the age of acquisition of the foreign language, and L1/L2 proficiency. Regarding the age of L2 acquisition, there is a current distinction between native, early and late bilinguals. A person may be considered as a native bilingual if they have been exposed to both languages since birth. On the contrary, early bilinguals are those exposed to the foreign language early in childhood, i.e., before the (debated) critical period (Lenneberg, 1967). This exposure may have been simultaneous, i.e., exposure to both languages before the age of three (McLaughlin, 1995), or successive, i.e., foreign language is introduced later during childhood, but still before the mastering of L1 (McLaughlin, 1995). Late bilingualism refers to individuals exposed to a foreign language once they have mastered their native language, i.e., during late adolescence or adulthood (Adler, 1977; Moradi, 2014). Still, due to the asymmetrical experience between L1 and L2, there should be a relatively unbalanced proficiency between L1 and L2 (unbalanced bilingualism). Nonetheless, late bilinguals may also be considered as expert bilinguals as soon as they reach a comparable degree of mastery in both languages. In-between, balanced bilinguals have acquired an equivalent proficiency in both languages, although these languages have not yet been fully mastered.

III. 2. 2. Cognitive and metalinguistic advantages associated with bilingualism

Bilingualism has been associated with several cognitive and metalinguistic advantages in child development, although this issue is still debated (see Antoniou, 2019 for a critical review). In the cognitive field, Barac, Bialystok, Castro, and Sanchez (2014) conducted a critical review of 102 studies published between 2000 and 2013 that documented the bilingual advantage on executive and attentional functioning. They reported that young bilinguals outperformed monolingual children in a range of cognitive tasks involving inhibition control, and to a lesser extent, working memory. Elsewhere, enhanced executive control was identified in six-year- old bilingual children compared to monolinguals which was independent from cultural background and language of schooling (Barac & Bialystok, 2012). Consistent observations were also reported in eight-year-old bilinguals (Bialystok & Viswanathan, 2009). Regarding the bilingual advantage on working memory, it was especially reported for tasks that required a larger cognitive control (Morales et al., 2013). Nonetheless, more studies reported controversial data regarding such a bilingual advantage (see Antoniou, 2019, for review). Moreover, in addition to theoretical, methodological and statistical concerns, it was assumed that the cognitive advantage reported for bilingualism may be task-specific rather than generalizable (Paap, Johnson, & Sawi, 2015; see also, Duñabeitia & Carreiras, 2015).

In addition to this debated cognitive advantage, bilingualism is also associated with enhanced metalinguistic awareness (Bialystok, 2001; Dodd, So & Lam, 2008; Loizou & Stuart, 2003). Bialystok, Luk and Kwan (2005) explored the contribution of enhanced metalinguistic skills in bilinguals on the acquisition of L1/L2 reading. They compared reading performance in three groups of bilingual first-graders differing in their combination of languages (Spanish-English, Hebrew-English, and Chinese-English bilinguals) and in one group of English native monolinguals. Both Spanish-English and Hebrew-English bilinguals outperformed the monolingual group on the phonological awareness task as well as in nonword-decoding. Thus, the authors reported a reading facilitation effect in English that was larger in children whose languages both shared a similar writing system, i.e., alphabetic languages. In addition, the transfer of these reading skills across languages was retrieved only if they shared a common writing system. Thus, enhanced metalinguistic skills in bilinguals facilitated L1/L2 reading acquisition. Despite enhanced metalinguistic skills, several studies reported a relative bilingual disadvantage in linguistic abilities. For example, bilingualism was associated with an overall poorer vocabulary (Poulin-Dubois, Bialystok, Blaye, Polonia, & Yott, 2013) as well as a slower access to the lexicon (Gollan, Montoya, Fennema-Notestine, & Morris, 2005).

III. 3. Bilingual advantage in L3 vocabulary learning

Although there is a lack of consensus on the potential cognitive and metalinguistic advantages associated with bilingualism, a consistent contribution to L3 language learning has been documented in bilingual adults compared to monolinguals (Cenoz & Valencia, 1994; Kaushanskaya & Marian, 2009a, 2009b; Kaushanskaya & Rechtzigel, 2012; Kaushanskaya, Yoo & Van Hecke, 2013; Keshavarz & Astaneh, 2004; Papagno & Vallar, 1995; Sanz, 2000; Van Hell & Mahn, 1997), as well as in bilingual adolescents with an immigrant background (Hesse, Göbel, & Hartig, 2008, but see Sanders & Meijers, 1995; van Gelderen et al., 2003 for a lack of L3 learning advantage in immigrant bilinguals).

III. 3. 1. Bilingualism is associated with enhanced proficiency in L3

In the early 90s, the beneficial contribution of bilingualism to L3 vocabulary skills was initially explored in bilingual students exposed to multiple languages since (early) childhood in a bilingual school context. Such a context is mostly found in countries in which there are two or more official languages, i.e., Luxemburgish, French and German in Luxemburg, or in regions where there are co-official languages, i.e., Spanish, Catalan and Basque in Spain. For example, Sanz (2000) explored L2/L3-English proficiency in Catalan-Spanish bilingual adults and Spanish monolinguals using a multiple-choice vocabulary task in English. They reported that bilingual adults outperformed their monolingual peers even when intra-individual variables such as motivation, intelligence and socioeconomical status were controlled. They concluded that bilingualism had a beneficial impact on L3 learning (see also, Keshavarz & Astaneh, 2004 for a larger effect of bi-literate compared to mono-literate bilingual). Importantly, this bilingual advantage in L3 vocabulary learning has been documented for close L1/L3 (Cenoz & Valencia, 1994; Sanz, 2000) as well as for distant L1/L3 languages (Abu-Rabia & Sanitsky, 2010; Hesse, Göbel, & Hartig, 2008; Keshavarz & Astaneh, 2004). Hesse and colleagues (2008) reported that the bilingual advantage was consistently found in several dimensions of L3 German skills (i.e., spoken and written comprehension, and writing) in immigrant bilinguals, with a large variety of native language, i.e., English, Polish, Russian, South Slavonic, Turkish, and thus, for L1/L3 languages that shared the same writing system or not.

Although these initial studies documented the bilingual advantage in L3 vocabulary learning, none of them included an experimental approach or used any word-learning paradigm to assess learning abilities directly from the onset of L3 language learning. In the following sections, we thus focus on L3 (pseudo)word-learning studies that used a learning paradigm.

III. 3. 2. Exploring the bilingual advantage through experimental paradigms

Contrary to previous studies that explored orthographic facilitation on L1 word or pseudoword-learning (see Colenbrander et al., 2019 for a review) using a paired-associate learning paradigm, the bilingual advantage in learning L3 vocabulary has been documented by using two different learning methods. The first involves the mediation between L3 and L1 mechanisms postulated by the RHM (Kroll & Stewart, 1994, please see. Chapter II-1.2 for explicit description of the model). Therefore, the learning phase was mostly characterized by the presentation of the novel wordform followed by its translation equivalent, using mediation via the native language translation, both presented visually (Kaushanskaya & Marian, 2009a, 2009b; Valente, Ferré, Soares, Rato & Comesaña, 2018) or auditorily (Kaushanskaya & Rechtzigel, 2012). The second learning method consisted of a direct mapping of the novel wordform with its associated concept by the presentation of a picture (Bartolotti & Marian, 2012a; Eviatar, Taha, Cohen & Schwarz, 2018; Kaushanskaya et al., 2013; Kaushanskaya et al., 2014).

While several studies also investigated learning retention after delay (Kaushanskaya, 2018; Kaushanskaya & Marian, 2009a, 2009b), most focused on the immediate assessment of learning (Bartolotti & Marian, 2017a; Eviatar et al., 2018; Kaushanskaya, 2018; Kaushanskaya et al., 2014; Kaushanskaya et al., 2013; Kaushanskaya & Rechtzigel, 2012; Kaushanskaya & Marian, 2009a, 2009b; Valente et al., 2018). Learning was mostly assessed by two different types of productive tasks, i.e., L3-L1/L2-L1 backward translation tasks (Kaushanskaya, 2018; Kaushanskaya & Marian, 2009a, 2009b; Kaushanskaya & Rechtzigel, 2012) and L3 naming tasks (Bartolotti & Marian, 2017a, 2017b). In addition, recognition tasks also provided a measure of word-learning performance. Forced-choice recognition tasks were more commonly used to assess the ability of participants to select the correct picture associated with its L2/L3 spoken form (Eviatar et al., 2018; Kaushanskaya et al., 2013; Kaushanskaya et al., 2014) or with its L3 written form (Bartolotti & Marian, 2017a), but also to link the L2/L3 spoken form to its related L1 written form (Kaushanskaya & Marian, 2009a, 2009b; Valente et al., 2018).

III. 3. 3. Experimental evidence of bilingual advantage on L3 word-learning

A consistent L3 word-learning advantage was consistently found in bilingual adults compared to monolinguals. Interestingly, such a L3 word-learning advantage was found in bilinguals who learned/were exposed to L2 in a wide range of learning contexts. According to Hirosh and Degani (2018), two different learning contexts may be distinguished: an environment-based and a classroom-based one. The first is where the foreign language is learned in an out-of-school context, whereas the latter is where it is learned in an academic context. Importantly, the bilingual advantage in L3 vocabulary learning was documented in both environment-based bilinguals (Kaushanskaya & Marian, 2009a, 2009b) and classroom-based ones (Kaushanskaya & Rechtzigel, 2012; Van Hell & Mahn, 1997). In addition, the bilingual advantage was also found in early bilinguals (Kaushanskaya & Marian, 2009a, 2009b) as well as in late bilinguals (Bogulski, Bice & Kroll, 2019).

III. 3. 3. 1. Modulation of bilingual advantage by degree of semantic familiarity: the case of concreteness vs. abstract novel items

In a complementary study, Kaushanskaya and Rechtzigel (2012) explored whether the bilingual advantage on L3 vocabulary learning was conditioned by the degree of semantic information involved during word-learning. They contrasted the learning performance for concrete and abstract pseudowords in Spanish-English bilinguals and English monolinguals. Importantly, previous experimental evidence had shown that the presentation of concrete words led to a wider lexical-semantic activation in monolinguals compared to abstract words (e.g., De Groot, 1989; Grondin, Lupker, & McRae, 2009; Schwanenflugel & Shoben, 1983). Furthermore, although a similar lexical processing between bilinguals and monolinguals was postulated by Kaushanskaya and Rechtzigel (2012), the exposure to a concrete word in a bilingual mind may also involve a wider (L1 and L2) lexical-semantic activation than in monolinguals, due to the larger number of features shared across languages for concrete than for abstract words (see the distributed feature model, De Groot, 1992, for the underlying mechanisms). As expected by the authors, they reported a learning advantage for L3 concrete (pseudo)words in bilingual adults than in monolinguals. Nevertheless, this learning advantage disappeared for abstract pseudowords, with comparable recognition performance in both groups. Thus, the bilingual advantage was thought to be partially driven by a larger sensitivity to semantic information during learning.

III. 3. 3. 2. Modulation of bilingual advantage by degree of phonological familiarity

In addition to a wider lexical-semantic processing, the bilingual advantage may be particularly sensitive to the degree of L3 phonological familiarity with L1. Kaushanskaya, Yoo and Van Hecke (2013) contrasted the learning of phonologically familiar pseudowords (selected from the database validated by Gupta et al., 2004) and of unfamiliar ones in two groups of English-Spanish classroom bilingual adults with various degrees of proficiency with Spanish. Each group of bilinguals was exposed either to the phonologically familiar pseudowords or to the unfamiliar ones. Importantly, phonologically familiar pseudowords included only phonemes consistent with L1-English, whereas the unfamiliar ones did not share (consonant) phonemes with both English and Spanish. During the learning phase, a picture was displayed on the computer screen associated with its associated spoken form, pronounced by an English native speaker. In the testing phase, learning was assessed using a forced-choice recognition task in which participants had to match the spoken form with its associated referent. Interestingly, the contribution of phonological familiarity was observed only when the pseudoword was associated with a familiar referent, with higher learning for phonologically familiar pseudowords than for unfamiliar ones. In addition, this effect of phonological familiarity was reinforced by the degree of proficiency with L2. Together, these findings suggest that bilingual learning is facilitated by L1/L3 cross-linguistic spoken familiarity. Although these studies throw much light on the bilingual learning advantage, little is known about whether the similarities between L2 and L3 contribute to enhancing this learning advantage.

III. 3. 3. 3. Contribution of pre-existing languages to L3 vocabulary learning: distinguishing between a scaffolding and an accumulation account

Whether and how knowledge of pre-existing languages contributes to L3 vocabulary learning are still debated questions. In the literature, the contribution of pre-existing languages to L3 word-learning has been documented by investigating neighbourhood density (Marian et al., 2012) and orthotactic/phonotactic probabilities as reflecting word likeliness. As a reminder, the neighbourhood density refers to the number of items that differ only by one grapheme with a target word (Marian et al., 2012). Orthotactic probability measures how often one or two letters are used in a given language and can be reflected by the positional segment probability or the positional bigram probability (probability that two letters occur in the same position within words of a given language; Vitevitch & Luce, 2004). Previous studies have reported the beneficial contribution of neighbourhood density size (Roodenrys & Hinton, 2002; Storkel Armbrüster, & Hogan, 2006; Thorn & Frankish, 2005) and phonotactic (Majerus, Poncelet, van der Linden, & Weekes, 2008; Storkel et al., 2006; Thorn & Frankish, 2005) as well as orthotactic probabilities (Bartolotti & Marian, 2014) to nonword-learning.

In this regard, two accounts of L3 word-learning and interaction with pre-existing languages have been proposed (and tested) in the literature (see Bartolotti & Marian, 2017a): an accumulation vs. a scaffolding account. According to the accumulation account, a novel word may be particularly affected by disruption during its first encounter. However, its trace in the phonological loop may be maintained by rehearsal processes until the word is stored in the lexicon. This rehearsal process may be even more efficient when the novel word shares some features with the pre-existing knowledge (native-like features). Thus, the accumulation account relies on an additive (cumulated) influence of prior languages to facilitate the learning of L3 novel forms. On the contrary, the scaffolding account posits that learning L3 vocabulary is characterized by the establishment of direct links between a novel word and a pre-existing lexical entry that share the same concept. Thus, the initial step in L3 word-learning relies on the anchoring of the less-experienced language (L3) to a more experienced one. Here, lexical mediation is driven only by one of the two languages, i.e., the one that shares the largest number of features with the L3 word.

The contribution of L1/L2 to L3 pseudoword-learning was explored by Bartolotti and Marian (2017a) to determine whether both languages interact with L3 learning, giving credence to the accumulation account, or whether it is restricted to one of the two languages only, consistent with the scaffolding account. They made 20 English-German bilingual adults learn pseudowords that shared features either with English only (i.e., copt, that has only English neighbours, such as coat and cost) or with German only (i.e., gach, that has only German neighbours, such as Bach, Dach and Fach) or with both English and German languages (e.g., nist, that is a close orthographic neighbour for the English word, nest, and the German word, Nest). According to the authors, if L3 word-learning is consistent with the accumulation account, then there should be a cumulative effect of both L1 and L2 on L3 learning. Thus, the learning advantage might be larger for L3 pseudowords that share features with both English and German languages. On the contrary, if an overall generalized L3 learning advantage is reported, then this supports the scaffolding account. Learning was assessed by a pseudoword-picture recognition task and a picture written naming task. Interestingly, a bilingual advantage was found for the three types of L3 pseudowords, suggesting that bilinguals usde both L1 and L2 for learning L3 pseudowords. Nonetheless, the absence of cumulative facilitation for pseudowords that had familiar patterns and were close orthographic distractors in both languages suggested that initial vocabulary transfer occurred by anchoring the L3 word to one of the two languages rather than to both languages. This finding is consistent with the scaffolding account.

In this section, we have seen that L3 vocabulary learning is mediated by the two pre-existing languages. Nevertheless, this bilingual advantage in L3 word-learning may be explained by a series of different mechanisms.

III. 3. 3. 4. Hypotheses associated with the bilingual word-learning advantage

In this section, we present the three main hypotheses to account for the bilingual advantage on L3 vocabulary learning, i.e., enhanced short-term phonological memory skills (Papagno & Vallar, 1995; Van Hell & Mahn, 1997), decreased sensitivity to L1 interference (Bartolotti & Marian, 2012b; Kaushanskaya & Marian, 2009; Meuter & Allport, 1999; Van

Assche, Duyck & Gollan, 2013) and enhanced phonological discrimination skills (Kaushanskaya & Marian, 2009a).

In the first hypothesis, the difference in short-term phonological memory skills between bilingual and monolingual adults is thought to explain the bilingual advantage in L3 vocabulary learning. Indeed, the contribution of phonological memory skills to vocabulary learning is well known, given that rehearsal processes tend to prevent a word from disruption until its phonological trace is stored in memory. In the literature, the major contribution of phonological short-term memory to foreign vocabulary learning has been documented in studies conducted in bilinguals (Majerus, Poncelet, Van der Linden & Weekes, 2008) and monolinguals (Gathercole & Baddeley, 1989). Nevertheless, Kaushanskaya and colleagues (Kaushanskaya & Marian, 2009a; Kaushanskaya & Rechtzigel, 2012) reported a persistent bilingual advantage in L3 word-learning when bilingual and monolingual participants were matched on their phonological memory skills. This suggested that the bilingual advantage cannot be reduced to enhanced phonological memory skills in bilinguals.

The second hypothesis posits that bilinguals experience a decreased sensitivity to cross-linguistic interference. Kaushanskaya and Marian (2009b) investigated L3 word-learning performance in English-Spanish bilingual and English monolinguals by contrasting two learning procedures: unimodal learning, in which only the word spoken form was presented during learning; and bimodal learning, in which both the written and spoken form were displayed during the learning. In both modalities, the English written translation was provided to the participants. Importantly, the bimodal learning procedure may have confronted participants with incongruent grapheme-to-phoneme correspondences with L1-English. Nonetheless, bilingual adults outperformed the monolinguals in both learning modalities, although their learning performance was comparable in both. Regarding monolinguals, however, they performed worse in bimodal learning than in unimodal learning. This led the authors to assume that being a bilingual was associated with a decreased sensitivity to cross-language interference. Nonetheless, this hypothesis posits that the bilingual advantage may be found in languages that share a similar script/writing system. However, as documented earlier, previous studies have reported a bilingual advantage for languages with different scripts (see. Kaushanskaya & Marian, 2009a, for a facilitated learning of L3 Chinese words in English-Spanish bilingual adults), which could not be explained by this decreased interference with pre-existing languages.

In the third hypothesis, Kaushanskaya and Marian (2009a) proposed that the bilingual learning advantage is related to enhanced phonological discrimination abilities in bilinguals. This hypothesis is based on the fact that bilinguals have to deal with two phonological systems early in life through repeated exposure to both languages, leading them to develop a more tolerant phonological system. Thus, learning novel phonological forms in L3 should be facilitated.

III. 3. 3. 5. Is the bilingual advantage found in bilingual children?

Although previous studies have relatively well documented the bilingual advantage in L3 vocabulary learning in adults, there is little evidence whether this advantage extends to bilingual children. This is not a trivial issue, given that learning L2 vocabulary as an adult or as a child does not involve comparable challenges (see Chapter II, Preamble for more details). Indeed, adults who learn a foreign language have to deal with the automatized activation of L1 due to their accumulated experience as a monolingual (Birdsong, 1999; MacWhinney, 2008). This may result in increased interference from L1 that makers learning L2 vocabulary even more difficult. On the contrary, due to their initially limited cognitive abilities, children are particularly dependent on the mutual exclusivity constraint, i.e., the tendency to map one concept to one word only (e.g., Clark, 2009), so it may be particularly challenging for them to learn L2 words that are associated with a pre-existing lexical entry in L1.

To our knowledge, only two previous studies explored the bilingual advantage in L3 vocabulary learning in bilingual children (Eviatar et al., 2018; Kaushanskaya et al., 2014). Both studies reported enhanced learning performance in bilingual children compared to their monolingual peers. Using a learning paradigm for which a spoken form was displayed in association with a familiar referent, Kaushanskaya et al. (2014) observed that classroom-immersion first-graders outperformed the monolingual group in a forced-choice recognition task. These results are comparable with those of Eviatar et al. (2018), who extended the bilingual advantage to both familiar and unfamiliar referents in two groups of bilinguals (Hebrew-Arabic and Arabic-Hebrew bilingual children) over several groups of monolinguals (Hebrew and Arabic). Nevertheless, both studies were conducted prior to reading acquisition, leaving little scope to determine whether the bilingual advantage in L3 learning occurs in literate children, given that the acquisition of written language may confront children with both interference and facilitating effects (see. Kaushanskaya & Marian, 2009b, for a reduced interference in bilingual adults for the bimodal learning procedure). Furthermore, the number of items during the learning session was restricted, i.e., six items in Eviatar et al. (2018) and 16 divided into two blocks with familiarity manipulated as an intra-individual variable (Kaushanskaya et al., 2014). Therefore, future studies should explore whether the bilingual advantage in L3 vocabulary learning extends to different profiles of bilingualism, and especially to bilingual children.

III. 4. Summary

In this chapter, we presented the main profiles of bilingualism as well their associated cognitive and linguistic advantages. As we have seen, despite the controversial bilingual advantage in cognitive and metalinguistic skills, a consistent L3 vocabulary learning advantage has been reported in bilingual adults. This bilingual advantage in L3 learning has been mostly assessed by two different learning paradigms. The first is based on the mediation mechanisms between L3 and L1, and is characterized by the presentation of the novel (written or spoken) form associated with its (written/spoken) translation equivalent. The second exposes participants to L3 novel forms by mapping them with their associated concept. We have seen that the bilingual advantage in L3 learning is modulated by the degree of semantic familiarity (concreteness) as well as by phonological familiarity with L1. Still, it remains unanswered whether the bilingual advantage in L3 vocabulary learning is modulated by the degree of orthographic and phonological overlap between L2 and L3, especially for L2/L3 cross-linguistic similarities such as cognate words. In addition, further studies are also required to determine whether the bilingual advantage is found in (bi)literate children with a differential bilingual experience, especially those attending a foreign language classroom-immersion programme since preschool.

Research questions and hypotheses

Learning vocabulary in a foreign language is still a hotly debated topic, especially in a world in which being a bilingual may be becoming the global norm (Baker, 2001). Despite the large attractiveness of bilingualism in professional and societal contexts, the average proficiency in a foreign language remains relatively low, especially in France, with large discrepancies between individuals and countries (see Beadle & Scott, 2014). In France, foreign languages are learned mostly at school, with low exposure to L2 and where the written modality is predominant, although orthography is only presented at the end of primary school. Spoken and written modalities are scarcely presented simultaneously during foreign language learning. Nevertheless, De Wilde and colleagues (2020) recently reported that Dutch monolingual children reached A1/A2 proficiency prior to exposure to L2 English in an academic context, due to their environmental and cultural (incident) exposure to English (e.g., in movies, songs and videogames).

To date, numerous studies have documented the mechanisms involved in learning our first language as well as the contribution of different factors to its learning, but little attention has been given to L2 vocabulary learning. Indeed, bilingualism has been mostly explained by cognitive models of written (BIA, BIA+) and spoken word-recognition (BIMOLA), which focus on bilingual adults with a high degree of proficiency in both languages, or by developmental ones which involve direct lexical links between L2 and L1 lexicons (through backward translation) in sequential bilinguals. On the other hand, how lexical and sublexical representations are acquired even though L1 is not yet fully mastered is an issue that has received relatively little attention.

Vocabulary learning in a foreign language confronts children with different challenges compared to their L1. Although L1 vocabulary learning calls upon the association between the spoken form and its related concept and eventually its spelling, once reading has been acquired, L2 word-learning requires children to learn and store novel spoken and written forms associated with a pre-existing concept. These novel sublexical representations require them to learn novel grapheme-to-phoneme representations, some of which are conflicting with the native ones. This problem of congruency is reinforced by the predominance of the written modality in L2 academic learning. Thus, we sought whether orthography contributes to L2 learning, and if so, whether its contribution can be disentangled from a more general visual advantage. Indeed, the presentation of written information during learning provides an additional visual cue for vocabulary learning. Better understanding of this issue would throw light on the mechanisms associated with foreign vocabulary learning, an issue little addressed so far. Findings might also have practical implications for teaching methods.

Previous studies have demonstrated the benefit of orthography, i.e., the so-called orthographic facilitation effect, for learning L1 low-frequency words (Rosenthal & Ehri, 2008) as well as pseudowords (Ricketts, Bishop, & Nation, 2009), for which semantic representations are poorly specified. Although instructive to understand how L1 representations are processed, these studies cannot fully account for L2 vocabulary learning, for which an L2 spoken and L2 written representations have to be integrated into a pre-existing semantic one, which has already been connected to phonological and (sometimes) to an orthographic representation in L1.

To our knowledge, only Hu (2008) investigated the contribution of orthography to L2 vocabulary learning in children and reported promising results. Unfortunately, due to methodological issues, that finding cannot be generalized regarding the benefit of orthography on L2 vocabulary learning. Thus, further studies are required to determine the contribution of orthography to foreign language learning and to go beyond some methodological biases by using a learning paradigm.

In this thesis, we used an adapted paired-associate learning paradigm that allowed us to simultaneously provide the spoken and the written form of an L2 word associated with its related concept. This learning paradigm is currently used in the literature, especially for L1 learning. The thesis builds on previous studies that aimed to understand the contribution of orthography to vocabulary learning. In particular, we explored to what extent orthographic facilitation occurs in L2/L3 vocabulary learning. For this purpose, three experimental studies were conducted.

The first study, also called the princeps study, explored whether exposure to orthography during learning might help children to acquire and memorize L2 vocabulary. We wondered whether an orthographic advantage would be found for orthographic and phonological learning as well as for the building of phono-semantic connections. Additionally, we sought to determine whether this putative orthographic advantage is modulated by the degree of reading automatization. To this end, we recruited third and fifth graders in order to contrast two levels of mastery in L1 decoding. Additionally, we manipulated two modalities of learning load to explore whether learning performance could be replicated irrespective of the size of the learning list. Importantly, increasing the learning load might also contribute to modifying the linguistic processes involved, and especially the contribution of orthography to L2 word-learning. Finally, we manipulated three modalities of learning repetitions as a within-variable to explore the gradual increase in learning performance associated with the number of exposures to novel words, to avoid duplicating studies during the thesis.

The second study aimed to determine whether the benefit of orthography during learning is modulated by the degree of grapheme-to-phoneme congruency. We thus manipulated two modalities of word grapheme-to-phoneme congruency to determine whether the orthographic advantage occurs irrespective of the degree of grapheme-to-phoneme congruency or whether it is restricted to congruent words. Due to the COVID crisis, data inclusion was severely impacted and had to be delayed until February 2022. An additional research interest was to determine whether exposure to written and spoken wordforms helped children to acquire L2-specific letter/sound correspondence rules. We included two additional experimental tasks to determine whether children could transfer L2 grapheme-phoneme correspondences rules to novel items. However, due to the delayed data collection associated with the crisis, the latter objective could not be addressed in the present work.

Together with grapheme-to-phoneme incongruences, it is also possible to document the impact of interlinguistic similarities through the cognate facilitation effect, which has been largely documented in lexical decision tasks (see e.g., Dijkstra et al., 2010). The two previous studies focused on learning a foreign language with a traditional learning method. In the third study, we determined whether learning a foreign language in a linguistic immersion program facilitates the learning of L3 vocabulary.

The third study was conducted within the framework of an Indoc research appointment in the Cognitive Psychological Lab in the University of Strasburg. The study explored whether children who attend a bilingual immersion program at school show a greater ability to learn vocabulary, including written, spoken and conceptual forms, in a third language (L3) compared to those attending standard monolingual classrooms, and to what extent this putative advantage varies depending on whether the words to be learned are L2/L3 cognates words or not. We thus contrasted L3 word-learning performance between children attending a foreign language classroom-immersion programme and a group of monolingual children. We manipulated two modalities of cross-linguistic similarities between L2 and L3, i.e., non-identical cognate words vs. non-cognate words.

EXPERIMENTAL CONTRIBUTION

Chapter IV. Extending the study of the benefit of orthography on L2 vocabulary learning

IV. 1. Study 1a: Does the presence of orthography help children to learn L2 words?

IV. 1. 1. Introduction

The present study aimed to determine whether the presence of the written form might help children to learn vocabulary in a foreign language, including the acquisition of written, spoken and conceptual forms, and to what extent this orthographic advantage might be modulated by L1 linguistic skills, and more especially by the degree of reading automatization.

As we have seen earlier, Colenbrander et al. (2019) conducted a systematic review that reported a consistent orthographic facilitation on L1 vocabulary learning, especially for orthographic and phonological learning, but also for semantic learning (despite mixed results associated with ceiling effects). Among these studies, Ricketts et al. (2009) reported an orthographic advantage for pseudoword learning, which was modulated by children's reading abilities. Interestingly, they reported significant correlations between measures of reading accuracy (regular, exception word and nonword reading) and orthographic facilitation. Thus, participants with the more advanced reading skills exhibited superior learning and they additionally benefited more from the presence of orthography displayed during learning. Comparable observations have been documented in previous L1 vocabulary learning studies that used similar word-learning paradigms (e.g., Ehri & Wilce, 1979; Rosenthal & Ehri, 2008).

Despite a relatively well-documented contribution of orthography on L1 vocabulary learning, it remains unanswered whether this orthographic facilitation might be extended to L2 word learning. Indeed, L2 vocabulary learning does not confront children to the same challenges as in L1, given that they have to memorize and to associate a novel spoken and written form to a pre-existent concept that is (usually) shared between languages (although the semantic overlap between languages may not be complete due to cultural and linguistic particularities; see., Dong et al., 2005). Additionally, given that orthography tends to be more stable and shared across languages than phonology, there is a larger overlap in written forms than in spoken ones between alphabetic languages (e.g., Marian, Bartolotti, Chabal, & Shook, 2012). Yet, shared orthography across languages may be accompanied by incongruent letter/sound mappings. Indeed, in this particular situation, one grapheme is associated with two phonemes, i.e., one phoneme in L1 and one in L2. As an example, the grapheme <u> is associated with the phoneme /y/ in French, but with the phoneme /u/ in German. During the early steps of foreign language learning in an academic context, children may rely on the L1 grapheme-to-phoneme correspondences to decode a L2 word, which result in its mispronunciation, i.e., production of the spoken form /ʃy/ instead of /ʃu/ for the German word <Schuh> (shoe in English) when relying on the French letter/sound mappings. Thus, learning a foreign language confronts children to a problem of congruency, for which the presence of orthography during learning may be misleading for the acquisition of novel phonological forms.

Contrary to L1 learning, children also have to acquire both written and spoken form simultaneously during L2 vocabulary learning. At the moment, the developmental models of bilingualism (e.g., BIAd, Grainger et al., 2010; RHM, Kroll & Steward, 1994) underspecified the sublexical orthographic and phonological dimensions, and thus, cannot provide any account of the L2 learning dynamics, nor any clue for the potential orthographic advantage on L2 vocabulary learning. To our knowledge, only one study explored the contribution of written information on learning pseudonames among Chinese fifth graders learning English as a foreign language (see Hu, 2008). Despite some promising results, such as an orthographic facilitation on picture naming, they have to be taken with caution due to several methodological challenges. First, participants differed widely on their L2 linguistic profiles, given that they were exposed to English as a foreign language for at least two years and that L2 teaching programs varied a lot across schools. Second, there was a restricted number of pseudonames, i.e., three of the six selected items were learned with orthography. Furthermore, these items were presented between one- and ten-times during the learning phase. Thus, participants also differed according to their exposure to the learning material. In light with these limitations, further studies are required to determine the contribution of orthography on L2 vocabulary learning and focus has to be oriented on the setting of experimental parameters, such as the size of the learning list and the required exposure to spoken and written form during learning.

Indeed, despite a lack of consistency in the literature, it appears important to determine which is the optimal exposure to novel words during learning. Twelve to fifteen repetitions are supposed to be required for a word to be integrated in the lexicon, when learning occurs in an ecological context (see., Beck et al., 2002). Nonetheless, Chambré et al. (2017) have reported that the presence of orthography contributed to an accelerated phonological learning, for which less exposure to spoken material was required in the orthographic method compared to the non-orthographic one. Indeed, after six exposure to spoken items, first graders were able to pronounce accurately about five of the six novel L1 words. Nonetheless, in L2 learning, children have to acquire the specific grapheme-to-phoneme correspondences to decode L2 words, thus, further additional exposure to learning material may be required.

Our study explored whether exposure to orthography facilitated the acquisition and memorization of L2 words, and to what extent the orthographic advantage might be modulated by L1 reading automatization. Using a paired-associated word learning paradigm, we contrasted the learning of 16 German words among two groups of third and of fifth graders. During the learning phase, children were assigned either to an orthographic (OLM) or to a non-orthographic learning method (NOLM). The OLM was characterized by the simultaneous presentation of L2 written and spoken forms associated with its related concept, whereas the NOLM substituted orthography by a series of undecodable symbols. Although previous L1 studies mostly focused on production, we opted for different measures of word recognition (see below) to assess learning, because of their lower cognitive cost. We expected that children assigned to the OLM would outperform those in the NOLM. In addition, although fifth graders should exhibit larger learning performance compared to third graders, we wondered whether the orthographic advantage might be reinforced among fifth graders, due to their higher level of reading proficiency (see Ricketts et al., 2009 for L1 (pseudoword) learning).

To assess vocabulary learning, we constructed three experimental tasks, 1) a forced-choice recognition task of the spoken form-to-picture relationship choose the correct image corresponding to the spoken form); 2) a go/no-go auditive recognition task (discrimination between spoken German words and close phonological distractors); and 3) an orthographic judgment task (recognition of the correct German written form among three written distractors). Learning was assessed immediately after learning and after a one-week delay to assess offline sleep consolidation, as previously evidenced in word learning studies conducted among children (see., Brown et al., 2012; Henderson et al., 2012). This battery of tasks allowed us to specify whether any orthographic advantage would occur for different dimensions of vocabulary learning, including written, spoken and conceptual forms. Though testing the presence of an advantage for the OLM group on the orthographic task might seem a trivial question, as this group was the only one exposed to the written form during learning, the task was designed so that we also could investigate the degree of precision of the orthographic representation. In addition, we explored whether the benefit of orthography was modulated by the degree of reading automatization, as evidenced in L1 studies (see Colenbrander et al., 2019 for review). Finally, we manipulated three modalities of learning repetitions, i.e., six, nine and twelve repetitions during learning, as a within-variable to explore the gradual increase of learning performance associated with the number of exposures to novel words, which aimed to avoid duplicating the studies along the thesis. This research question will be specifically addressed in Study 1c for the sake of clarity.

IV. 1. 2. Method

IV. 1. 2. 1. Participants

One hundred ninety-three children were recruited from eleven elementary schools in the "Region Hauts de France" area, France. Data inclusion started on April 2018 and continued on the following years in the same school period, i.e., from February to June. This ensured us that children would have achieved comparable L1 skills. Unfortunately, due to the COVID-19 sanitary crisis, data inclusion was stopped on March 2020. Elementary schools were closed from 16th March to 29th June 2020 by decision of the French government. Further interventions in schools were not possible before early 2021. All participants came from the same catchment area. All of them were French native speakers or had learned French for at least six years. Importantly, children were not exposed to German before and none of them reported previous knowledge of German prior to the study. A questionnaire was initially included in our experimental design to determine children's exposure to languages other than French as well as their parents' socio-economic status but had to be removed due to mixed feedback from schools and parents4. Furthermore, we insured that participants did not suffer from recognized learning disabilities or any sensory disorders. Participants should have normal or corrected-to-normal vision. However, among them, thirty-seven children (18 third vs 19 fifth graders) did not complete both learning and testing sessions and thus, were removed from further analysis. Therefore, among the remaining 156 participants, 81 children were third graders (mean age = 9.02 years; SD = 0.29). The remaining 75 children were fifth graders (mean age = 10.62 years; SD = 0.49). The two groups of participants were randomly assigned to one of the two learning

[4] This could be explained through French sociocultural norms regarding wealth and success, as well as that educational system stems on minoring cultural, religious and social differences among children.

methods, i.e., an orthographic learning method (OLM; simultaneous presentation of written and spoken forms during learning) vs a non-orthographic learning method (NOLM), in which spelling was substituted by a series of identical symbols. Seventy-eight participants, i.e., 39 third vs 39 fifth graders, attended on orthographic learning method. The remaining 78 participants, i.e., 42 third vs 36 fifth graders, learned German words through a non-orthographic learning method. Participants were matched on chronological age between the two learning methods ($t(156) = 0.76$, $p=.45$). The study was approved by the Research Ethics Committee at the University of Lille (accreditation number: **2018-286-S63**).

Cognitive and language background tests

Cognitive and language skills in French were measured using background tests from standardized batteries. This ensured that any difference in learning performances between groups were not attributed to better cognitive or linguistic skills of children attending an orthographic learning method to learn German vocabulary. Importantly, we used the same background as described below throughout this doctoral research work. Non-verbal and verbal intelligence were assessed respectively through the sets A, B and C of the coloured progressive RAVEN matrices (Raven, 1981) and the vocabulary subtest of the WISC-IV (Wechsler, 2005). This subtest requires participants to define orally a list of 36 French words with decreasing frequency and increasing difficulty. Phonological short-term memory was controlled through the pseudoword repetition task subtest of the NEPSY II (Korkman et al., French adaptation, ECPA, 2012), given that it is highly correlated with vocabulary learning (Gupta et al., 2003). Reading age as well as reading skills, i.e., reading accuracy and reading speed, were assessed by using the Alouette task (Lefavrais, 1967; 2005), which consists in reading aloud a French text composed of 265 unpredictable words within three minutes. Two calculated indices reflected our participants' reading skills, i.e., reading accuracy and reading speed. Reading accuracy was calculated by multiplying by 100 the ratio between the number of words accurately read compared to the total number of words read. Reading fluency reflects the number of words that would have been read in a three-minute period; thus, a reading fluency score higher than 265 means that a participant have read the whole text in less than three minutes. Participants' scores to background tasks are presented in Table 1 for third and fifth graders respectively. Separate statistical descriptive analyses were conducted on third and fifth graders to ensure that participants were matched on cognitive and linguistic skills in both learning methods, i.e., orthographic learning method vs. non-orthographic learning method.

Table 1. *Summary of the participants' performances to cognitive and linguistic background tasks among third graders and fifth graders according to the learning method (OLM vs. NOLM)*

	Orthographic learning method		Non-orthographic learning method		*t*-test	*p*-value	Cohen's d
	M	SD	**M**	SD			
Third graders							
Chronological age	108.48	2.98	107.57	3.42	1.1	.28	
Reading age	113.06	17.89	104.54	15.95	2.12	.04	0.51
Reading fluency	251.17	86.27	209.32	87.19	2.02	.04	0.48
Reading accuracy	94.63	3.44	92.76	3.71	2.19	.04.	0.52
NWRT (/40)	32.68	4.23	32.33	4.98	0.30	.76	
RAVEN matrices (/36)	23.59	3.79	22.07	3.77	-1.54	.13	
L1Vocabulary (/68) (WISC-IV)	24.09	5.47	23.76	5.36	0.26	.80	
Fifth graders							
Chronological age	127.78	5.28	127.28	5.75	0.37	.72	
Reading age	131.43	23.10	132.38	22.42	- 0.17	.86	
Reading fluency	336.73	98.06	338.55	97.49	- 0.08	.94	
Reading accuracy	96.48	2.43	97.03	1.60	- 1.10	.28.	
NWRT (/40)	34.50	3.61	35.19	3.58	0.37	.71	
RAVEN matrices (/36)	25.53	4.29	26.25	4.79	- 0.78	.44	
L1Vocabulary (/68) (WISC-IV)	35.25	5.94	34.81	5.49	- 0.31	.75	

Note—Reading measures were obtained at the Alouette test (Lefavrais, 1967; 2005): Reading fluency scores reflect the number of words that would have been read in three minutes (reading fluency score higher than 265 means that the participant have read the whole text in less than three minutes); Reading accuracy was calculated by multiplying by 100 the ratio between the number of words read accurately compared to the number of words read; NWRT: Nonword repetition task subtest of NEPSY II (Korkman et al., French adaptation ECPA, 2012) and assessed short-term phonological memory skills; RAVEN matrices were used as a measure of non-verbal reasoning skills (Raven, 1981); L1(French) Vocabulary subtest of Wechsler Intelligence Scale for Children (WISC IV; Wechsler, 2005).

Descriptive analyses conducted on third graders

Eight third graders did not complete the background tests and, thus, were removed from further analysis. Among them, five participants attended an orthographic learning method. The remaining three participants were assigned to the non-orthographic one. Independent sample t-tests were conducted on the remaining 73 participants, 34 in the OLM vs 39 in the NOLM to check whether the two groups of third graders were matched on their cognitive and language skills. While third graders from the orthographic learning method outperformed their peers from the non-orthographic learning method in reading skills (p =.04), they were matched on all the cognitive and language background tests (all *p-values* > .05).

Descriptive analyses conducted on fifth graders

Six fifth graders did not complete the background tests, and, thus, were removed from further analysis. Among them, one participant was assigned to the orthographic learning method, while the remaining five participants were in the non-orthographic one. Independent sample t-tests were conducted on the remaining 69 participants, i.e., 38 in the orthographic group vs 31 in the non-orthographic group, to ensure that both groups of fifth graders were matched on their cognitive and language skills. They revealed homogeneous cognitive and language skills in both groups (all *p-values* > .10).

IV. 1. 2. 2. Learning and testing phases

This study was split into one learning session and two testing sessions namely an immediate one (right after the learning session) and a one-week delayed one (see details below). Both learning and testing sessions took place in each elementary school with groups of three-to-five children. Importantly, all the experimental studies conducted throughout this thesis work followed a similar procedure for both learning and testing sessions. The experimental design is illustrated in Figure 6.

Figure 6. *Organization of the learning and testing sessions for Study 1.*

Day 1

- Learning sessions
    - Learning block 1 (six word repetitions)
    - Training forced-choice picture recognition task 1
    - Learning block 2 (three additional repetitions, i.e., nine repetitions in total)
    - Training forced-choice picture recognition task 2
    - Learning block 3 (three additional repetitions, i.e., twelve repetitions in total)
- Immediate testing session
    - Forced-choice picture recognition task
    - Go/no-go spoken recognition task (immediate session)
    - Orthographic judgment task

Day 7

- Delayed testing session:
    - Go/no-go spoken recognition task (spontaneous session)
    - Forced-choice picture recognition task
    - Go/no-go spoken recognition task (delayed session)
    - Orthographic judgment task
- Cognitive and linguistic background tasks

IV. 1. 2. 2. 1. Learning phase

Words:

Sixteen typical German words were selected from the SUBTLEX-DE-database (Brysbaert et al., 2011). They comprised between four and seven letters (mean = 5.00, SD = 0.89) and between four and seven phonemes (mean = 4.38, SD = 0.62). Half of the selected German words were congruent in French (ex *Birne*), whereas the other half included at least one grapheme-to-phoneme incongruency with French (*Stern*, for which the grapheme <s> is associated with the phoneme /ʃ/ in German and with /s/ in French). We ensured that their French translation equivalents were frequent enough so that participants already encountered them multiple times before the study. The French translation equivalents had a frequency between 20.35 for the French word “poire (pear)” and 773.91 occurrences per million for “tête (head)” (mean frequency = 169.90, SD = 208.26). These frequencies were extracted from MANULEX-database (Lété, Sprenger-Charolles & Colé, 2004), which is a corpus-base of children reading books. Furthermore, all the words were selected according to their concreteness and imageability to ensure the direct activation of the concept associated with the picture. Concreteness ratings of the French translation equivalents stemmed on Bonin, Méot, and Bugaiska (2018); concreteness was estimated on a 5-point Likert scale (mean = 4.61, SD = 0.61). To our knowledge, no database reported any exhaustive measure of imageability in French. For this reason, imageability ratings were estimated by using the Glasgow psycholinguistic norms (Scott et al., 2019): there, imageability was rated on a 7-point Likert scale (mean = 6.69, SD = 0.74). Minimal bigram frequency with German as well as cross-language orthographic and phonological similarities with French were estimated by using CLEARPOND database (Marian et al., 2012), to ensure that the selected German words did not share a large overlap with French on both written and spoken forms. We reported the degree of orthographic and phonological overlap with French translation equivalents for all items by using the Orthographic Levenshtein Distance and the Phonological Levenshtein Distance, respectively. Both Levenshtein distances were calculated using the vwr-package (Keuleers, 2013) on R-Software; the phonemes were transcribed into the phonetics alphabet using a X-SAMPA converter to calculate a Levenshtein Distance. Learning stimuli are presented in Appendix 1.

Pictures:

German selected words were paired to black and white picture, so that each word was associated with the same picture during learning phase. Pictures were selected from the MULTIPIC-database (Duñabeitia et al., 2018). All the words were selected according to their concreteness and imageability to ensure the direct activation of the concept associated with the picture.

Sound recordings:

Spoken forms, i.e. German words pronunciation, were recorded with three German native speakers using AUDACITY-software (Team, 2015). The audio stream was then normalized across each word and we also proceeded to a noise attenuation procedure. Hence, we had three versions of the recorded German words. We ensured that participants were exposed to the three versions of the recordings during the learning phase. Our strategy relied on two arguments. First, the exposure to several native speakers prevented participants to rely on specific prosodic indices (tone, pitch or accentuation) to complete the experimental tasks during the testing phases. Second, in addition to an ecological language learning environment, participants had to flexibly adjust their phonological representation foreach German word to allow them to generalize their recognition of the German spoken forms.

Procedure:

Before learning, we ensured that each picture was correctly recognized by participants by using a French naming task. During learning, participants seated in front of a laptop, while auditive information was provided through headphones. As mentioned earlier, prior to learning session, participants were randomly assigned to one learning method (OLM vs NOLM). Orthographic Learning Method (OLM) was characterized by a simultaneous presentation of both German spoken and written wordform associated to their corresponding picture. For the non-orthographic learning method, the German spelling was substituted by a series of identical symbols (#####). Thus, all participants were exposed to audio-visual sources of information, regardless of the learning method. Each word was presented for at least three seconds (with no time limit). Participants were then allowed to move to the next word. Participants were exposed to each German word twelve times[5] during the learning phase. This ensured a sufficient

[5] The statistical analyses conducted on the degree of exposure to German words during learning will be presented in Study 1c.

exposure to the learning material. Importantly, spoken items were provided only once for each trial. A switch in German speaker occurred between each of the three learning blocks. The first block included six-word repetitions, whereas the second and third ones only had three-word repetitions. After each of the first two learning blocks, learning progress was assessed by using a forced-choice picture recognition task. We will refer to them as "training" forced-choice picture recognition tasks and performance to these tasks will be presented in Study 1c. No corrective feedback was provided during these "training" tasks. Familiarization to the "training" tasks was prevented by using experimental safeguard as exposed in the Testing phase section. Learning phase lasted between 25 and 40 minutes according to the participants' learning pace.

IV. 1. 2. 2. 2. Testing phase

Three computerized tasks, i.e. a forced-choice recognition task, a go/no-go spoken recognition task and an orthographic judgment task, were conducted for both the immediate and the one-week delayed testing session. For the immediate testing session, these tasks were displayed following the above order. In addition to these tasks, the one-week delayed testing session started with the go/no-go spoken recognition task, to determine participants' performance without prior exposure to spoken information, referred to as "spontaneous" go/no-go spoken recognition task. The speaker's voice was switched after each experimental task. Immediate and one-week delayed testing lasted between 20 and 35 minutes. Background cognitive and language skills, as presented above, were assessed at the end of the one-week delayed testing. Testing material is available in Appendices (please see, Appendix 2 for the forced-choice picture recognition task, Appendix 3 for the go/no-go auditive recognition task, and Appendix 4 for the orthographic judgment task).

Forced-choice picture recognition task:

For each trial, one of the learned spoken word was displayed associated with an array of four pictures on the computer screen. The target picture was presented among three other trained pictures in a 2 x 2 grid. The position of both target and distractive picture was counterbalanced between each trial; each distractive picture is used to an equal number of trials. For immediate and one-week delayed testing, two out three distractors were similar and the third one was substituted by another one across sessions, to avoid familiarization with the distractive pictures. Accuracy and response times were recorded for each trial.

Go/no-go spoken recognition task:

Stimuli. Besides the 16 German words, two lists of 16 pseudowords were constructed using WUGGY software (Keuleers, & Brysbaert, 2010). They were phonological distractors to the learning material (one to two phonemes different from the real words, like Birg for the item Berg). They were recorded along with the German words by the three German native speakers. The recording of each pseudoword immediately followed those of their related German word, to ensure their pronunciation was as close as possible to German. The first list of pseudowords was used for immediate testing (and the delayed session), whereas the second one was displayed for the spontaneous session only to prevent any familiarization to the spoken pseudowords presented in the delayed session.

Procedure. For each trial, a spoken item (word or pseudoword) was displayed in headphones. No visual information was provided on the computer screen. For this task, participants were required to recognize German words by pressing the button as fast as possible. For pseudowords, participants had to refrain from giving any response. The up-coming items were displayed immediately after pressing the Space key or after a three-second delay. This response time interval was sufficient to allow participants to produce or refrain their response, but short enough to prevent any decrease in participants' attention. Accuracy and response times were recorded for each trial.

Orthographic judgment task:

Stimuli. For each of the German word, three types of distractors were created, i.e. close and distant orthographic distractors, and phonological distractors. The close orthographic distractors were created by a one-letter transposition (Birne –Binre). The distant ones shared a small orthographic overlap with the target word. This overlap was characterized by one-to-three graphemes (Birne-Biclo), depending on word size. The phonological distractors were *homophonic*[6] with the German word when using the French grapheme-to-phoneme correspondences (Birne-Bilneux). These three types of distractors were designed in order to identify whether and to what extent participants paid attention to written form during the learning phase as well as the contribution of L1 letter/sound mapping in the encoding of the L2 written form.

Procedure. Four spellings of each German words, i.e. the target word and its three related distractors, were presented on the screen in a 2 x 2 grid. Participants were required to recognize the correct spelling of each target word by clicking on one of the written transcriptions with the computer mouse. The position of target and distractors was randomized across sessions and trials. Accuracy and response times were recorded, as well as, for each committed error, the selected distractive spelling.

[6]Given that there is no complete phonological overlap between languages, we created the phonological distractors to get as close as possible of the German pronunciation.

IV. 1. 3. Results

IV. 1. 3. 1. Data analysis

All statistical analyses reported below used generalized mixed model, that were conducted on R Software (R Core team, 2017), using lmer and glmer functions from the lme4 package (Bates, Kliegl, Vasishth, & Baayen 2015). These analyses were conducted on accuracy measures for each task. Statistical analyses on response times were conducted for the go/no-go spoken recognition task only, given that it was the only experimental task which included a speed criterion. The random effects were modelled in a random structure, following a compromise between the maximal random structure (Barr et al., 2013) and the parsimonious one (Bates et al., 2015). Starting from the random structure, which included at least by-participants and by-items random intercepts, we then adjusted the model for each experimental task by including fixed effects, i.e. grade (third vs fifth graders), learning method (orthographic vs non-orthographic learning method) and session (immediate vs delayed session) and interaction effects. We used a model comparison approach by progressively entering each fixed main and interaction effects, by comparing each model with the previous one, and eventually including the variables that led to the most adjusted model. The experimental factors were included step-by-step, starting with the one that led to the most adjusted model. At each step, Chi-squared tests were performed to test the significant adjustment differences across models; p-values were determined using lmer-package (Kuznetsova et al., 2017). This led to the selection of the most adjusted model, i.e., with the smallest Akaike Information Criteria (AIC). This statistical approach seemed very relevant, given that the existing scientific literature did not give us a clear idea of how some of our variables would contribute or not to learning performance. The procedure was stopped as soon as the further inclusion of any experimental factor did not better fit the previous model. For models with binary outcome variables, we conducted mixed logistic models and significant main and interaction effects were highlighted using a cut-off point of p<.05. For the continuous outcomes, especially for the Go/no-go spoken recognition task, mixed linear models were computed and significant effects were reported using a cut-off point of t > 2. In the event of interaction, we computed subset models to explore the contribution of each variable modality. Given that third graders were not matched on their reading skills, we included reading age as a covariate in the statistical analyses. For all three experimental tasks, we present below the most adjusted model. Descriptive statistics are presented for each experimental task in Table 2.

Table 2. *Participants' performance for all three experimental tasks according to Grade (third vs. fifth graders), learning method (OLM; orthographic learning method vs. NOLM; non-orthographic learning method) and session (immediate vs. delayed sessions; and vs. delayed sessions; and vs. spontaneous session).*

	Third graders				Fifth graders			
	NOLM		OLM		NOLM		OLM	
	M	SD	**M**	SD	**M**	SD	**M**	SD
Forced-choice recognition task (accuracy in percent)								
Immediate	48.72	23.87	72.16	22.17	71.88	16.65	83.88	16.35
Delayed	51.76	21.01	68.94	20.14	72.60	15.88	80.72	14.58
Go no go auditive recognition task (discrimination score)								
Immediate	1.28	0.58	1.55	0.64	1.73	0.66	1.80	0.61
Spontaneous	0.79	0.73	0.90	1.05	1.57	0.73	1.64	0.81
Delayed	1.01	0.77	1.78	0.78	1.66	0.70	1.80	0.68
Go no go auditive recognition task (response time)								
Immediate	1537	305	1572	315	1491	274	1576	225
Spontaneous	1520	275	1578	274	1530	261	1564	217
Delayed	1562	289	1501	268	1434	242	1499	209
Orthographic judgment task								
Immediate	28.71	14.37	61.13	18.11	43.15	23.05	74.18	16.30
Delayed	29.81	12.36	63.48	18.97	44.76	24.28	73.85	19.08

IV. 1. 3. 2. Forced-choice picture recognition task

Two third graders from the orthographic group exhibited recognition scores below three standard deviations, with the correct recognition of one German word only. Thus, they were removed from further analysis. Statistical analyses were conducted on 140 participants, i.e., 71 third vs 69 fifth graders. Among the 71 third graders, 32 attended an orthographic learning method. The remaining 39 third graders learned the German words with a non-orthographic learning method. Thirty-eight of the 69 fifth graders learned the German words with orthographic information whereas the remaining 31 children did not.

Accuracy:

Given that the dependent variable, i.e., accuracy, was binary, the participants' performance to the forced-choice picture recognition task were analysed by using mixed logistic models. The most adjusted model included reading age, learning method (orthographic vs non-orthographic learning method), grade (third vs fifth graders) as fixed effects as well as by-participant, by-item and by-school random intercepts (AIC = 4930, $\chi^2(1) = 36.83$, $p < .001$). This model and its parameter are reported in Table 3. Despite the inclusion of reading age as a covariate, the main effect of grade was still significant, with an odds of accurate picture recognition 2.12 times higher in fifth graders than in third graders (respectively, 78.38% vs. 58.46%, $p < .001$). Furthermore, the odds of accurate picture recognition was 2.49 times higher for children in the orthographic learning method than for those in the non-orthographic one (respectively, 74.44% vs. 60.26%, $p < .001$). The inclusion of the interaction between Group and Learning method did not better fit the model ($\chi^2(1) < 1$, $p = .81$).

Table 3. *Summary of the logistic mixed model analysis for variables predicting accuracy in the forced-choice recognition task.*

Model and predictors	Estimate	SE	95% CI		*z*-value	*p*-value
			LL	UL		
Intercept	0.216	0.091	0.095	0.494	-3.631	<.001
Reading age	1.015	0.003	1.008	1.021	4.296	<.001
Learning method	2.491	0.355	1.885	3.293	6.411	<.001
Grade	2.123	0.364	1.516	2.971	4.387	<.001

```
Model = glmer (forced_choice$Accuracy~Read_age+ Learning_method+ Grade +(1|participant) + (1|item)+(1|school),data=forced_choice,family=binomial(link=logit),control=glmerControl(optimizer ="bobyqa"))
```

IV. 1. 3. 3. Go/no-go spoken recognition task

Seven participants (two third graders vs five fifth graders) did not complete all go/no-go spoken recognition tasks and were, thus, removed from the analysis. Among them, five participants were assigned to the orthographic learning method (one third vs four fifth graders). The remaining two participants (one third vs one fifth graders) attended the non-orthographic learning method. Surprisingly, a large proportion of false alarms was committed for one pseudoword (Kitte). This pseudoword was phonologically too ambiguous for being correctly rejected by participants and, thus, we decided to remove this item from the analysis, i.e., 2.1 % of the remaining data. In addition, we removed from analysis response times that were lower than 300 milliseconds, i.e., 3.7% of the remaining data. Unexpectedly, three more third graders (two in the orthographic learning method) had to be removed from analysis, given that only half of their responses remained. The proportion of accurate recognition for words and rejection for pseudowords according to grade (third vs fifth graders), learning method (orthographic vs non-orthographic learning method) and session (immediate, spontaneous and delayed session) is presented in Table 4.

Table 4. *Summary of the accurate recognition of words and pseudowords in the go/no-go auditive recognition task according to Grade (third vs. fifth graders), learning method (OLM; orthographic learning method vs. NOLM; non-orthographic learning method) and session (immediate vs. delayed sessions; and vs. spontaneous session).*

	Third graders				Fifth graders			
	NOLM		OLM		NOLM		OLM	
	M	SD	**M**	SD	**M**	SD	**M**	SD
Words (in percent)								
Immediate	73.8	17.1	71.5	14.2	79.1	14.0	75.8	10.8
Spontaneous	64.4	17.2	66.5	16.4	75.2	15.8	69.1	19.2
Delayed	67.5	13.2	78.4	16.4	75.7	14.4	76.7	18.1
Pseudowords (in percent)								
Immediate	67.3	18.4	79.2	10.9	76.0	16.4	83.6	11.5
Spontaneous	64.1	22.4	70.6	25.9	76.1	15.6	83.2	16.2
Delayed	66.9	19.7	78.6	19.5	76.3	18.8	81.1	14.9

The go/no-go spoken recognition task is more suitable for a potential bias in response strategies to occur, i.e., pressing the key space for all items or for none. For this reason, we ran a signal detection theory analysis, by calculating d' scores for sensibility –we will refer to discrimination score along this thesis. Discrimination score were obtained by the difference between the z-transformed distribution of correct word recognition (hits) and those of the incorrect acceptance of pseudowords (false alarms). A preliminary transformation was performed on the extreme recognition scores, using Macmillan & Kaplan's (1985) requested transformation. Recognition scores of 1 were transformed following the (n-0.5/n) equation, with n corresponding to the number of items. Null scores were recalculated using the (0.5/n) requested transformation. We applied a two-step cut-off by removing participants with discrimination score below 0 as well as a proportion of false alarms higher than the random level for the immediate session only. This ensured us that participants had fully understood the task instructions and had processed the task efficiently. Twelve participants, i.e., ten third graders vs two fifth graders, met the cut-off and were removed from further analysis. Statistical analyses were conducted on the 117 remaining participants, i.e., 55 third vs 62 fifth graders. Among them, 61 participants, i.e., 25 third vs 36 fifth graders, were assigned to the orthographic learning method. The 56 remaining participants, i.e., 30 third vs 26 fifth graders, attended the non-orthographic learning method.

Table 5. *Summary of the mixed linear regression analysis for variables predicting discrimination scores in the go/no-go spoken recognition task in the analysis including immediate and delayed sessions.*

Model and predictors	Estimate	SE	*t*-value
Intercept	0.768	0.282	2.719
Reading age	0.004	0.002	1.431
Learning method	0.490	0.151	3.243
Grade	0.460	0.161	2.860
Learning method x Grade	-0.390	0.207	-1.883
Third graders			
Intercept	1.047	0.506	2.069
Reading age	0.001	0.005	0.195
Learning method	0.514	0.167	3.071
Fifth graders			
Intercept	1.051	0.382	2.755
Reading age	0.005	0.003	1.744
Learning method	0.099	0.131	0.755

Discrimination scores:

Immediate vs Delayed testing:

Discriminative scores were analyzed for immediate and delayed testing using generalized mixed models. Due to the calculation of discriminative scores, the random structure only included by-participant random intercepts. We first only considered immediate and delayed discriminative scores in the analysis. This design gave us a measure of discriminative performance after a one-week delay, for the go/no-go auditive recognition task conducted in the same order for both immediate and delayed testing. The best fitted model included reading age, learning method, grade as well as the interaction between learning method and grade as fixed effects and by-participant random intercepts (AIC = 476, χ (1) = 3.65, p=.06). The parameters of the model are presented in Table 5. Reading age was not a significant covariate in the analysis of discriminative score ($t = 1.43$). A significant main effect of learning method was highlighted ($t = 3.24$), supporting that children in the orthographic learning method outperformed the ones in the non-orthographic learning method (respectively, 1.74 vs 1.40). Furthermore, fifth graders had higher discriminative scores compared to the third graders (respectively, 1.75 vs 1.38, $t = 2.86$). The interaction between Grade and Method was marginally significant ($t = -1.89$) and was explored by computing separate models for each grade. Interestingly, among the group of third graders, a significant main effect of learning method was retrieved ($t = 3.07$), indicating larger discriminative scores for participants who attended the orthographic learning method compared to those in the non-orthographic one. For fifth graders, however, there was no significant difference in discriminative performance according to the learning method ($t = 0.76$). Interestingly, reading age was a non-significant covariable in the analyses of the discriminative scores among both third ($t = -0.20$) and fifth graders ($t = 1.74$), supporting that the proportion of accurate recognition of words as well as of correct rejection of pseudowords was not modulated by the degree of reading expertise in this task.

Immediate vs Spontaneous session:

The above analysis reported a benefit of orthography in the discrimination between spoken words and pseudowords, that was however restricted to third graders. We further conducted a statistical analysis to compare discriminative scores between immediate and spontaneous testing sessions. As a reminder, the “spontaneous” go/no-go spoken recognition task took place at the beginning of the delayed session and included pseudowords to determine whether the benefit of orthography might be retrieved after delay in the absence of re-exposure to the spoken material. Here, the best fitted model included Reading age, Grade, Session as well as Method as fixed effects and by-participant random intercepts (AIC = 506, $\chi 2 = 3.51$, $p = .06$).

The parameters of the models are presented in Table 6. The main effect of grade was significant (t = 3.15), with fifth graders showing higher discriminative scores compared to third graders (respectively, 1.70 vs 1.21). Furthermore, discriminative scores were significantly larger in the immediate session compared to the spontaneous one (respectively, 1.60 vs 1.34, t = -3.14). There was a marginal main effect of learning method (t =1.89). Reading age was a marginally significant covariable in the analysis of discrimination scores between immediate and "spontaneous" testing (t= 1.86), indicating a tendency for children with a larger reading experience to exhibit higher discriminative scores compared to the less-skilled readers. Surprisingly, the interaction between Grade and Method did not reach significance (AIC = 506.4, $\chi 2$= 1.77, p =.18).

Table 6. *Summary of the mixed linear regression analysis for variables predicting discrimination scores in the go/no-go auditive recognition task in the analysis including immediate and spontaneous sessions.*

Model and predictors	Estimate	SE	*t*-value
Intercept	0.751	0.282	2.665
Reading age	0.005	0.002	1.856
Learning method	0.195	0.103	1.894
Grade	0.361	0.115	3.145
Session	-0.263	0.084	-3.137

Summary of the statistical analyses conducted on the discriminative scores:

Fifth graders exhibited higher discriminative scores than the third graders at immediate as well as after a one-week delayed testing. The benefit of orthography on discriminative score was retrieved among third graders from immediate testing and was maintained even after a one-week delay. The discriminative scores were comparable both groups of fifth graders regardless of the learning method. However, discriminative scores were lower in "spontaneous" testing compared to the two other go/no-go testing sessions.

Response times:

This analysis was conducted on correct word responses only. As mentioned earlier, we removed response times that were below 300 milliseconds, i.e., 2.1% of the remaining data. Maximum response times were 3000 milliseconds. Statistical analyses were conducted on raw data using the generalized linear mixed model as advocated by Lo and Andrews (2015). According to these authors, GLMM are more efficient in satisfying normality assumptions compared to link-function transformations.

Generalized linear mixed-effects models were conducted for immediate and delayed testing, as well as for immediate and spontaneous testing. The most adjusted model included Reading age and Session as fixed effects as well as by-participant, by-item and by-school random intercepts (AIC= 3769, $\chi 2$= 18.64, $p < .001$). The main effect of session was significant, supporting that response times were faster during the delayed testing compared to the immediate one (respectively, 1490 vs 1570 milliseconds, $t = 4.33$). Reading age was however a non-significant covariable in the analyses of response times ($t = 0.86$). We also conducted a follow-up analysis between immediate and "spontaneous" testing. Here, the most adjusted model only included by-participant, by-item as well as by-school random intercepts (AIC = 3813, $\chi 2 = 73.4$, $p <.001$).

IV. 1. 3. 4. Orthographic judgment task.

***Accuracy*:**

Statistical analyses were conducted on the remaining 140 participants, i.e., 71 third and 69 fifth graders. Among them, 70 participants were assigned to the non-orthographic learning method, i.e., 39 third vs 31 fifth graders, and the remaining 70 ones to the orthographic learning method, i.e., 32 third vs 38 fifth graders. As mentioned before, measures of accuracy were analysed through mixed logistic models, given that this variable was binary. Here, the best fitted model included reading age, learning method (orthographic learning method vs non-orthographic learning method) and grade (third vs fifth graders) as fixed effects as well as by-participant, by-item and by-school random intercepts (AIC= 5185, $\chi^2(1) = 27.68$, $p < .001$). The parameters of the models are presented in Table 7. Post-hoc analyses revealed that the odd of accurate spelling recognition was 4.25 times higher toward children in the orthographic learning method compared to those in the non-orthographic one (respectively, 68.66% vs 35.78%, $p < .001$). Furthermore, despite the inclusion of reading age as a covariable, the main effect of grade was still significant, with an odds of accurate spelling recognition 1.63 times higher among fifth graders than in third graders (respectively, 60.50% vs 35.78%, $p <.001$). The inclusion of the interaction between learning method and grade did not fit the model better to the data (AIC = 5161, $p = .88$).

Table 7. *Summary of the logistic regression analysis for variables predicting accuracy in the orthographic judgment task.*

Model and predictors	Estimate	SE	95% CI		*z*-value	*p*-value
			LL	UL		
Intercept	0.061	0.025	0.028	0.136	-6.853	<.001
Reading age	1.016	0.003	1.009	1.023	4.791	<.001
Learning method	4.247	0.553	3.290	5.483	11.100	<.001
Grade	1.629	0.256	1.197	2.217	3.103	.002

Pattern of errors*:*

For exploratory purpose, we also conducted statistical analyses on the committed errors. As a reminder, three different types of distractors were presented for each trial: close and distant orthographic distractors and phonological distractors. The close orthographic distractors were characterized by a one-letter transposition (Birne – Binre). The distant ones only shared a small orthographic overlap with the German word (Birne – Biclo). The phonological distractors were homophonic with the target word, according to the French grapheme to phoneme correspondences (Birne – Bilneux). For each participant and item, we identified which distractor was selected instead of the correct spelling of the German words. The proportion of errors was comparable on both immediate and one-week delayed session. For this reason, we included both sessions for statistical analyses. These statistical analyses followed the same procedure. First, chi-square homogeneity tests were conducted to determine whether the committed errors were equivalently distributed on the three types of distractors among both learning methods (orthographic vs non-orthographic learning method) and, then, among both third and fifth graders. Second, if significant, given that chi-square homogeneity test is an omnibus test, we conducted Scheffé post-hoc pairwise comparisons[7] between individual conditions in accordance with the Goodman procedure (Goodman, 1963) described in Franke et al. (2011). All pairwise comparisons are presented in Table 8.

Table 8. *Summary of the pairwise comparisons conducted on the pattern of committed errors.*

	ψ	SE	Scheffé test	*p*
Close orthographic distractor				
Non-orthographic vs orthographic method	-.215	.023	-9.54	<.001
Third vs Fifth graders	-.068	.022	-3.14	.01
Non-orthographic method: Third graders vs Fifth graders	-.059	.026	-2.30	.07
Distant orthographic distractor				
Non-orthographic vs orthographic method	.065	.016	4.01	.0003
Third vs Fifth graders	.048	.016	2.98	.02
Non-orthographic method: Third graders vs Fifth graders	.044	.021	2.09	.11
Phonological distractor				
Non-orthographic vs orthographic method	.149	.022	6.77	<.001
Third vs Fifth graders	.020	.022	0.91	.66
Non-orthographic method: Third graders vs Fifth graders	.015	.027	0.58	.85

Distribution of errors according to learning method:

A 2x3 chi-squared homogeneity test conducted between learning method and the type of errors revealed that the proportion of errors are not equal across both learning methods (χ^2 (2, 2138) = 90.32, $p < .001$, Cramer's $V = 0.21$). Post-hoc analyses showed that the proportion of committed errors was larger for close orthographic distractors in the orthographic learning

[7]The Scheffé post-hoc test is more usually retrieved for ANOVA, but also, to a lesser extent, for post-test comparisons following a chi-square homogeneity test. We chose this specific post-hoc test for its conservative approach, i.e., minoring the type I error. Note that the Scheffé critical value corresponds to the squared chi-square statistic.

method compared to the non-orthographic one (respectively, 54.6 % vs 33.1 %, χ^2 (1, 858) = 90.32, $p < .001$), but lower for distant orthographic distractors (respectively, 12.7 % vs 19.2 %, χ^2 (1, 365) = 16.10, $p < .001$), as well as for phonological ones (respectively, 32.8 % vs 47.7 %, χ^2 (1, 915) = 45.77, $p < .001$).

Distribution of errors according to grade:

A further 2x3 chi-square homogeneity test was conducted to determine whether the three types of distractors were equally distributed between third and fifth graders. Unsurprisingly, they were not in the two groups (χ^2 (2, 2138) = 13.42, $p = .001$, Cramer's V =.08). Post-hoc analyses using the Scheffé criterion for significance revealed a larger proportion of close orthographic distractors among fifth graders compared to third graders (respectively, 44.2 % vs 37.4 %, χ^2 (1, 858) = 9.86, $p = .01$), but a smaller one for distant orthographic distractors (14.2% vs 19.0 %, χ^2 (1, 365) = 8.87, $p = .02$). Nonetheless, the proportion of phonological distractors was equivalently distributed in both groups (χ^2 (1, 915) = 0.82, $p = .66$).

Distribution of errors according to grade and learning method:

The two previous 2x3 chi-square homogeneity tests revealed that the committed errors were not equally distributed between learning methods nor between grades. In this follow-up analysis, we explored whether there was an asymmetrical contribution of the learning method on the pattern of errors as a function of grade level. For this purpose, we have split the analyses for each learning method (orthographic vs non-orthographic learning method) to compare the distribution of errors between third and fifth graders. Two 2x3 chi-square homogeneity tests were conducted: one for each learning method. Interestingly, the three types of distractors were equivalently distributed between fifth and third graders for the orthographic learning method (χ^2 (2, 702) = 3.74, $p = .15$), but not for the non-orthographic learning one (χ^2 (2, 1436) = 7.12, $p = .03$). Post-hoc analyses only highlighted that the proportion of close orthographic errors was marginally different between fifth and third graders (respectively, 36.7 % vs 30.8 %, (χ^2 (1, 475) = 5.27, *p* = .07). Furthermore, although participants committed a larger proportion of phonological errors, they were equally distributed among fifth and third graders (respectively, 46.8% vs 48.3%, χ^2 (1, 685) = 0.32, *p* = .85). Distant orthographic errors were equally distributed among participants (χ^2 (1, 276) = 4.36, *p* = .11).

Correlation between background linguistic skills and learning performance:

We explored whether the benefit associated with orthography would be correlated with the participants' linguistic skills, and more especially reading and vocabulary skills, an hypothesis that has been tested on L1 (pseudo)word learning studies (see., Ricketts et al., 2009). Pearson correlation coefficients were calculated for each experimental task, i.e., forced-choice picture recognition task, go/no-go spoken recognition task, orthographic judgment task, by contrasting learning method, i.e., OLM vs. NOLM, and grade, i.e., third vs. fifth graders.

For the forced-choice picture recognition task, we first calculated Pearson's correlation coefficients among the group of third graders. Surprisingly, there was no significant correlation between background linguistic tasks, i.e., L1 reading and L1 vocabulary, non-verbal intelligence, phonological short-term memory skills and learning performance (all ps >.05). Reading age was indeed not correlated with the performance to the forced-choice picture recognition task, neither for the participants assigned to the orthographic learning method (r=.26, p=.15), nor to the non-orthographic one (r =.24, p=.15). Furthermore, there was no significant correlation between reading skills and L1 vocabulary measures (all ps >.05). Among the fifth graders, a marginal correlation between reading age and learning performance was reported for the orthographic learning method (r=.32, p=.053), but not for the non-orthographic learning method (p=.11). Reading age was however positively correlated with L1 vocabulary among participants assigned to the orthographic learning method (r =.51, p= .001), but only marginally correlated among those in the non-orthographic one ($p = .053$). This is consistent with the Matthew effect reported between reading and vocabulary knowledge (Stanovitch, 1986): in sum, fifth graders with the better reading skills were also those with the larger vocabulary knowledge in L1 and reciprocally.

For the go/no-go auditive recognition task, correlation between discrimination score and reading skills were not significant, irrespective of the learning method and of the grade (third vs. fifth graders; all $ps > .05$).

For the orthographic judgment task, although there was no significant correlation between reading skills and accurate recognition of the spelling among third graders assigned to the orthographic learning method ($p = .12$), this correlation between reading and written word recognition was significant for those in the non-orthographic learning method ($r = .58$, $p < .001$). Vocabulary knowledge was also significantly correlated with performance to the orthographic judgment task, but for the NOLM group only ($r = .39$, $p = .01$). Among fifth graders however, we observed an opposite pattern of results, with a marginally significant correlation between reading skills and accurate written word recognition for children who attended an orthographic learning method ($r = .32$, $p = .053$) whereas this correlation was not significant for those in the non-orthographic method ($p = .16$). Overall, fifth graders with the more advanced reading skills took more benefit from orthography in the orthographic judgment task.

IV. 1. 4. Discussion

In this study, we sought to determine whether the presence of orthography facilitated the acquisition and memorization of vocabulary in a foreign language among children, and to what extent this orthographic facilitation may be modulated by the degree of reading automatization. We also explored the benefit of orthography might be reported for orthographic, phonological learning as well as for (reciprocal) L2 phonological to semantics connection. Before to present the results, it should be noted that the paired-associated learning paradigm allowed us to provide these three different sources of information during learning and, as expected, was particularly efficient for L2 vocabulary learning studies. Indeed, immediate testing highlighted that participants were able to correctly associate the L2 spoken form to its associated meaning for about 9.6 (60%) of the 16 German words for children assigned to the non-orthographic group compared to about 12.5 (78%) of the 16 ones for those in the orthographic group after 12 exposure to the learning material.

In addition, the present study also explored whether orthography was processed during learning as well as the degree of overlap between the written form and its encoded orthographic representation. For this purpose, we compared the German (L2) word learning performance among Grade 3 and Grade 5 children by contrasting an orthographic learning method to a non-orthographic one, each relying on a paired-associate learning paradigm. Importantly, we ensured that the (L2) selected German words did not share any orthographic or phonological overlap with its (L1) French translation equivalent. In addition, participants were not exposed to L1 during both learning and testing sessions. This prevented us from potential biases in learning performance associated with cross-linguistic similarities conveyed by (identical and non-identical) cognate words.

IV. 1. 4. 1. Evidence of an early and consistent orthographic facilitation on L2 vocabulary learning

The results revealed a (rather) consistent orthographic advantage on L2 word learning. Indeed, irrespective of the grade (third vs. fifth graders), children assigned to the orthographic learning method outperformed the ones in the non-orthographic method on two of the three experimental tasks, i.e., forced-choice picture recognition task and orthographic judgment task. These results are consistent with the lexical quality hypothesis (Perfetti & Hart, 2002), which postulated that learning should be optimal for word representation that include an orthographic, a phonological as well as a semantic representation, i.e., connection between the L2 spoken form and its associated concept. For the go/no-go spoken recognition task however, an orthographic facilitation was retrieved among third graders, but not among fifth graders who exhibited comparable performance irrespective of the learning method. Importantly, although fifth graders outperformed third graders on all three experimental tasks, no significant interaction between grade and learning method was reported for any of the experimental task, supporting that the orthographic facilitation, i.e., the difference in L2 learning performance between the orthographic and the non-orthographic learning method, was not modulated by the increasing level of L1 mastery, such as reading automatization and growth in vocabulary knowledge.

Indeed, the benefit of orthography on L2 word learning was already retrieved among Grade 3 children, who had a lower degree of experience with the written language compared to fifth graders. Still, this learning advantage is consistent with previous studies conducted on L1 vocabulary learning, which also reported an orthographic facilitation among second graders (Rosenthal & Ehri, 2008) and third graders (see., Ricketts et al., 2009). In addition, Chambré and colleagues also documented the emergence of a written advantage on the learning of phonological and written words embedded in short definitions among first graders (see., Chambré et al., 2017; Chambré et al., 2020). Reporting an orthographic advantage on L2 vocabulary learning among third graders also reflects their automatic (and partial) decoding attempts, knowing that, in the French educational system, most of the teaching time is dedicated to the acquisition of the letter/sound correspondence rules during the first two elementary school years. The interplay between L2 orthography and L2 phonology will be discussed in the following section.. It should be mentioned that the moderating effect of the incongruent letter/sound mapping on the benefit of orthography will be discussed in Study 1b.

IV. 1. 4. 2. Evidence of an orthographic advantage for the learning of L2 phonological form

In this section, we will discuss more explicitly the experimental evidence for an orthographic advantage on L2 phonological learning. In this study, contrary to previous L1 vocabulary learning studies (see., Colenbrander et al., 2019 for a systematic review), the acquisition of L2 spoken forms has not been assessed by using a picture naming task, but through a go/no-go spoken recognition task, which is a pure phonological one. The differences and arguments associated with our selection of experimental tasks will be discussed in the General Discussion.

For the go/no-go spoken recognition task, an orthographic advantage on L2 spoken recognition was only reported among third graders immediately after learning, characterized by a higher discrimination score, i.e., between German words and close phonological pseudowords in the orthography-present group compared to the non-orthographic group. Such an observation evidenced that orthography helped Grade 3 children to learn L2 novel phonological forms, an assumption that has been consistently reported in L1 studies for pronunciation learning (see., Ricketts et al., 2009; Rosenthal & Ehri, 2008), but not for phonological recognition (see., Valentini et al., 2018). These inconsistent observations between our study and those of Valentini et al. (2018) may be accounted by the nature of the phonological task and will be discussed in the General Discussion.

Interestingly, after a one-week delay, the contribution of learning method on spoken word recognition was marginally significant, supporting that discrimination scores decreased among third graders between immediate and spontaneous session. In average, discrimination scores decreased from 1.55 and 1.29 to 0.90 and 0.79 for children in the orthographic and those in the non-orthographic group respectively. Raw data showed a decreased spoken recognition of L2 German words (a decrease of 5% in OLM vs. one of 9.4% in NOLM) as well as an increased false alarm rate (an increase of 8.8% in OLM vs. one of 3.2 % in NOLM). As a reminder, delayed testing session started with the spontaneous go/no-go spoken recognition task to determine whether participants were able to discriminate between L2 German words learned and a novel list of close phonological distractors, prior to re-exposure to the spoken material through the testing tasks. Contrary to our expectations, these results did not support an offline-sleep consolidation of the spoken form, compared to the one evidenced in previous studies (see., Brown et al., 2012; Henderson et al., 2012). Nonetheless, given that our studies used the same experimental design, they will provide us some further evidences of this phenomenon. Thus, they will be discussed in the General Discussion.

Furthermore, after re-exposure to the spoken material during the delayed testing, the orthographic advantage was retrieved for the accurate recognition of the L2 phonological forms among third graders. Interestingly, children in the orthographic group benefited more from phonological reactivation compared to those in the non-orthographic one, which was characterized by an increase in accurate L2 German words recognition as well as a decreased false alarm rate.

For the fifth graders however, despite larger discriminative performance compared to the third graders, orthography did not contribute to enhance L2 phonological learning. Interestingly, raw data showed that, although participants in the orthographic method performed less accurately for German word recognition compared to those in the non-orthographic one (73.3 % vs 76.7 % respectively), they committed a lower proportion of false alarm (17.4% vs 23.9 % respectively), suggesting a more conservative strategy of response. Future studies will provide us further evidence (or not) of the absence of phonological facilitation in fifth graders and will be developed in the General Discussion.

IV. 1. 4. 3. Evidence for a limited processing of orthography during learning

Unsurprisingly, the presence of orthography helped children to acquire and memorize the spelling of L2 German words, as evidenced by higher accurate recognition of L2 written form among children who were exposed to orthography compared to those who were not. Here again, fifth graders outperformed the third graders, still there was no interaction between grade and learning method, suggesting that the amount of orthographic facilitation was not modulated by the degree of L1 mastery. In average, when exposed to orthography during learning, children were able to select the correct German written form for about 11 of the 16 words (68 %), suggesting that a relative encoding of L2 orthography occurred during learning. Previous L1 studies also reported a consistent orthographic facilitation for L1 spelling to dictation tasks (see., Ricketts et al., 2009; Rosenthal & Ehri, 2008) as well as for forced-choice spelling recognition task (e.g., Valentini et al., 2018). Importantly, contrary to these previous studies, we ensured that participants attending an orthographic learning method were not exposed to an additional visual cue compared to those in the non-orthographic one. In light with the results collected along this doctoral work, the (specific) nature of the orthographic facilitation on L2 orthographic learning will be discussed by contrasting between a visual advantage and an orthographic one per se.

More than two third of the German written forms were accurately recognized by participants who were exposed to orthography during learning, supporting that they paid attention to the orthographic information. In addition, we also focused on the pattern of errors. Interestingly, when participants failed to recognize the correct written form, they selected a different distractor whether they were exposed to orthography or not during learning. Indeed, participants committed a larger amount of close orthographic errors when they were exposed to orthography, whereas they preferentially selected the homophonic distractor when they were not. This supported that in the absence of exposure to orthography, participants relied on their L1 grapheme-to-phoneme correspondences rules, which misled them. On the contrary, the presence of the L2 written form shaped the encoding of German words, still the memorized orthographic representation was characterized by an incomplete form overlap with the German written wordform. Therefore, given that the difference between the written form and the close orthographic distractor was restricted to one grapheme (substitution or transposition), the orthographic representation had to be fully specified to accurately discriminate between these two spellings. Interestingly, despite no differences in the pattern of committed errors according to grade for participants who were exposed to orthography during learning, we reported that fifth graders preferentially selected the close orthographic distractors rather than the distant ones, compared to third graders in the non-orthographic learning method. Thus, fifth graders could have been aware that grapheme-to-phoneme correspondences varied across languages, due to their ongoing experience with English as a foreign language in both a school and a out-of-school context (see., De Wilde et al., 2020), which confronted them with incongruent letter/sound and sound/letter mappings as well as with novel English specific phonemes (ex, the English bigram <th> whose associated phoneme /ð/ does not exist in French). In light with these results, we evidenced that participants paid attention to the written form during learning. However, it is still unclear to determine the degree of orthographic overlap between the encoded orthographic representation and its written form. Future studies are required to explore this processing more precisely (see General Discussion for proposals).

IV. 1. 4. 4. L1 linguistic skills and orthographic facilitation on L2 vocabulary learning

In this study, we explored whether the orthographic advantage was modulated by the degree of L1 mastery. Importantly, although fifth graders outperformed the third graders on all three experimental tasks, we did not report any interaction between the learning method and grade for two of the three experimental tasks, i.e., forced-choice picture recognition task and orthographic judgment task, supporting that the orthographic facilitation was rather not modulated by the increased linguistic skills. Thus, the benefit of orthography arose early during learning and rather independently of participants linguistic skills. Further experimental evidences have been provided by L1 vocabulary learning studies conducted on children suffering from developmental language disorders (Ricketts et al., 2015) or dyslexia (Baron et al., 2018). In their study, Ricketts et al. (2015) reported that children with language disorders still reported an orthographic facilitation on orthographic, phonological learning as well as on semantic learning (although marginally significant). Nonetheless, the interrelation between reading skills, grade and orthographic facilitation will be addressed in the General Discussion.

IV. 1. 4. 5. Summary

In summary, the present study documented the contribution of orthography on L2 vocabulary learning, which was retrieved for semantic learning, i.e., by establishing a connection between the L2 phonological representation and its associated concept and for orthographic learning irrespective of the degree of L1 mastery, i.e., retrieved among both third and fifth graders, an issue little addressed so far. For L2 phonological learning however, the benefit of orthography was only retrieved among third graders. Still, the lack of orthographic advantage for L2 phonological learning could be explained by their deeper orthographic encoding, that may have confronted them to both interfering and facilitation effects as a function of spelling to sound systematicity between L2 and L1 (see Study 2).

Although promising, our results have to be replicated in a further study. To do so, we conducted several testing phases among different groups of participants by contrasting two modalities of the size of the learning list (16 German words vs. 24 ones). Thus, thus provided us the opportunity to test this orthographic advantage on L2 vocabulary learning with an increased learning load, i.e., eight supplementary German words. This may provide us some evidences whether increasing the learning load may moderate the coding of orthography during learning, and more especially for phonological learning.

IV. 2. Study 1b –The moderating effect of the increased learning load on the orthographic facilitation on L2 vocabulary learning

IV. 2. 1. Introduction

In the previous study, we reported that orthographic facilitation could be extended to L2 vocabulary learning. Participants were exposed to 16 German words during learning session and we assessed the orthographic, phonological and semantic learning immediately and one-week after learning. An orthographic facilitation was retrieved for all three recognition tasks among third graders. Among fifth graders however, there was no contribution of orthography on L2 phonological learning, given that their discriminative scores were comparable whether they learned German words with orthography or without. Two main hypotheses were postulated. First, given that the go/no-go spoken recognition task was a pure phonological task (no additional visual clue was provided during testing), and due to the restricted number of items, i.e., 16 German words, relying on orthography may be unnecessary (and involved higher cognitive cost) to perform accurately. On the contrary, given that alphabetic languages do overlap more on orthography than on phonology (see., Marian et al., 2012), learning L2 spoken forms with orthography may have confronted fifth graders to both incongruent and congruent grapheme-to-phoneme correspondences with L1. Indeed, although mostly conducted among adults, previous studies reported a contrasted contribution of orthography on learning novel spoken forms acquisition of novel phonological form as a function of grapheme-to-phoneme congruency with L1 (see., Barrios & Showalter, 2020 for a review), despite no actual consensus. As an example, Hayes-Harb and Becker (2010) reported that the presence of orthography led to misremembered phonological forms, due to the incongruent grapheme-to-phoneme correspondence with L1, whereas Showalter and Hayes-Harb (2015) reported a limited contribution of orthography on learning novel phonemic contrasts. Both studies used the same testing task, i.e., an auditive word-picture matching task, still they observed a different contribution of orthography on phonological learning. Thus, the interplay between interfering and facilitated contribution of orthography on L2 learning may have been neutralized in the previous study, especially if fifth graders relied on a deep rather than on a shallow orthographic encoding during learning. Therefore, we wondered whether increasing the learning load may force fifth graders to rely on a more partial orthographic encoding during learning as retrieved among third graders.

This study aimed to replicate the orthographic advantage on L2 word learning, evidenced in the previous study and we wondered whether increasing the learning load, i.e., learning 24 German words instead of 16 ones, may affect the encoding of novel wordforms during learning. We hypothesized that the orthographic facilitation might be retrieved irrespective of the learning load.

To assess this, we used the same three experimental tasks as in Study 1a, i.e., a forced-choice picture recognition task, a go/no-go spoken recognition task, and an orthographic judgment task. For the learning material, we included German words that included congruent or incongruent grapheme-to-phoneme correspondences with L1. For exploratory purpose, we also addressed whether the orthographic facilitation may have been modulated by the degree of grapheme-to-phoneme congruency between L1 and L2.

IV. 2. 2. Methodological part

Experimental design:

This follow-up study involved the same experimental design as the one used in the princeps study. It included both a learning phase as well as both an immediate testing and a one-week delayed testing sessions. We used the same sixteen German words from the previous study, to which we added eight novel German words that belonged to the same semantic categories. During learning phase, each word was presented twelve times, following the same repetition design we used before, i.e., six initial presentations followed by two blocks of three item presentations. Between each block of item presentations (six repetitions vs nine vs twelve repetitions), a forced-choice recognition task took place to measure the proportion of German words learned by children. Both immediate and one-week delayed testing included the same experimental tasks as the ones used in the previous study, i.e., forced-choice recognition task, go/no-go spoken recognition task and orthographic judgment task. The one-week delayed testing started with a "spontaneous" go/no-go spoken recognition task. Importantly, experimental inclusions took place in parallel with those of the princeps study within the same elementary schools from April 2018 to March 2020. This ensured us that participants in both 16-item and 24-item study had a comparable schooling background prior to experimental inclusions.

IV. 2. 2. 1. Participants

One hundred thirty-five children were in this study. Among them, 67 children were schooled in fifth grade whereas the 68 remaining participants were in third grade. As mentioned earlier, they came from the same catchment area and were French native speakers. Importantly, children had not been exposed to German prior to the study and none of them reported experience with German language. In addition, participants had a restricted experience with English, to which they are scarcely exposed in an academic context for less than one and an half hour per week since first grade. None of the participants suffered from sensory, or any diagnosed learning and cognitive disabilities. Nine children, i.e., eight in third grade vs one in fifth grade, did not attend all learning and testing sessions and were thus removed from the study. Participants were randomly assigned to one of the two learning method, i.e., an orthographic vs a non-orthographic learning method.

Cognitive and language background tasks*:*

Similar to the previous study, we also ensured that children assigned to the orthographic learning method were matched on their linguistic and cognitive skills to those in the non-orthographic method. Ten participants, three third graders vs seven fifth graders, did not complete all the background linguistic and cognitive tasks and were thus removed from analysis. Separate descriptive analyses conducted on third and fifth graders are presented in Table 9. Children were matched on all the background tasks. The 116 remaining participants were matched on all the background tasks. Among them, 56 children, i.e., 29 in third grade vs 27 in fifth grade, were assigned to the orthographic method. The 60 remaining participants, i.e., 28 third graders vs 32 fifth graders, were in the non-orthographic one.

Table 9. *Summary of the participants' performances to cognitive and linguistic background tasks among third graders and fifth graders according to the learning method (OLM vs. NOLM)*

	Orthographic learning method		Non-orthographic learning method		t-value	p-value	Cohen’s d
	M	SD	**M**	SD			
Third graders							
Age (in months)	106.38	2.80	105.48	3.69	1.06	.30	
Reading age	106.10	16.03	107.86	17.86	- 0.39	.70	
Reading fluency	211.46	84.27	221.71	91.25	- 0.44	.66	
Reading accuracy	94.49	3.31	93.81	3.93	0.71	.48	
NWRT	34.48	2.31	34.00	3.56	0.59	.56	
RAVEN matrices	22.43	4.53	23.04	6.09	- 0.42	.68	
L1-Vocabulary	27.21	5.85	28.61	6.36	- 0.87	.39	
Fifth graders							
Age (in months)	128.30	5.67	127.16	5.39	0.79	.43	
Reading age	126.04	20.81	118.91	26.60	1.15	.26	
Reading fluency	311.22	84.76	288.25	115.15	0.44	.66	
Reading accuracy	96.28	2.41	96.03	2.09	0.86	.39	
NWRT	34.21	2.38	35.07	2.93	0.99	.33	
RAVEN matrices	23.46	4.95	24.90	5.11	- 1.08	.29	
L1-Vocabulary	33.27	7.89	31.29	7.80	0.95	.35	

We also conducted separate descriptive analyses between third and fifth graders from both studies (Study 1a vs Study 1b). Surprisingly, third graders from both studies (16 items vs 24 items) were not matched on chronological age (respectively, 108.28 vs 106.05 months, $t(127) = 3.76$, $p < .001$, Cohen's $d = .67$) nor on vocabulary size (respectively, 23.58 vs 27.83, $t(127) = -1.24$, $p < .001$, Cohen's $d = .70$). For the orthographic method, third graders from the 16-item study were not matched to the ones in the 24-item on their short-term phonological memory skills (respectively, 32.68 vs 34.48, $t(59) = -1.97$, $p = .05$, Cohen's $d = -0.51$). Furthermore, for the non-orthographic method, fifth graders included in the 16-item study were not matched to the ones in the 24-item study on reading age (respectively, 132.88 vs 119.86 months, $t(60) = 2.09$, $p = .41$, Cohen's $d = .53$), nor on vocabulary size (respectively, 35 vs 29.83, $t(60) = 2.66$, $p = .01$, Cohen's $d = .68$). Descriptive analyses conducted on 16- and 24-items are presented in Table 10

Table 10. *Summary of the participants' performances to cognitive and linguistic background tasks in the 16-item condition (Study 1a) and in the 24-items condition (Study 1b)*

	16-item condition		24-item condition		t-value	p-value	Cohen's d
	M	SD	**M**	SD			
Third graders							
Orthographic learning method							
Age (in months)	108.63	2.88	106.38	2.80	3.08	.003	0.79
Reading age	113.06	17.89	106.10	16.03	1.59	.12	
Reading fluency	251.17	86.27	211.46	84.27	1.82	.08	
Reading accuracy	94.63	3.44	94.49	3.31	0.16	.87	
NWRT	32.68	4.23	34.48	2.31	-1.97	.05	-0,51
RAVEN matrices	23.59	3.79	22.43	4.53	- 0.14	.88	
L1-Vocabulary	24.09	5.47	27.21	5.85	- 2.15	.04	- 0,55
Non-orthographic learning method							
Age (in months)	108.00	3.81	105.18	3.69	3.03	.004	0.75
Reading age	104.54	15.95	107.86	17.86	-0.80	.43	
Reading fluency	209.32	87.19	221.71	91.25	-0.56	.58	
Reading accuracy	92.76	3.71	93.81	3.93	-1.12	.27	
NWRT	32.33	4.98	34.00	3.56	-1.48	.15	
RAVEN matrices	22.07	3.77	23.04	6.09	-1.85	.07	
L1-Vocabulary	23.76	5.36	28.61	6.36	- 3.35	.001	-0.84

Fifth graders							
Orthographic learning method							
Age (in months)	127.73	5.92	128.30	5.67	- 0.39	.70	
Reading age	131.43	23.10	126.04	20.81	0.96	.34	
Reading fluency	336.73	98.06	311.22	84.76	1.09	.28	
Reading accuracy	96.48	2.43	96.28	2.41	0.31	.76	
NWRT	34.50	3.61	34.21	2.38	0.31	.76	
RAVEN matrices	25.53	4.29	23.46	4.95	1.73	.09	
L1-Vocabulary	35.25	5.94	33.27	7.89	1.13	.26	
Non-orthographic learning method							
Age (in months)	127.34	5.58	127.16	5.39	0.14	.89	
Reading age	132.38	22.42	118.91	26.60	2.22	.03	0.55
Reading fluency	338.55	97.49	288.25	115.15	1.89	.06	
Reading accuracy	97.03	1.60	96.03	2.09	2.15	.04	0.54
NWRT	35.19	3.58	35.07	2.93	0.14	.89	
RAVEN matrices	26.25	4.79	24.90	5.11	1.08	.28	
L1-Vocabulary	34.81	5.49	31.29	7.80	2.08	.04	0.52

IV. 2. 2. 2. Learning phase

***Words*:**

Eight supplementary German words were selected from the SUBTLEX-DE-database (Brysbaert et al., 2011) and were added to the sixteen ones from Study 1. Half of the German words included congruent grapheme to phoneme correspondences (ex, Pferd which accurate pronunciation could be produced when using the French letter/sound mapping). The remaining half included incongruent German words (ex, Stern which is pronounced /ʃtɛrn/ in German but /stɛːʁn/ when using the French letter/sound mappings).We ensured that the novel selected words shared comparable linguistic characteristics with the 16 pre-selected German words, so that both the 24-items and 16-items learning conditions were matched on orthographic and phonological size, frequency of their French translation equivalents, minimal bigram frequency in German, orthographic and phonological neighbourhood using Levenshtein distance, concreteness and imageability (all ps values > .10). German words were between five and seven letters long (mean = 5.08, SD = 1.02) and their mean phonological size was of 4.38 (SD = 0.65) phonemes. Mean frequency of their French translation equivalents was of 162.36 occurrences per million (SD = 187.93). Mean ratings of concreteness and of imageability were respectively of 4.60 out of 5 (SD = 0.66) and of 6.65 out of 7 (SD = 0.83). Neither German word had close orthographic, nor phonological neighbours with French; orthographic (mean = 0.20, SD = 0.18) and phonological (mean = 0.15, SD = 0.14) Levenshtein distances were calculated using the vwr-package (Keuleers, 2013) on R-Software.

***Pictures*:**

The eight novel German words were associated with their corresponding black and white pictures from the multipic-database (Duñabeitia et al., 2018).

Sound recordings:

Pronunciation of the eight novel German words were recorded during the same recording session than in the princeps study, along with the same German native speakers. Thus, we included three recorded versions of the eight novel German words to the previous recordings.

***Procedure**:*

As for the princeps study, both learning and testing sessions took place directly in schools by groups of three to five children. Learning and testing phases were identical to those presented in the previous study (please see Procedure presented in Study 1a for details). Here, however, learning phase lasted between 35 and 45 minutes, whereas immediate and one-week delayed testing sessions were around 30 minutes long. Background cognitive and language skills were assessed at the end of the delayed session or, if not possible, in the following days. Testing material is available in Appendices (please see, Appendix 5 for the forced-choice picture recognition task, Appendix 6 for the go/no-go auditive recognition task, and Appendix 7 for the orthographic judgment task).

IV. 2. 3. Results

IV. 2. 3. 1. Data analysis

As for the previous study, participants' performance, i.e., accuracy and response times, in the three experimental tasks, i.e., forced-choice recognition task, go/no-go spoken recognition task and orthographic judgment task, were analysed using generalized mixed model. These statistical analyses were conducted on R Software (R Core team, 2017) using lmer and glmer function from the lme4 package (Bates et al., 2015). The random structure was modelled following a compromise between the maximal fitting of random effects recommended by Barr et al. (2013) and the parsimonious approach (Bates et al., 2015). For this purpose, the random structure included at least by-participant and by-item random intercepts. We further included supplementary random effects as long as they led to a better adjusted random structure. Then, fixed effects, i.e., grade (third vs fifth graders), method (orthographic vs non-orthographic learning method), session (immediate vs delayed session) and congruency (congruent vs incongruent German words) as well as two- and three-way interaction effects were included. We used a model comparison approach by progressively entering each fixed main and interaction effects, by comparing each model with the previous one, and eventually including the variables that led to the most adjusted model. The inclusion of experimental factors stopped once it did not lead to a better adjusted model compared to the previous one. At each step, Chi-squared tests were performed to test the adjustment of the model; p-values were determined using lmer-package (Kuznetsova et al., 2017). For the forced-choice recognition task as well as for the orthographic judgment task, logistic mixed models were computed given that accuracy variable was binary. Cut-off for significance was then $p < .05$. For the go/no-go spoken recognition task, we computed linear mixed model and cut-off significance was $t > 2$. Interaction effects were explored by performing subsets models to determine the contribution of each modality on participants' performance. Given that participants were matched on each of their cognitive and language skills, no background score was included as covariable. Descriptive statistics are presented for each experimental task in Table 11. We also presented the descriptive statistics according to the response times in Appendix 8, according to congruency in Appendix 9, as well as according to congruency for response times in Appendix 10.

Table 11. *Participants' performance for all three experimental tasks according to Grade (third vs. fifth graders), learning method (OLM; orthographic learning method vs. NOLM; non-orthographic learning method) and session (immediate vs. delayed sessions; and vs. spontaneous session).*

	Third graders				Fifth graders			
	NOLM		OLM		NOLM		OLM	
	M	SD	**M**	SD	**M**	SD	**M**	SD
Forced-choice recognition task (accuracy in percent)								
Immediate	50.30	19.31	73.28	18.65	63.36	22.42	80.71	13.58
Delayed	54.46	16.59	74.53	15.07	61.80	18.61	80.86	13.14
Go no go auditive recognition task (discrimination score)								
Immediate	0.88	0.47	1.43	0.59	1.29	0.66	1.60	0.64
Spontaneous	0.98	0.81	1.32	1.11	1.16	0.66	1.65	0.78
Delayed	0.94	0.83	1.32	0.75	1.18	0.61	1.84	0.87
Go no go auditive recognition task (response time)								
Immediate	1518	203	1573	211	1518	207	1502	285
Spontaneous	1638	242	1632	236	1551	256	1532	176
Delayed	1574	214	1569	213	1523	181	1450	244
Orthographic judgment task								
Immediate	30.91	10.15	60.34	18.95	38.67	21.55	70.22	16.08
Delayed	31.85	14.00	56.90	20.74	38.41	18.59	68.06	16.79

IV. 2. 3. 2. Forced-choice picture recognition task

Statistical analyses were performed on the 116 remaining participants. Among them, 56 children, i.e., 29 third vs 27 fifth graders, were assigned to the orthographic learning method. The 60 remaining participants, i.e., 28 children in third grade vs 32 ones in fifth grade, were not exposed to German spellings during learning phase, i.e., non-orthographic learning method.

Mixed logistic models were computed, given that accuracy was a binary outcome variable. Comparably with previous study, the most adjusted model included Method (orthographic vs non-orthographic learning method) and Grade (third vs fifth graders) as fixed effects as well as by-participant, by-item and by-school random intercepts (AIC = 6035, $\chi 2$ = 10.77, p = .001). The parameters of the models are presented in Table 12. There was a main effect of method (p < .001), with an odds of accurate picture recognition 2.29 times higher for children in the orthographic learning method than for those in the non-orthographic one (respectively, 77.22 % vs 57.82 %). Furthermore, Grade was also a significant main effect (p = .001), with an odds of accurate recognition 1.79 times higher toward fifth graders than in third graders (respectively, 70.92 % vs 63.33 %). Again, the interaction between Method and Grade did not reach significance (AIC = 6037, $\chi2$ <1, p = .63). Interestingly, the inclusion of congruency did not led to a better adjusted model (AIC = 6037, $\chi2$ <1, p = .41), nor the inclusion of the interaction between congruency and grade (AIC = 6039, $\chi2$ <1, p = .73), nor the one between congruency and learning method (AIC = 6038, $\chi2$ <1, p = .40).

Table 12. *Summary of the logistic mixed model analysis for variables predicting accuracy in the forced-choice recognition task.*

Model and predictors	Estimate	SE	95% CI		*z*-value	*p*-value
			LL	UL		
Intercept	1.116	0.309	0.649	1.919	0.396	.692
Learning method	2.254	0.331	1.691	3.004	5.547	<.001
Grade	2.033	0.441	1.329	3.111	3.269	.001

IV. 2. 3. 3. Go/no-go spoken recognition task.

Prior to statistical analyses, response times lower than 300 milliseconds were removed from analysis. Thus, 1031 response times met the cut-off criterion, i.e., 6.07% of the data. This could be attributed to participants that hold down the space key all along the go/no-go spoken recognition task. Six participants, i.e., four children in third grade vs two in fifth grade, had less than 50% of their response left and were thus removed from analysis. The proportion of accurate word recognition and of correct rejection of close phonological pseudowords are presented in Table 13. Given the nature of the go/no-go spoken recognition task, discrimination scores were calculated by the difference of the z-transformed distribution of accurate word identification (hits) and of the one of the incorrect acceptances of pseudowords (false alarms). We applied a correction on extreme recognition score, i.e. scores equal to 0 and those of 1, using Macmillan & Kaplan’s (1985) requested transformation. In order to prevent response strategies, negative discrimination scores as well as false alarm rate higher than random level at immediate testing session were removed from further analysis. Discriminative scores of seven participants, i.e., two third vs five fifth graders, met the cut-off criterion and thus, were not included in statistical analyses. Among them, four children (two third graders) were assigned to the non-orthographic learning method whereas the three remaining fifth graders were in the orthographic one. Statistical analyses were reported on the 103 remaining participants, i.e., 51 third graders vs 52 fifth graders. Among the 51 third graders, 23 were in the non-orthographic learning method and the 28 remaining children in the orthographic learning method. Among the 52 fifth graders, 26 children were in the orthographic learning method.

Table 13. *Summary of the accurate recognition of words and pseudowords in the go/no-go auditive recognition task according to Grade (third vs. fifth graders), learning method (OLM; orthographic learning method vs. NOLM; non-orthographic learning method) and session (immediate vs. delayed sessions; and vs. spontaneous session).*

	Third graders				Fifth graders			
	NOLM		OLM		NOLM		OLM	
	M	SD	**M**	SD	**M**	SD	**M**	SD
Words (in percent)								
Immediate	62.63	13.85	70.93	14.37	69.34	13.99	72.77	14.56
Spontaneous	59.50	15.10	62.74	20.06	69.23	14.33	72.95	14.97
Delayed	62.73	13.30	71.96	17.18	68.40	13.92	79.81	13.28
Pseudowords (in percent)								
Immediate	65.28	20.72	76.25	16.60	73.34	19.77	77.57	17.96
Spontaneous	70.20	23.84	79.84	19.74	69.68	23.47	78.33	16.62
Delayed	66.29	25.09	71.50	20.43	71.18	19.91	77.19	22.96

Immediate vs Delayed session:

Discriminative scores were analyzed for immediate and delayed testing using generalized mixed models. The random structure only included by-participant random intercepts. An initial statistical analysis was conducted on immediate and delayed discriminative scores. This design allowed us to determine whether discriminative scores were sensibly impacted by delay, for the two go/no-go spoken recognition tasks conducted in the same conditions for both immediate and delayed testing. Here, the most adjusted model included learning method as well as grade as fixed effects and by-participant random intercepts

(AIC = 408, $\chi 2(1) = 8.93$, p =.003). The parameters of the models are presented in Table 14. There was a main effect of the learning method (t = 3.81), with higher discriminative score among children in the orthographic method compared to participants in the non-orthographic one (respectively, 1.54 vs 1.09). A significant main effect of Grade was also reported (t = 3.01), supporting that fifth graders outperformed third graders in discriminative scores (respectively, 1.47 vs 1.16). Interestingly, the interaction between grade and learning method did not led to a better adjusted model (AIC = 410, $\chi 2(1) < 1$, p =.88).

Table 14. *Summary of the mixed linear regression analysis for variables predicting discrimination scores in the go/no-go spoken recognition task in the analysis including immediate and delayed sessions.*

Model and predictors	Estimate	SE	*t*-value
Intercept	0.919	0.107	8.615
Learning method	0.453	0.119	3.805
Grade	0.358	0.119	3.007

Immediate vs Spontaneous testing:

Contrary to the previous study, fifth graders, as well as third graders, performed the go/no-go spoken recognition task more accurately when they attended an orthographic learning method compared to those who did not. In addition, fifth graders exhibited higher discriminative scores compared to third graders. Here again, discriminative scores were not significantly impacted after a one-week delay. The following analysis was conducted between immediate and "spontaneous" testing sessions to determine whether the orthographic advantage might be retrieve prior to re-exposure to spoken material. As a reminder, one-week delayed testing session started with the "spontaneous" go/no-go spoken recognition task. Here, the most adjusted model included Learning method (orthographic vs non-orthographic learning method) and Grade (third vs fifth graders) as fixed effects as well as by-participant random intercepts (AIC = 453, $\chi 2(1) = 5.74$, p =.02). The model and its parameters are presented in Table 15. There was a significant main effect of the learning method (t = 3.23), with higher discriminative scores for children in the orthographic learning method compared to the non-orthographic one (respectively, 1.50 vs 1.09). A main effect of grade was also reported (t = 2.39), supporting that fifth graders outperformed the third graders (respectively, 1.41 vs 1.17). The interaction between Learning method and Grade did not reach significance (AIC = 455, $\chi2(1) < 1$, p =.88). Contrary to the previous study, there was no main effect of Session (AIC = 458, $\chi2(1) < 1$, p =.70).

Table 15. *Summary of the mixed linear regression analysis for variables predicting discrimination scores in the go/no-go spoken recognition task in the analysis including immediate and spontaneous sessions.*

Model and predictors	Estimate	SE	*t*-value
Intercept	0.953	0.111	8.585
Learning method	0.400	0.124	3.225
Grade	0.296	0.124	2.393

Summary:

Both statistical analyses conducted between immediate and delayed testing as well as between immediate and "spontaneous" testing session reported a main effect of learning method and of grade. Discriminative scores were higher among children who learned German words with orthography compared to those who did not. In addition, fifth graders outperformed third graders. These performances were not modulated by session, supporting discriminative scores remained stable after delay. The benefit of orthography emerged immediately after the learning phase.

Response times:

Given that the go/no-go spoken recognition task was the sole experimental task with a speed criterion, we further conducted statistical analyses on response times. Response times were between 300 and 3000 milliseconds. Data analysis were conducted on raw response times using the generalized linear mixed model as advocated by Lo and Andrews (2015). According to these authors, GLMM are more efficient in satisfying normality assumptions compared to link-function transformations.

For statistical analysis conducted on immediate and delayed testing, the most adjusted model only included Grade as fixed effect as well as by-participant, by-item and by-school random intercepts (AIC = 5007, $\chi2(1) = 2.7$, p =.09), with a marginal main effect of grade (t = -1.67). Thus, there was a tendency for fifth graders to produce faster response times compared to third graders (respectively, 1471 vs 1559 milliseconds). A follow-up analysis was performed on immediate and "spontaneous" session. Here, the most fitted model included session as fixed effect as well as by-participant, by-item and by-school random intercepts (AIC = 5109, $\chi2(1) =$ 17.10, p =.001), with slower response times during the "spontaneous" session compared to the immediate one (respectively, 1584 vs 1528 milliseconds, t = 3.42).

IV. 2. 3. 4. Orthographic judgment task

***Accuracy**:*

As a reminder, statistical analyses were conducted on the remaining 119 participants, i.e., 60 third and 59 fifth graders. Among them, 56 children, i.e., 29 third vs 27 fifth graders, learned German words through an orthographic learning method whereas the 63 remaining participants (including 31 third graders) were assigned to the non-orthographic learning method. Accuracy was a binary outcome variable; thus, mixed logistic models were computed. The most adjusted model included Learning method and Grade as fixed effects as well as by-participant, by-item and by-school random intercepts (AIC = 6864, $\chi2(1) = 5.74$, p =.02). The model and its parameters are presented in Table 16. Learning method was significant, with an odds of accurate spelling recognition 3.86 times higher toward children in the orthographic learning method compared to those in the non-orthographic one (respectively, 65.70 % vs 35.02%, p <.001). Furthermore, there was a main effect of Grade, supporting that an odds of accurate spelling recognition 1.42 times higher in fifth than in third graders (respectively, 52.54

% vs 44.55 %, p =.01). Neither the inclusion of Congruency (AIC = 6866, $\chi2(1) < 1$, p =.63), nor the interaction between Congruency and Learning method (AIC = 6868, $\chi2(1) < 1$, p =.75), nor the one between Congruency and Grade (AIC = 6868, $\chi2(1) < 1$, p =.73) reach significance.

Table 16. *Summary of the logistic regression analysis for variables predicting accuracy in the orthographic judgment task.*

Model and predictors	Estimate	SE	95% CI		*z*-value	*p*-value
			LL	UL		
Intercept	0.427	0.070	0.310	0.588	-5.225	<.001
Learning method	3.855	0.461	3.051	4.872	11.296	<.001
Grade	1.424	0.203	1.077	1.883	2.480	.01

Pattern of errors:

Statistical analyses were also conducted on the committed errors for exploratory purpose, to determine whether participants were more likely to choose one specific distractor according to the learning method they were assigned to. We also wondered whether the choice of one distractive spelling over another differed according to the grade level. As a reminder, we identified for each participant and item, which distractor was selected instead of the correct spelling of the German words. We then calculated a proportion of committed error for each type of distractive spelling. Again, the proportion of errors was comparable across session, so both testing sessions were included for statistical analyses. Distribution of the committed errors within the three types of distractive spellings (close vs distant orthographic distractor vs phonological distractor) were assessed using chi-square homogeneity tests. Then, if significant, Scheffé post-hoc pairwise comparisons were conducted between individual conditions to identify the locus of the heterogeneous distribution of errors. This procedure followed the Goodman procedure, described in Franke et al. (2011). All pairwise comparisons are presented in Table 17.

Table 17. *Summary of the pairwise comparisons conducted on the pattern of committed errors.*

	ψ	SE	Scheffé test	*p*
Close orthographic distractor				
Non-orthographic vs orthographic method	-.197	.019	-10.26	<.001
Third vs Fifth graders	-.069	.018	-3.80	<.001
Orthographic method: Third graders vs Fifth graders	-.087	.032	-2.69	.03
Non-orthographic method: Third graders vs Fifth graders	-.079	.021	-3.73	.001
Distant orthographic distractor				
Non-orthographic vs orthographic method	.074	.014	5.17	<.001
Third vs Fifth graders	.010	.014	0.68	.79
Orthographic method: Third graders vs Fifth graders	.017	.022	0.79	.73
Non-orthographic method: Third graders vs Fifth graders	.013	.018	0.72	.77
Phonological distractor				
Non-orthographic vs orthographic method	.123	.019	6.55	<.001
Third vs Fifth graders	.059	.018	3.26	.005
Orthographic method: Third graders vs Fifth graders	.069	.030	2.29	.07
Non-orthographic method: Third graders vs Fifth graders	.066	.022	2.96	.01

Distribution of errors according to learning method:

A 2x3 chi-squared homogeneity test conducted between learning method and the type of errors revealed that the proportion of errors was not equal across both learning methods (χ^2 (2, 2941) = 105.11, $p < .001$, Cramer's $V = 0.19$). Post-hoc analyses showed that children in orthographic learning method committed a larger proportion of errors for the close orthographic distractors compared to those in the non-orthographic one (respectively, 53.4 % vs 33.7 %, χ^2 (1, 1183) = 105.18, $p < .001$). On the contrary, a lower proportion of errors for distant orthographic distractors (respectively, 13.5 % vs 20.9 %, χ^2 (1, 543) = 26.78, $p < .001$) as well as for phonological ones (respectively, 33.1 % vs 45.4 %, χ^2 (1, 1215) = 42.86, $p < .001$) was retrieved among participants in the orthographic learning method compared to the non-orthographic one.

Distribution of errors according to grade:

A further 2x3 chi-square homogeneity test was conducted to determine whether the three types of distractors were equally distributed between third and fifth graders. Unsurprisingly, they were not in the two groups (χ^2 (2, 2138) = 15.21, $p = .001$, Cramer's V =.07). Consistent with the previous study, post-hoc analyses using the Scheffé criterion for significance revealed a larger proportion of close orthographic distractors among fifth graders compared to third graders (respectively, 44.0 % vs 37.1 %, χ^2 (1, 1183) = 14.47, p = .001). Interestingly, the proportion of errors for phonological distractors was lower among fifth graders compared to third graders (respectively, 38.1 % vs 44.0 %, χ^2 (1, 1215) = 10.64, p = .004). An equivalent distribution of errors for distant orthographic distractors was reported between fifth and third graders (χ^2 (1, 543) < 1, p = .79).

Distribution of errors according to grade and learning method:

Consistent with the previous study, the proportion of errors for each distractive spelling was determined both by the learning method and by the grade level. In this follow-up analysis, we expected to retrieve the asymmetrical contribution of the learning method on the committed errors according to the grade level. Thus, two 2x3 chi-square homogeneity tests were conducted on each learning method. Interestingly, contrary to the previous study, the three types of distractors were not equivalently distributed between fifth and third graders for the orthographic learning method (χ^2 (2, 976) = 7.26, p = .03, Cramer's V = .09), nor for the non-orthographic learning one (χ^2 (2, 1965) = 14.34, p = .001, Cramer's V = .09). Post-hoc analyses reported that fifth graders committed a larger proportion of errors for the close orthographic errors compared to third graders in both orthographic learning method (respectively, 58.5 % vs 49.8 %, (χ^2 (1, 521) = 7.23, p = .03) and in the non-orthographic one (respectively, 37.8 % vs 29.9 %, (χ^2 (1, 662) = 13.90, p = .001). On the contrary, a lower proportion of errors for the phonological distractors was retrieved in fifth graders compared to third graders in the non-orthographic learning method (respectively, 42.0 % vs 48.6 %, (χ^2 (1, 892) = 8.75, p = .01), but marginally in the orthographic method (respectively, 29.0 % vs 35.9 %, (χ^2 (1, 323) = 5.26, p = .07). Distant orthographic errors were equally distributed among participants in orthographic learning method (χ^2 (1, 132) < 1, p = .73) and in non-orthographic one (χ^2 (1, 411) < 1, p = .77).

Distribution of errors according to congruency:

Previous statistical analyses did not reveal any significant contribution of congruency on spelling recognition. However, for exploratory purpose, we investigated whether the distribution of the committed errors was modulated by congruency. For this purpose, two 2x3 chi-square homogeneity tests were computed for each modality of the learning method to compare the distribution of committed errors between congruent and incongruent German words. Interestingly, an heterogeneous distribution of errors according to congruency was only retrieved for the orthographic learning method ($\chi2(2, 976) = 34.82$, $p =.001$, Cramer's $V = .19$). Post-hoc analyses using Scheffé criterion as significance level revealed a larger proportion of close orthographic distractors for incongruent words compared to the congruent ones (respectively, 62.32 % vs 45.26 %, $\chi2(1, 521) = 25.11$, $p < .001$). Nonetheless, the proportion of errors for the phonological distractors were lower for incongruent words than for congruent German words (respectively, 25.05 % vs 42.11 %, $\chi2$ (1, 323) = 34.90, $p < .001$).

The distribution of committed errors between congruent and incongruent German words was also determined by grade level. Interestingly, the committed errors were equally distributed between congruent and incongruent words in fifth graders (χ^2 (2, 1344) = 3.67, $p = .16$), but not in third graders (χ^2 (2, 1597) = 10.59, $p = .005$, Cramer's $V =.08$), Indeed, third graders committed a larger proportion of phonological errors for congruent words than for incongruent ones (respectively, 48.02 % vs 40.20 %, χ^2 (1, 703) = 9.95, $p = .007$),), whereas the reverse results were reported for close orthographic distractors (33.67 % vs 40.20 %, χ^2 (1, 592) = 7.60, $p = .02$), This asymmetrical distribution of errors among third graders was only retrieved for orthographic learning method (χ^2 (2, 576) = 13.54, $p = .001$, Cramer's $V = .15$),

Correlation between background linguistic skills and learning performance:

As a reminder, in the previous study conducted with 16 German words, overall, there were non-significant correlations between reading skills and two out of the three experimental tasks, i.e., forced-choice picture recognition task and go/no-go auditive recognition task, among third graders. However, a significant correlation was reported between reading age and orthographic judgment task that was restricted to NOLM participants. On the contrary, among fifth graders, significant correlations were retrieved between reading skills and the orthographic judgment task as well as a marginal one for the forced-choice picture recognition task.

In a nutshell, consistent effects were reported for the experimental task both with 16-items as well as with 24-items, despite a lack of orthographic facilitation in the go/no-go task among fifth graders for the 16-items conditions. Therefore, we wondered whether comparable correlation between reading skills and performance to the testing tasks might be retrieved for the 24-item condition. We thus calculated Pearson's correlation between background linguistic measures and experimental tasks.

For the forced-choice recognition task, there was a significant correlation between reading age and performance to this task among third graders, both for the orthographic learning method ($r=.52$, $p=.004$) and for the non-orthographic one ($r= .56$, $p =.002$). Among fifth graders, there was also a significant correlation between reading and learning performance for participants assigned to the orthographic method ($r= .40$, $p =.04$), but not for those who attended a non-orthographic method ($p=.10$). Overall, contrary to previous results in the 16-item condition, children with higher reading skills exhibited more accurate picture recognition. Still, among the fifth graders, better readers also showed a larger benefit for orthography. A significant correlation between reading skills and vocabulary knowledge was reported among third graders in the orthographic group ($r= .68$, $p <.001$) as well as among those in the non-orthographic one ($r=.51$; $p=.005$). On the contrary, this correlation did not reach significance among fifth graders (all $ps >.05$).

Consistent with the 16-item condition, no significant correlation between reading skills and accurate spoken word recognition was retrieved for the go/no-go auditive recognition task among participants (all $ps >.05$).

For the orthographic judgment task, contrary to the 16-item condition, the correlation between reading skills and accurate written word recognition did not reach significance (all ps>.05),

In a nutshell, for the 24-item condition, reading skills were only significantly correlated with the performance in the forced-choice picture recognition task, for which participants had to link a spoken word to its associated concept. Thus, children with the better reading skills were also those who exhibited the larger accurate picture recognition. However, fifth graders with the better reading skills showed more benefit from orthography.

IV. 2. 4. Discussion

This follow-up study had two experimental purposes. First, it explored whether the orthographic advantage reported on the previous study was robust enough to be replicated when modifying only one experimental parameter, i.e., the size of the learning list. Additionally, we assessed whether the increase of the learning load may impact the benefit of orthography in L2 vocabulary learning. For this purpose, we compared Grade 3 and Grade 5 children's L2 word learning performance by contrasting an orthographic learning method to a non-orthographic one through a paired-associate learning paradigm.

IV. 2. 4. 1. Replication of the orthographic facilitation on L2 vocabulary learning

Consistent with the previous results, the follow-up study replicated a consistent orthographic facilitation on L2 word learning. Here again both third and fifth graders exhibited more accurate orthographic and semantic learning, i.e., linking the spoken form to its associated meaning, when they were exposed to orthography during learning. Nevertheless, contrary to the previous study, we reported that children assigned to the orthographic learning method outperformed the ones in the non-orthographic group on all three experimental tasks, i.e., forced-choice picture recognition task, orthographic judgment task but also go/no-go spoken recognition task, irrespective of the grade. Indeed, the orthographic facilitation on L2 phonological learning was also reported among fifth graders. The multimodal sources of information provided during learning helped children to build a strong lexical representation, that included both an orthographic, phonological, and semantic representations, which is consistent with the lexical quality hypothesis (Perfetti & Hart, 2002). Interestingly, in line with previous published studies, recognition performance remained stable after a one-week delay, suggesting that the encoded spoken and written form were then integrated into the lexicon, due to the offline-sleep consolidation as documented among children (see., Brown et al., 2012; Henderson et al., 2012). This offline-sleep consolidation occurred regardless of the learning method. By using a paired-associate word learning paradigm, we exposed participants simultaneously to a dual-coding, i.e., written and spoken form associated with their meaning for the orthographic learning method vs. spoken form and meaning (illustrated by a picture) for the non-orthographic learning method, which is associated with enhanced learning performance (see., Hulme et al., 2007). This supports that the paired-associate learning paradigm was once again adapted to conduct L2 word learning studies.

IV. 2. 4. 2. Learning performance between 16-item and 24-item conditions

The presence of orthography during learning helped children to accurately associate a spoken form to its meaning for about 18.4 (77%) of the 24 German words immediately after learning. In the absence of exposure to written information, their learning performance was still about 13.8 (56%) of the 24 L2 words. Thus, at first sight, in both 16-item and 24-item condition, participants were able to associate the spoken form to its meaning for a similar proportion of items. Nevertheless, participants in the 24-item condition learned a higher number of German words compared to those in the 16-item condition (an average of 3.8 and 6 supplementary words for the non-orthographic and orthographic group respectively compared to the 16-item condition). Several hypotheses have been considered. First, it was possible that the eight supplementary words added to the 16-item learning list may have been easier to learn compared the other words. Nonetheless, we ensured that both learning lists were matched on a series of linguistic criterion, such as orthographic and phonological size, frequency, minimal and maximal bigram frequency, orthographic and phonological cross-linguistic neighborhood size. Additionally, there was no significant difference in accurate recognition of the spoken form between the added German words and the other ones, supporting that the increased performance in the 24-item condition cannot be attributed to a potential bias associated to more salient words. Second, this difference in learnability may be (partially) attributed to the variability in L1 cognitive and linguistic skills/profiles between participants from both learning conditions (16-item vs. 24-item). Indeed, third graders in the 24-item condition outperformed their peers on the L1 vocabulary size. Interestingly, the reciprocal relationship between vocabulary and decoding has been well documented through the Matthew effect (Stanovitch, 1985), knowing that previous vocabulary knowledge also supports enhanced decoding of irregular words (see., Nation & Cocksey, 2009a). However, the reverse pattern of vocabulary knowledge was reported among fifth graders, who performed less accurately to the L1 vocabulary task in the 24-item compared to the 16-item condition, but still reported enhanced L2 learning performance. Thus, the variability in participants' linguistic profiles across studies cannot (convincingly) account for this trend in learning performance. Beyond the methodological issues and variability in cognitive and linguistic skills, we postulated that this asymmetrical learning performance may rely on inter-individual differences, in parents' socioeconomic status or in positive attitude toward/motivation for learning. Indeed, difference in parents' socioeconomic status may explain the gap in learning performance, given that SES has an impact on literacy acquisition (see., Fluss et al., 2009). However, despite no objective measure of the parents' socioeconomic status (as mentioned earlier, we first included a parental questionnaire, but, due to negative feedback, we had to remove it), data inclusion took place in the same elementary schools and during the same time of the school year for both studies, in order to minimize the impact of SES on learning performance. Furthermore, participants were randomly assigned to one of the two studies (Study 1a vs. Study 1b). These experimental precautions may have (partially) alleviated the potential bias of S.E.S on learning performance. Beyond S.E.S, other inter-individual factors, such as motivation and positive attitude toward learning may also account for this gap in learning performance. Nevertheless, to date, we cannot convincingly explain this gap in learning performance across studies.

IV. 2. 4. 3. L1 reading and vocabulary skills on L2 vocabulary learning

In a nutshell, for the 24-item condition, reading skills were only significantly correlated with the performance in the forced-choice picture recognition task, for which participants had to link a spoken word to its associated concept. Thus, children with the better reading skills were also those who exhibited the larger proportion of accurate picture recognition, irrespective of the learning method to which they were assigned to. However, fifth graders with the better reading skills showed more benefit from orthography. The absence of significant correlations between reading skills and accurate written recognition for the orthographic judgment task is inconsistent with the previous studies conducted on L1 learning, which reported that more advanced readers benefited more from orthography in spelling (e.g., Ricketts et al., 2009; Rosenthal & Ehri, 2008). Nevertheless, one possible explanation is that using a decoding strategy would have misled participants given that one of the foils was homophonic with the target when relying on the French letter/sound mappings. Overall, we did not report systematic relationships between L1 linguistic skills and L2 spoken/written word recognition, suggesting that learning a foreign language may not rely on/require L1 reading automatization. Interestingly, an orthographic facilitation on L1 vocabulary learning was also documented among beginning readers (Chambré et al., 2017), as well as among children with dyslexia (e.g., Baron et al., 2018) or with developmental language disorders (Ricketts et al., 2015). In light with these evidences, we suggested that a minimal orthographic knowledge is required to support word learning. However, these results should be taken with caution and further studies are required to confirm these assumptions by using more reliable linguistic background tests.

IV. 2. 4. 4. Depth of the orthographic encodin?

This follow-up study also aimed to explore whether the increase of the learning load may modify the orthographic coding when participants are exposed to the written form. Consistently with the previous study, an orthographic advantage was reported for learning L2 written wordforms, as evidenced by higher accurate spelling recognition for children exposed to orthography during learning compared to those who were not. Indeed, here again, two thirds of the German written forms were recognized immediately after learning, supporting that both third and fifth graders paid attention to orthography during learning. Although we expected that the increase of the learning load may alter the quality of the orthographic encoding, measures of accuracy did not provide any evidence to reinforce this assumption. Furthermore, third graders committed a larger proportion of errors compared to fifth graders, supporting that they may have encoded orthographic forms in a shallower way. However, the absence of significant interaction between grade and learning method supports that the orthographic facilitation was comparable among third and fifth graders, and thus, was not modulated by the degree of L1 mastery. Yet, the pairwise comparisons conducted on the committed errors revealed that fifth graders, regardless of the learning method to which they were assigned, were more attracted to the close orthographic distractor, i.e., characterized by one letter substitution/transposition with the target wordform (with a ratio of two close orthographic errors for one phonological error) compared to the third graders. On the contrary, third graders, although they committed more close orthographic errors compared to the two others when exposed to orthography, selected the phonological distractor more frequently compared to fifth graders. The difference in the pattern of errors between grades provides some hypotheses relative to the cumulated experience with foreign language (English) at school in fifth graders, an issue that will be discussed in General discussion.

IV. 2. 4. 5. Orthographic advantage on L2 phonological learning

By increasing the learning load, we expected that fifth graders would allocate less attentional resources to the written form during learning, which would have resulted in building more shallow orthographic representation in memory than for the 16-item condition. It was also possible that participants would simply rely on a pure visual encoding, i.e., without extracting the letter/sound mapping that is specific to L2. Interestingly, the orthographic advantage on L2 phonological learning was significant, with fifth graders outperforming their peers on L2 spoken recognition once they were exposed to written information during learning. A similar pattern of results was retrieved among third graders. The orthographic facilitation was nonetheless not impacted by the L1 level of mastery. These results suggested a strong interplay between orthography and phonology during learning, an issue that will be discussed in General Discussion. Similarly, most studies conducted on L1 learning documented the benefit of orthography on the acquisition of novel (pseudo)word pronunciation (see., Colenbrander et al., for a systematic review).

Interestingly, the raw data reported that fifth graders in the non-orthographic group had lower accurate recognition of German words compared to the orthographic one (69% vs 73% respectively), and they committed a higher proportion of false alarm (27% vs. 22% for the non-orthographic vs. the orthographic group respectively). Thus, discrimination between words and their close phonological distractors was less accurate when participants were not exposed to orthography during learning. Importantly, as a reminder, fifth graders exhibited comparable discriminative performance in the 16-item study, whether they were exposed to orthography or not. In light of these results, we suggested that, until a “critical” learning load was not reached, it was possible for participants to perform as well irrespective of the learning method. However, as soon as the learning load overcame children' phonological short-term memory abilities, then, the benefit of orthography was reported among fifth graders. For third graders, given that their cognitive and linguistic skills are lower than those of fifth graders, the benefit of orthography was retrieved regardless of the learning load.

Contrary to the previous study, re-exposure to the spoken material after delay did not led to increased discrimination between German words and their close phonological distractors, supporting that the orthographic advantage was not impacted by the L2 phonological reactivation.

IV. 2. 4. 6. Congruency vs incongruency

For exploratory purpose, we wondered whether the orthographic facilitation was modulated by the degree of grapheme-to-phoneme congruency between L2 (German) and L1 (French). Previous studies conducted on monolingual adults documented whether the presence of the written form was deleterious for learning novel phonological form (or phonemic contrasts) when confronting participants to incongruent letter/sound mappings (see., Barrios & Showalter, 2021 for review). Mixed results were however reported (see, Escudero et al., 2015 for an orthographic advantage, but see., Hayes-Harb & Becker, 2010, for a written disadvantage on phonological learning). Unexpectedly, we found no significant effect of congruency, nor interaction between congruency and learning method (and grade) for all three recognition tasks, which is consistent with a previous study that reported no particular advantage nor disadvantage of an orthographic method on learning conflicting phonological contrasts (see., Showalter & Hayes-Harb, 2015). However, the absence of moderating effect of congruency may be explained by our distinction between congruent and incongruent words. Indeed, we looked at our selected words again and we noticed that some of the congruent ones also included grapheme-to-phoneme incongruencies with L1, especially for the final grapheme <e> which is silent in French but pronounced in German (ex, Birne, Glocke, Hose, Kette, Lippe). In addition, among the incongruent German words, we observed that some of them only included one grapheme-to-phoneme incongruency (ex, Hand, Stern, Tafel). Thus, the distinction between the congruent and the incongruent selected words may not be salient enough to allow us to disentangle potential learning disadvantage associated with exposure to L2 written forms.

Future studies may address more exclusively whether the orthographic advantage may be modulated by the degree of grapheme-to-phoneme congruency between L1 and L2, but including highly incongruent German words.

IV. 2. 4. 7. Summary

The follow-up study replicated the orthographic advantage on L2 vocabulary learning, which was reported for orthographic, phonological and semantic learning, irrespective of the degree of L1 mastery. Contrary to the previous study, an orthographic facilitation was highlighted on L2 phonological learning among fifth graders. We thus suggested that, contrary to our expectations, the increase of the learning load did not impact the depth of the orthographic encoding. On the contrary, for the go/no-go spoken recognition task, the orthographic advantage arose among fifth graders with the increasing learning load. In summary, we reported a consistent orthographic advantage on L2 vocabulary learning, which was replicated among a novel sample of participants as well as for an increased learning load. Although we did not report any impact of congruency on the generalized orthographic advantage on L2 vocabulary learning, future studies are required to confirm these results by using highly inconsistent German words.

An additional research interest was to determine the optimal exposure to novel spoken and written forms required to reach a compromise/balance between an accurate/optimal word learning and preservation of positive attitude toward learning. To date, there is no consensus on this issue.

IV. 3. Study 1c: Setting the optimal degree of exposure to words in L2 vocabulary learning studies

IV. 3. 1. Introduction

In addition to the modulation of the learning load, we also wanted to determine the degree of exposure to L2 words required for children to reach their learning peak. To date, there is a lack of consistency in the vocabulary learning literature. Most studies alternated between production and repetition blocks during learning sessions but also provided (explicit or implicit) corrective feedback irrespective of the participants' response (see., Hu, 2008; Jubenville et al., 2014; Ricketts et al., 2009. Rosenthal & Ehri, 2008); thus, it was difficult to exactly determine the degree of exposure to learning material in the literature. It is also highly plausible that this parameter is dependent of the size of the learning list. However, exposure to spoken (and written) forms was generally comprised between six training sessions (three production vs. three repetition blocks; see., Ricketts et al., 2009) and 18 ones (see., Jubenville et al., 2014). In Hu (2008) however, participants had a maximum of ten learning trials for each of the three pseudowords to learn them; thus, there was an unbalanced exposure to learning material between their participants. It is however important to mention that manipulating the degree of exposure to (pseudo)words during learning was not one of his research purposes.

In an ecological context, a word has to be encountered several times and in a varied contextual background to be stored in a child lexicon, that was estimated to twelve to fifteen exposures (see., Beck et al., 2002). Nonetheless, in an experimental context, Chambré et al. (2017) have reported that the presence of orthography contributed to an accelerated phonological learning, for which less exposure to spoken material was required in the orthographic method compared to the non-orthographic one. Indeed, after six exposure to spoken items, first graders were able to pronounce accurately about five of the six novel L1 words that were embedded in stories. Nonetheless, in L2 learning, children have to acquire the specific grapheme-to-phoneme correspondences to decode L2 words, thus, further additional exposure to learning material may be required.

To explore this, we manipulated three modalities of learning repetitions, i.e., six, nine and twelve repetitions during learning, as a within-variable to explore the gradual increase of learning performance associated with the number of exposures to novel words, which aimed to avoid duplicating the studies along the thesis. These collected data came from Study 1a and Study 1b, during which we assessed our participants' learning progress using two "training" forced-choice recognition tasks in the learning phase.

Participants performed the first one after being exposed six times to each German word and the second one after nine presentations (three additional exposures to learning material). Furthermore, learning phase was immediately followed by an immediate testing, including a forced-choice repetition, providing us a measure of learning after twelve exposure to each German word. The main aim of these follow-up analyses was to determine the most adapted exposure to German words during learning phase for participants to reach their learning peak, in accordance with their learning abilities as well as their grade level. The subsequent aim was also to explore at what level of exposure to learning material the benefit of orthography and of grade might arise.

IV. 3. 2. Method

This follow-up study relies on the two previous ones and thus, experimental data were collected during learning phase for the 16-item and 24-item condition. As a reminder, we used three (passive) learning blocks. Each spoken item was only provided once for each trial and a switch in German speaker occurred between each of the three learning blocks. The first block included six-word repetitions, whereas the second and third ones only had three-word repetitions. After each of the first two learning blocks, learning progress was assessed by using a forced-choice picture recognition task. We will refer to them as "training" forced-choice picture recognition tasks. No corrective feedback was provided during these "training" tasks. Familiarization to the "training" tasks was prevented by using experimental safeguards. Indeed, the position of both target and distractive picture was counterbalanced between each trial; each distractive picture was used to an equal number of trials. In addition, two out three distractors were similar and the third one was substituted by another one across forced-choice picture recognition tasks.

IV. 3. 3. Results

IV. 3. 3. 1. Data analysis

Statistical analyses were conducted on repetition measures, i.e., six vs nine vs twelve items presentations. Given that the number of presentations for each item was ordered (six vs nine vs twelve item presentations), we implemented planned contrast coding on this variable (six item presentations vs nine presentations; nine vs twelve presentations). Statistical analyses were computed using logistic mixed models, given that accuracy was a binary outcome variable. Separate statistical analyses were conducted according to the number of German words that participants had to learn, i.e., 16 vs 24 German words, given that participants were not matched on all the cognitive and linguistic background tests in both studies. Descriptive statistics for participants' performance to the forced-choice picture recognition tasks are presented in Table 18.

Table 18. *Participants' performance to forced-choice picture recognition task according to Grade (third vs. fifth graders), learning method (OLM; orthographic learning method vs. NOLM; non-orthographic learning method) and degree of exposure to learning material (six vs. nine vs. twelve repetitions).*

	Third graders				Fifth graders			
	NOLM		OLM		NOLM		OLM	
	M	SD	**M**	SD	**M**	SD	**M**	SD
Forced-choice recognition task – 16 items (accuracy in percent)								
6 repetitions	41.00	17.60	48.11	15.99	62.50	18.98	60.36	15.19
9 repetitions	55.00	21.94	70.27	21.39	76.17	17.35	82.57	15.99
12 repetitions	49.22	20.39	72.16	22.17	71.88	16.65	83.88	16.35
Forced-choice recognition task- 24 items (accuracy in percent)								
6 repetitions	39.73	11.02	52.44	16.43	57.16	21.15	68.83	17.04
9 repetitions	55.36	21.33	74.43	19.62	65.10	16.88	81.02	14.81
12 repetitions	50.30	19.31	73.28	18.85	63.28	21.89	80.71	13.58

IV. 3. 3. 2. Statistical analyses conducted on the 16-items study

The most fitted model included Repetition, Grade, Learning method as well as the interaction between Learning method and Repetition as fixed effects and by-participant, by-item and by-school random intercepts (AIC = 6737, $\chi 2$ (2) = 33.21, $p < .001$). The model and its parameters are presented in Table 19. A main fixed effect of repetition was highlighted with a larger accurate performance after nine exposure to German words than after six exposure only (respectively, 54.26 % vs 72.84 %, $p < .001$). The odds of accurate picture recognition were 2.60 times higher after nine exposure to German words than after six exposure. Interestingly, these odds fell to 0.89 times when contrasting learning performance after nine and twelve exposure to German words (respectively, 72.84 % vs 70.63 %, $p = .12$). There was also a main effect of grade level, with fifth graders outperforming children in third grade (respectively, 75.55 % vs 56.84 %, $p < .001$). The odds of accurate picture recognition were indeed 2.97 times higher in fifth graders compared to third graders.

Table 19. *Summary of the logistic regression analysis for variables predicting accuracy on the repeated forced-choice picture recognition task associated to increased exposure to German words for the 16-item condition.*

Model and predictors	Estimate	SE	95% CI		*z*-value	*p*-value
			LL	UL		
Intercept	0.980	0.183	0.679	1.414	-0.109	.913
Repetition (6 vs 9)	2.013	0.203	1.652	2.452	6.951	<.001
Repetition (9 vs 12)	0.888	0.068	0.765	1.031	-1.555	.119
Grade	2.974	0.434	2.234	3.958	7.468	<.001
Learning method	1.873	0.237	1.461	2.401	4.951	<.001
Repetition (6 vs 9) x Learning method	1.726	0.257	1.289	2.312	3.662	<.001
Six repetitions						
Intercept	0.950	0.210	0.616	1.466	-0.232	.817
Learning method	1.289	0.173	0.991	1.677	1.893	.058
Nine repetitions						
Intercept	2.230	0.628	1.284	3.873	2.848	.004
Learning method	2.359	0.466	1.601	3.476	4.341	<.001
Orthographic learning method						
Intercept	3.168	0.741	2.003	5.012	4.929	<.001
Repetition (6 vs 9)	3.628	0.410	2.907	4.527	11.405	<.001
Non-orthographic learning method						
Intercept	1.758	0.414	1.108	2.789	2.397	.017
Repetition (6 vs 9)	2.008	0.202	1.649	2.446	6.933	<.001

The interaction between repetition and learning method was only significant for contrasting between six and nine item repetitions and was thus explored by computing separate models for each modality of the item presentation variable. Interestingly, although a marginal main effect for learning method was retrieved after six item presentation, this effect reached significance after nine presentation, with an odds of accurate picture recognition 2.36 times higher in orthographic learning method than in the non-orthographic one (respectively, 79.52% vs 66.08 %, $p < .001$). In addition, the odds of accurate picture recognition were 3.63 and 2.01 times higher respectively for orthographic and non-orthographic learning method after nine exposures to German words than after six exposures only.

IV. 3. 3. 3. Statistical analyses conducted on the 24-items study.

Statistical analyses were then conducted on repetition measures using data from the 24-items. Here, the most fitted model also included Repetition, Grade, Learning method as well as the interaction between Repetition and Learning method as fixed effects and by-participant, by-item and by-school random intercepts (AIC = 9541, $\chi2$ (2) = 20.13, p <.001). The model and its parameters are presented in Table 20. The main effect of repetition was significant, with an odds of accurate picture recognition 1.75 times higher after nine exposure to German words than after six exposure only (respectively, 68.79% vs 54.49%, p<.001). This effect was however marginal when contrasting between nine and twelve item repetitions, with odds only 0.85 higher after nine than after twelve exposure (p=.06). There was also a main effect of grade, with an odds of accurate picture recognition 1.78 times higher in fifth graders than in third graders (respectively, 68.71 % vs 57.75 %, p < .001).

Table 20. *Summary of the logistic regression analysis for variables predicting accuracy on the repeated forced-choice picture recognition task associated to increased exposure to German words for the 24-item condition.*

Model and predictors	Estimate	SE	95% CI		*z*-value	*p*-value
			LL	UL		
Intercept	1.008	0.224	0.652	1.558	0.034	.972
Repetition (6 vs 9)	1.754	0.145	1.492	2.063	6.799	<.001
Repetition (9 vs 12)	0.848	0.070	0.721	0.997	-1.993	.060
Grade	1.940	0.350	1.363	2.763	3.677	<.001
Learning method	1.782	0.224	1.393	2.281	4.593	<.001
Repetition (6 vs 9) x Learning method	1.504	0.187	1.178	1.920	3.276	.001
Six repetitions						
Intercept	0.930	0.165	0.658	1.316	-0.409	.683
Learning method	1.631	0.235	1.231	2.163	3.402	<.001
Nine repetitions						
Intercept	1.764	0.371	1.167	2.665	2.694	.007
Learning method	2.286	0.403	1.618	3.229	4.692	<.001
Orthographic learning method						
Intercept	2.985	0.661	1.934	4.607	4.937	<.001
Repetition (6 vs 9)	2.718	0.259	2.255	3.275	10.507	<.001
Non-orthographic learning method						
Intercept	1.300	0.248	0.894	1.891	1.374	.169
Repetition (6 vs 9)	1.744	0.143	1.484	2.049	6.759	<.001

Consistent with 16-items, the reported interaction between repetition and learning method was only significant for contrasting between six and nine exposure to learning material and was, thus, explored by computing separate models for each modality of the item presentation variable. There was a significant main effect of learning method both after six exposure to German words as well as after nine exposure (both ps <.001). Nonetheless, although an odds of accurate picture recognition 1.63 between orthographic and non-orthographic learning method was reported after six exposure, the odds was 2.29 times higher in orthographic learning method after nine exposure. Furthermore, the odds of accurate picture recognition was 2.72 and 1.74 times higher respectively for orthographic and non-orthographic learning method after nine exposure to German words than after six exposure only.

IV. 3. 4. Discussion

This study aimed to determine the degree of exposure to L2 words required for children to reach the learning peak, but also to explore which degree of exposure to written information was required to retrieve an orthographic advantage on L2 vocabulary learning, assessed through three forced-choice picture recognition tasks. We contrasted three modalities of word repetitions, i.e., six, nine and twelve repetitions, and we assessed the gradual increase of participants' learning performance.

In the following section, we will look on the gradual learning performance obtained for the L2 vocabulary learning. The statistical analyses revealed comparable significant effects for Study 1a (16-item condition) and for Study 1b (24-item condition); thus, we will only discuss the results obtained for the 24-item condition for the sake of clarity. After six exposures to German words, third graders were able to accurately link the spoken form to its meaning for about 11 (45.8%) of the 24 German words, whereas fifth graders performed accurately for 15 (62.5%) of the 24 words, supporting once again that the paired-associate learning paradigm was adapted for L2 vocabulary learning studies. In addition, fifth graders outperformed the third graders from six exposures to German words, supporting that increased level of school education was associated with enhanced vocabulary learning.

Interestingly, the learning peak was reached after nine exposure to German words, resulting in the accurate association spoken form/meaning for about 15.6 (65%) and 17.5 (73%) of the 24 German words among third and fifth graders respectively. Indeed, additional exposure to German words did not improve participants' learning performance (62% vs. 72% in third and fifth graders respectively). Once again, a glass ceiling in learning was reported.

IV. 3. 4. 1. Emergence of the orthographic advantage on L2 vocabulary learning

In both previous studies, we reported an orthographic advantage on the acquisition of L2 vocabulary immediately after learning, an observation consistent with the previous L1 learning studies (see., Colenbrander et al., 2019). The subsequent goal of this study was to determine which degree of exposure to L2 words was required to report a beneficial contribution of orthography on vocabulary learning. A marginally significant effect of the learning method was highlighted after six exposures to the learning material, still, it became significant after nine exposures. This suggests that orthography played an early benefit on L2 vocabulary, although re-exposure to German words led to consolidate more deeply. Here again, the orthographic facilitation was not modulated by the degree of L1 mastery, supporting that orthography did require automatized reading skills to help children in learning L2 vocabulary.

IV. 3. 4. 2. The nature of the orthographic advantage on L2 vocabulary learning

As evidenced above, the beneficial contribution of orthography on L2 vocabulary acquisition was retrieved during early steps of foreign language learning, for which participants had no prior (explicit) exposure to written and spoken forms. Interestingly, Chambré et al. (2017) reported that the presence of orthography led to an accelerated phonological learning among first graders. Indeed, according to these authors, the presence of orthography may reduce the number of word encounter to integrate its phonological in memory. In the present study, learning was assessed through a forced-choice picture recognition task, for which children had to associate a spoken form to its meaning. Success for this task required that participants 1) recognize the spoken form (and thus activate its phonological representation in lexicon) and 2) accessed its semantic representation through the activation of the phonological-semantic connection (which was created during learning). In the General Discussion, we will thus address whether the access to semantics was mediated or not by phonology. Thus, we wondered whether, in the absence of orthographic information during learning, children may require additional encounters of the German words to perform as accurately as those in the orthographic learning method. Still, when looking to the data, no additional gain in learning was provided by adding three further exposure to learning material. This supports that the presence of orthography did not only speed up the acquisition of L2 vocabulary, but may have also strengthened the connection between each lexical representation (meaning, pronunciation and spelling), due to the multimodal sources of information displayed during learning. This assumption is consistent with both the lexical quality hypothesis (Perfetti & Hart, 2002), which supports that activation of orthography may also activate phonological and semantic representations, and the recoding of phonology by orthographic mapping (see., Ehri, 2014).

IV. 3. 4. 3. Summary

In line with the previous studies, this follow-up study provided us an optimal experimental framework to conduct our future L2 vocabulary learning studies: participants reached their learning peak for 24 German words after having encountered each word nine times during (passive) word learning session. This learning setup was also efficient to highlight the contribution of orthography on L2 vocabulary learning as well as the increased learning performance associated with increased degree of L1 mastery (significant effect of grade).

Therefore, by using this experimental learning framework, we will now explore whether the benefit of orthography may be modulated by the degree of grapheme-to-phoneme congruency between L1 and L2 by contrasting between highly incongruent and highly congruent German words.

Chapter V. On the (limited) moderating effect of grapheme-to-phoneme congruency with L1 on the orthographic advantage on L2 learning

V. 1. 1. Introduction

In the princeps study, we documented the benefit of orthography on L2 vocabulary learning that was reported (rather) consistently for orthographic, phonological and semantic learning among third and fifth graders. This orthographic facilitation was not impacted by the increase of learning load, although some evidence of an orthographic advantage on L2 phonological recognition was reported among fifth graders. In addition, we explored whether the orthographic facilitation was moderated by the degree of incongruent mapping between graphemes and phonemes. Indeed, due to the presentation of the written form during learning, participants may have infered the spoken form through (partial) decoding attempts. Although beneficial for congruent German words, this learning strategy may have confronted children to encode incorrect spoken forms for incongruent ones, leading to a deleterious contribution of orthography on L2 vocabulary learning.

However, previous results did not report significant differences in recognition performance between congruent and incongruent German words. This absence of moderating effect of the degree of congruency was surprising and we wondered whether the distinction between the congruent and the incongruent selected words was not salient enough to allow us to disentangle any potential learning disadvantage associated with exposure to L2 written forms.

This second study aimed to determine whether the benefit of orthography may be modulated by the degree of grapheme-to-phoneme congruency between L1 and L2 by contrasting between highly incongruent and highly congruent German words. Due to delayed data collection, these supplementary objectives will be exposed in further works. In addition, we explored whether exposure to both orthography and phonology during learning helped children to extract and transfer the mappings between graphemes and phonemes that are specific to foreign language, i.e., German.

To do so, we made fifth graders learn 24 German words. This study was conducted among fifth graders to ensure that participants had gather enough experience with reading to decode written forms on an automatized way. Half of these German words were highly incongruent with L1 (ex., Zaun, /tsaʊ̯n/ in German vs. /zon/ in French) whereas the remaining half were rather congruent (ex., Kamm, /kam/ in German and in French) with the French grapheme to phoneme correspondence rules.

Learning performance were assessed by using the same three experimental tasks as in Study 1, i.e., a forced-choice picture recognition task, a go/no-go spoken recognition task, and an orthographic judgment task. To explore the transfer of the L2 grapheme-to-phoneme correspondence rules to "unlearned" items, we included a spelling generalization task as well as a L2 word reading task. Due to the sanitary crisis, the latter experimental task will not be presented in this doctoral work.

V. 1. 2. Methodological part

<u>Data inclusion</u>: Data inclusion was supposed to start on March 2020, but had to be rescheduled due to the COVID-19 sanitary context and the national closure of elementary schools. In addition, we had to obtain the approval from the State School inspectorate to intervene in schools again. Furthermore, only two elementary schools agreed to take part to our study. Data inclusion took place in February 2021 in the first elementary school with 19 fifth graders. The third epidemic wave stopped the ongoing data collection which will be conducted in the following months. In parallel to data inclusion with children, we adapted this study to adults, in order to contrast learning performance, as well as the contribution of orthography in

managing grapheme-to-phoneme incongruencies between children with growing experience with reading, i.e., fifth graders, and expert readers. Data collection is still into progress and, for the sake of consistency, we only presented preliminary results for exploratory purpose.

V. 1. 2. 1. Participants

Nineteen fifth graders were recruited in the same elementary school located in the Hauts de France region, France. All participants were native speakers of French or experienced a daily exposure to French for at least six years. Furthermore, they had no prior knowledge of German language prior to the study. We also insured that participants did not suffer from recognized learning disabilities or any sensory disorders. However, one participant was unable to decode any French word accurately and had to be removed from the study. In addition, three participants did not complete the second testing sessions and were removed from further analysis. Therefore, the remaining 15 fifth graders (mean age = 10.45 years, SD = 0.43 year) attended the learning of German words with orthography.

Cognitive and language background tests

Cognitive and language skills in French were measured using background tests from standardized batteries. This ensured that any difference in learning performances between groups were not attributed to better cognitive or linguistic skills of children attending an orthographic learning method to learn German vocabulary. Importantly, they were assessed using the same background tasks as described above, i.e., RAVEN matrices (Raven, 1981), vocabulary subtest of the WISC IV (Wechsler, 2005), pseudoword repetition task subtest of the NEPSY II (Korkman et al., 2012), reading skills (reading age) using the Alouette task (Lefavrais, 1967; 2005). In addition to these background tasks, we also included two further measures of reading skills, i.e., reading accuracy and fluency. Reading accuracy was assessed using the word reading subtest of the ODEDYS 2 (Jacquier-Roux et al., 2005). For this task, participants were asked to read a list of 20 low frequent French words as well as a list of 20 pseudowords as accurate as possible. In addition, reading fluency was assessed using two successive one-minute tests. The first one included French regular words to test the lexical route whereas the second one only included pseudowords to assess the phonological route in accordance with the Dual-Route Cascaded model of reading (Coltheart et al., 2001). Participants' score to background tasks are presented in Table 21.

Table 21. *Descriptive statistics (mean and standard deviation) on cognitive and linguistic background tasks among fifth graders for the orthographic learning method.*

	Orthographic learning method	
	M	SD
Age (in months)	125.38	5.15
Reading age[1]	123.50	16.60
Reading fluency[1]	309.41	69.38
Reading accuracy[1]	96.50	1.86
OMT- Words	82.69	14.97
OMT- Pseudowords	45.44	9.01
ODEDYS- Words	19.00	0.82
ODEDYS- Pseudowords	16.75	2.08
NWRT	35.19	2.56
Phoneme deletion	11.06	1.12
RAVEN matrices	26.00	3.35
L1-Vocabulary	33.88	4.92

Note—Reading measures were obtained at the Alouette test (Lefavrais, 1967; 2005): Reading fluency scores reflect the number of words that would have been read in three minutes (reading fluency score higher than 265 means that the participant have read the whole text in less than three minutes); Reading accuracy was calculated by multiplying by 100 the ratio between the number of words read accurately compared to the number of words read; One minute reading task for words (OMT-Words) and for pseudowords (OMT-Pseudowords) reflects the number of items correctly read in a one-minute time. Reading accuracy for words and pseudowords was assessed through the word reading subtest of the ODEDYS- 2 (Jacquier-Rioux, Valdois, Zorman, Lequette et Pouget, 2005); NWRT: Nonword repetition task subtest of NEPSY II (Korkman et al., French adaptation ECPA, 2012) and assessed short-term phonological memory skills; RAVEN matrices were used as a measure of non-verbal reasoning skills (Raven, 1981); L1(French) Vocabulary subtest of Wechsler Intelligence Scale for Children (WISC IV; Wechsler, 2005).

V. 1. 2. 2. Learning and testing phases

Consistent with previous studies, the learning session was followed by an immediate as well as a one-week delayed testing sessions. Both experimental sessions took place in the elementary school with groups of three to four children. Importantly, prior to learning, participants' "spontaneous" decoding abilities in German were assessed using a German word reading task. The experimental design is illustrated in Figure 7.

Figure 7. *Organization of the learning and testing sessions for Study 2.*

Day 1

- Training session
  - German naming task (training session)
  - Spelling generalization task (training list)
- Learning sessions
  - Learning block (nine word repetitions with a pause after each three word repetitions)
- Immediate testing session
  - Forced-choice picture recognition task
  - Go/no-go spoken recognition task (immediate session)
  - Orthographic judgment task
  - Spelling generalization task (delayed list)
  - German naming task (delayed list)

Day 7

- Delayed testing session:
  - Go/no-go spoken recognition task (spontaneous session)
  - Forced-choice picture recognition task
  - Go/no-go spoken recognition task (delayed session)
  - Orthographic judgment task
  - Spelling generalization task (delayed list)
  - German naming task (delayed list)
- Cognitive and linguistic background tasks

V. 1. 2. 2. 1. Learning phase

Words:

Twenty-four typical German words were selected from the SUBTLEX-DE-database (Brysbaert et al., 2011). Half of the selected words were congruent (Kamm), meaning that there was a one-to-one relationship between grapheme and phoneme with French. The remaining words were highly incongruent, i.e., including between two and four grapheme-to-phoneme incongruencies (mean = 2.5, SD = 0.67 incongruencies). As an example of incongruent German word, “Bauch” had two grapheme-to-phoneme incongruencies between German and French, given that the bigrams <au> and <ch> were associated respectively with the phonemes /aʊ̯/ and /x/ in German, but with the French phonemes /o/ and /ʃ/. Congruent and incongruent German words were matched on orthographic and phonological size, frequency of their French translation equivalents, minimal bigram frequency, and orthographic neighbourhood size using the Orthographic Levenshtein Distance. Imageability and concreteness were assessed using the Glasgow psycholinguistic norms (Scott et al., 2019), given that it was the sole database for which a measure of concreteness and imageability was retrieved for the selected words. Surprisingly, congruent and incongruent word lists were not matched on imageability (respectively, 6.71 vs 6.40 on a 7-point Likert scale, p =.02), but on concreteness (respectively, 6.56 vs 6.30 on a 7-point Likert scale, p =.10). German words had a mean orthographic size of 5.58 letters (SD = 1.12) and their mean phonological length was of 4.17 phonemes (SD = 1.05). Mean frequency of their French translation equivalents was of 89.09 occurrences per million (SD = 92.05), with frequencies comprised between 2.09 for “Klingel” (bell) and 353.91 occurrences per million for “Pferd” (horse). Learning stimuli are presented in Appendix 11.

Pictures:

Consistent with previous studies, we selected 24 black and white pictures from the MULTIPIC-database (Dunabeitia et al., 2018), that were matched to the German selected words.

Recordings:

Three German native speakers, working in the Goethe Institute, have been contacted to record the German words pronunciation. Contrary to the previous study, due to the COVID-19 sanitary crisis, recordings have been conducted online in a quiet environment, using AUDACITY-software (Team, 2015). The audio stream was normalized and we proceeded to a noise attenuation procedure. Thus, we had three different speakers for each German word. Participants were exposed to the three version of the recordings during learning.

Procedure:

Prior to learning, we conducted two successive experimental tasks in a one-to-one experimental context, i.e., one participant with the sole presence of the investigator: a German word reading task and a German spelling task. The one provided us an initial measure of participants' decoding attempts using French grapheme-to-phoneme correspondences while the latter reflected participants' spelling identification strategies using their French phoneme-to-grapheme correspondences. As a reminder, participants reported no previous exposure to German prior to the study.

Then, learning session was conducted by groups of three to four participants. Before learning, we ensured that participants were able to identify each picture and to name them using a French naming task. Learning session followed the same experimental procedure as exposed in the previous study. For each German word, both spoken and written wordforms were presented simultaneously and they were associated with their corresponding picture. Each word was presented for at least three seconds (with no time limit); then, participants were allowed to move to the next item. Spoken wordform was only provided once for each trial. Participants were exposed to each German word nine times during learning session. Indeed, previous study reported that nine item repetitions provided sufficient exposure to German words for participants to learn vocabulary in a non-ecological context. Learning session was divided in three blocks of three item presentation. Learning session lasted between 20 and 25 minutes according to participants' learning pace. Testing session was conducted immediately after learning.

V. 1. 2. 2. 2. Testing phase

Consistent with the previous study, we used the same three computerized tasks, i.e., a forced-choice recognition task, a go/no-go spoken recognition task and an orthographic judgment task. In addition to these tasks, we also included a German word reading task as well as a German spelling task. We will refer to the latter as the German spelling generalization task. As exposed above, an initial measure of German decoding and spelling attempts was assessed prior to the learning phase.

For the immediate and one-week delayed testing sessions, experimental tasks were provided following the same procedure as described in Study 1. As a reminder, one-week delayed testing session started with a "spontaneous" go/no-go spoken recognition task to determine participants' performance prior to re-exposure to spoken material. Both testing sessions were however concluded by a measure of participants' reading and spelling abilities in German that were assessed in a one-to-one experimental context. The speaker's voice was randomly determined for each experimental task. Furthermore, there was a switch in speaker after each experimental task. Immediate and one-week delayed testing lasted between 35 and 45 minutes. Background cognitive and language skills, as presented above, were assessed at the end of the one-week delayed testing.

***Presentation of the experimental tasks*:**

Although the same experimental tasks were used across studies, we proceeded to several experimental adjustments for the purpose of this study, such as the inclusion of both close and distant phonological distractors in the go/no-go spoken recognition task. In the following paragraphs, we will only present these experimental adjustments for the relevant experimental tasks, i.e., go/no-go spoken recognition task and orthographic judgment task. We will also present the two novel experimental tasks in more details, i.e., German word reading task and German spelling generalization task. Testing material is available in Appendices (please see,

Appendix 12 for the forced-choice picture recognition task, Appendix 13 for the go/no-go auditive recognition task, Appendix 14 for the orthographic judgment task and Appendix 15 for the spelling generalization task).

Go/no-go spoken recognition task:

Stimuli. In addition to the 24 German words, two lists of 48 pseudowords were constructed using WUGGY (Keuleers & Brysbaert, 2010). Among them, 24 pseudowords were close phonological distractors to the learning material. Indeed, they were distant from one to two phonemes of the German selected words. As an example, the pseudoword "Fahrnad" (/f.a.r.n.a.t/) differed by only one phoneme from the German word "Fahrrad" (/f.a.r.a.t/). The remaining half were distant phonological distractors, which only shared one to two phonemes with the learning material according to the target's phonological size. The distant phonological distractor associated with the German word "Fahrrad" was "Famodu" (/f.a.m.O.d.U/). We also included 24 German fillers (12 congruent German words) to ensure that there was a comparable number of words and pseudowords during the experimental task. Recording of fillers and pseudowords immediately followed those of German words, to ensure that their pronunciation was as close as possible to German. Immediate and delayed go/no-go spoken recognition tasks were conducted using the first list of fillers and pseudowords. The second list of pseudowords and fillers was displayed for the "spontaneous" go/no-go spoken recognition task.

Orthographic judgment task:

Stimuli. Consistent with previous study, three types of distractive spellings were created and were associated to each German word, i.e., close and distant orthographic distant distractors, and phonological distractors. The close orthographic distractors were created by either a one-letter transposition (Fahrrad-Farhrad), when this letter transposition led to legal plausible German wordform, or by a one-letter substitution (Zaun-Zain). The locus of the orthographic modification was comparable for both congruent and incongruent German words.

The distant orthographic distractors only shared a small orthographic overlap with the German target word (Fahrrad – Fahschip), leading to spellings highly implausible with German graphotactics. This orthographic overlap was comprised between one to three graphemes, depending on word orthographic size. Both close and distant orthographic distractors shared a smaller phonological overlap with the German target word. The phonological distractors were homophonic with the German words, when using French grapheme-to-phoneme correspondences (Fahrrad-Farrade). These phonological distractors had highly implausible spellings with German graphotactics.

German spelling generalization task:

Spellings. The German spelling generalization task was designed as an extension of the orthographic judgment task, but with German pseudowords. Here, we chose pseudowords instead of German words, to ensure that incongruent items only included one specific grapheme-to-phoneme incongruency with French. Importantly, each incongruent pseudoword included one among the six specific grapheme-to-phoneme incongruencies (<ch> /x- ʃ/, <au> /aʊ-o/, <ei> /aɪ -ɛ̃/, <er> /ɐ- e/, <g> /g-ʒ/, <z> /ts-z/) to which participants have been exposed during learning phase. As an example, the final bigram <ch> is associated with the phoneme /x/ in German, but with the phoneme /ʃ/ in French.

Two lists of 24 pseudowords were created using WUGGY-database (Keuleers et al., 2010) and their spelling was highly plausible with German graphotactics. Half of these pseudowords included one incongruent grapheme-to-phoneme correspondence between German and French. These pseudowords were between four and seven letters long (mean = 5.29 letters, SD = 1.00 letter) and we ensured that congruent and incongruent pseudowords were matched on their orthographic size.

Three distractive spellings were associated to each German-like pseudoword, i.e., a close and a distant orthographic distractor and a phonological distractor. The close orthographic distractor was created by a one-grapheme substitution (Drau-Dreu), leading to a plausible spelling in German and increasing its phonological distance with the target pseudoword (/aʊ-o/ vs /ɔʏ-ø/). The distant orthographic distractor shared a scarce orthographic overlap, i.e., restricted to one-to-two graphemes, with the target pseudoword (Drau-Droy). The phonological distractor was homophonic with the target pseudoword when using the French grapheme-to-phoneme correspondences (Drau-Draho). Importantly, spellings of both distant orthographic and phonological distractors were highly implausible with German graphotactics.

Sound recordings. The pronunciation of each target pseudoword was also recorded following the same recording procedure as detailed above. German native speakers were asked to pronounce these pseudowords as if they were real German words. For recordings, each pseudoword was associated to a close phonological German word (Drau-Frau) to ensure that its pronunciation was as close as possible to the one we expected, especially for the selected grapheme-to-phoneme incongruences.

Procedure. As described above, there were two lists of 24 pseudowords. The first one was used prior to the learning session (we will refer to it as "spontaneous" spelling generalization task). The second list of pseudowords was used for both immediate and one-week delayed session, i.e., immediate and delayed spelling generalization tasks. They were designed to explore whether participants were able to generalize the German specific letter-to-sound mappings to unlearned German-like pseudowords and whether their performance was modulated by grapheme-to-phoneme incongruencies. In addition, we explored whether there was a switch on the graphotactics rules participants would rely on after exposure to German.

For each trial, a target pseudoword was presented among its three distractive spellings. The pronunciation of the target pseudoword was displayed in the headphones. Participants had to select the matching spelling that was paired to the spoken form. No corrective feedback was provided. Accuracy was recorded as well as, for each committed error, the nature of the selected distractive spelling.

German word reading task:

Stimuli. Seventy-two German words were selected. Among them, 24 German words were considered as congruent, given that they did not include any grapheme-to-phoneme incongruences with French. The remaining 48 German words were incongruent and included at least one of the six different types of incongruences (<ch> /x- ʃ/, <au> /aʊ-o/, <ei> /aɪ -ɛ̃/, <er> /ɐ- e/, <u> /u:-y/, <z> /ts-z/). Five of them were shared with the German generalized spelling task. The <g> grapheme-to-phoneme incongruency was however replaced by the <u> one. Indeed, the grapheme <u> is associated with the phoneme /uː/ in German, but with /y/ in French. Importantly, participants were exposed to all these incongruences during learning phase. Half of the incongruent words had one grapheme-to-phoneme incongruency (K*au*f /k *aʊ*f/ vs /k*o*f/) whereas the other half included two grapheme-to-phoneme incongruencies with French (K*auz*, /kaʊts/ vs /koz/). Congruent and incongruent German words were paired on their phonological (respectively, 3.88 vs 3.92 phonemes) and on their orthographic size (respectively, 4.83 vs 5.21 letters). We also ensured that there were also matched on their number of syllables (respectively, 1.13 vs 1.33 syllables). Importantly, both types of incongruent German words were also matched on their phonological size, to ensure that participants' reading performance could not be directly attributed to length differences, rather than on item difficulty.

Selected German words were divided in two lists of 48 items. The first one was used prior to learning session to explore participants' spontaneous decoding attempts in a novel language. The second one was used at the end of both the immediate and the one-week delayed testing sessions to determine whether participants were able to produce the German specific letter-to-sound mappings or whether they rather rely on the French grapheme-to-phoneme correspondences to pronounce these unlearned German words. If so, accurate pronunciation of German congruent words was expected, but not for incongruent words. Within these lists, each congruent word was presented twice during the German word reading task. Each congruent word was associated with its related slightly and highly incongruent German words, which were only presented once during the experimental task. Each specific incongruent grapheme-to-phoneme correspondence rules with French was equally represented in both lists.

Procedure. For each trial, the spelling of a German word was provided on the computer screen and participants were asked to read it aloud as accurately as possible. Participants were instructed that they could only pronounce the German word once. Then, they could move to the following word by pressing the Key space. The order of word presentation was randomized. Each pronunciation attempt was recorded in a separate mp4-file. The order of word presentation as well as response times were recorded in an excel file. Then, for each item, we determined a word latency time, i.e. the time interval between the presentation of the item and participants' initiation of word pronunciation, using an onset extraction software.

V. 1. 3. Preliminary results

V. 1. 3. 1. Data analysis

Due to the sanitary context as well as experimental mortality, statistical analyses could only be conducted on the remaining 15 participants. Thus, preliminary results for this study will be presented in the following paragraphs. As mentioned above, data inclusion will resume in the next months. Despite the low number of participants, it should be noted that there were at least 24 observations for each participant, leading to a minimal number of 720 observations for each experimental task. In addition, we ensured that the applications conditions for mixed model were fulfilled, i.e., residual distribution as well as variance of random effects followed a normalized distribution. For this reason, all statistical analyses reported below used generalized mixed model and were conducted on R-software (R Core team, 2017), using lmer and glmer functions from the lme4 package (Bates et al., 2015). Data analysis procedure was thus similar to those of previous studies. The random effects were modelled following a compromise between the maximal random structure (Barr et al., 2013) and the parsimonious one (Bates et al., 2015). The random structure included by-participant and by-item random intercepts. Then, fixed effects, i.e., Congruency (congruent vs incongruent German words), Session (immediate vs delayed) as well as interaction effects, were included for each experimental task following a forward stepwise procedure. At each step, chi-squared tests were performed to test the differences in model adjustments and p-values were determined using lmer-package. The procedure was stopped as soon as the further inclusion of any experimental factor did not better fitted the previous model. For models with binary outcome variables, we conducted mixed logistic models and significant main and interaction effects were highlighted using a cut-off point of $p<.05$. For the continuous outcomes, especially for the Go/no-go spoken recognition task, mixed linear models were computed and significant effects were reported using a cut-off point of $t > 2$. In the event of interaction, we computed subset models to explore the contribution of each variable modality. For all four experimental tasks, we presented below the most adjusted model. Descriptive statistics are presented for each experimental task in Table 22 and in Table 23 (for the go/no-go spoken recognition task).

Table 22. *Participants' performance for all three experimental tasks (forced-choice picture recognition task, orthographic judgment task, spelling generalization task) according to session (immediate vs. delayed sessions; and vs. spontaneous session) and to the degree of congruency (congruent vs. incongruent German items).*

	Fifth graders	
	OLM	
	M	SD
Forced-choice recognition task (accuracy in percent)		
Immediate	**79.95**	**18.95**
congruent	82.21	17.60
incongruent	77.08	20.30
Delayed	**67.97**	**19.02**
congruent	67.71	16.40
incongruent	68.23	21.65
Go no go auditive recognition task (discrimination score)		
Immediate	**1.22**	**0.71**
congruent	1.50	0.88
incongruent	0.94	0.53
Spontaneous	**1.19**	**0.99**
congruent	1.19	0.86
incongruent	1.19	1.11
Delayed	**1.27**	**0.96**
congruent	1.16	0.81
incongruent	1.37	1.11
Orthographic judgment task (accuracy in percent)		
Immediate	**70.08**	**22.05**
congruent	66.62	24.73
incongruent	73.53	19.37
Delayed	**60.28**	**22.06**
congruent	59.44	20.62
incongruent	61.11	23.50
Spelling generalization task		
Training	**35.97**	**14.92**
congruent	49.12	14.41
incongruent	22.81	15.43
Immediate	**43.86**	**16.97**
congruent	52.19	16.63
incongruent	35.53	17.31
Delayed	**46.36**	**18.72**
congruent	55.73	18.69
incongruent	36.98	18.75

Table 23. *Discriminative score to the go/no-go spoken recognition task according to the degree of congruency (congruent vs. incongruent), session (immediate, spontaneous and delayed) and to the degree of phonological overlap between word and pseudowords (close phonological vs. distant phonological distractors).*

	Congruent		Incongruent	
	M	SD	**M**	SD
Go no go auditive recognition task (discrimination score)				
Immediate	**1.50**	**0.88**	**1.08**	**0.53**
close phonological distractor	1.50	0.88	0.78	0.44
distant phonological distractor	1.50	0.88	1.09	0.61
Spontaneous	**1.19**	**0.86**	**1.19**	**1.11**
close phonological distractor	0.86	0.69	1.00	1.06
distant phonological distractor	1.52	1.02	1.38	1.15
Delayed	**1.16**	**0.81**	**1.38**	**1.11**
close phonological distractor	1.06	0.73	1.15	0.96
distant phonological distractor	1.26	0.88	1.60	1.25

V. 1. 3. 2. Forced-choice recognition task

Accuracy is a binary outcome variable and thus, mixed logistic models were computed. The most adjusted model included Session as fixed effects as well as by-participant, by-item random intercepts (AIC = 667, $\chi 2$ (1) = 22.65, p <.001). There was a significant main effect of session, with an odds of accurate picture recognition 2.66 times higher in delayed testing compared to immediate testing (respectively, 82.22 % vs 69.17 %, p <.001). Nor the inclusion of congruency (AIC = 689, $\chi 2$ (1) < 1, p = .66), nor the interaction between congruency and session (AIC = 689, $\chi 2$ (1) < 1, p = .20) reach significance.

V. 1. 3. 3. Go/no-go spoken recognition task

Before statistical analyses, response times lower than 300 milliseconds were removed from analysis. Thus, 102 response times met the cut-off criterion, i.e., 3.15 % of the data. This could be attributed to participants who pressed the response key after delay. Two participants had less than 50% of their response left and were thus removed from analysis. The proportion of accurate word recognition and of correct rejection of close and distant phonological pseudowords are presented in Table 24. Discrimination scores were calculated by the difference of the z-transformed distribution of accurate word identification (hits) and of the one of the incorrect acceptances of pseudowords (false alarms). For each participant, separate discrimination scores were calculated for both close and distant phonological distractive pseudowords. We applied a correction on extreme recognition score, i.e. scores equal to 0 and those of 1, using Macmillan & Kaplan's (1985) requested transformation. We prevented response strategies by checking whether any participant had negative discrimination score. Contrary to previous studies, such scores were not retrieved among participants. Thus, statistical analyses were conducted on the remaining 13 participants.

Table 24. *Summary of the accurate recognition of words and pseudowords in the go/no-go auditive recognition task according to session (immediate vs. delayed sessions; and vs. spontaneous session), degree of congruency (congruent vs. incongruent) and to the degree of phonological overlap between words and pseudowords (close phonological distractors vs. distant phonological distractors).*

	Congruent		Incongruent	
	M	SD	**M**	SD
Words (in percent)				
Immediate	73.68	14.24	59.21	16.41
Spontaneous	66.67	15.11	61.67	22.22
Delayed	66.67	18.97	71.57	15.13
Close phonological Pseudowords (in percent)				
Immediate	61.84	24.74	69.74	19.29
Spontaneous	63.89	16.86	70.00	23.10
Delayed	71.08	23.35	68.14	25.54
Distant phonological Pseudowords (in percent)				
Immediate	74.27	25.20	79.82	21.93
Spontaneous	80.00	25.00	85.56	16.51
Delayed	79.73	24.38	76.47	32.41

Immediate vs Delayed session:

Discrimination scores were first analyzed for immediate and delayed testing using generalized mixed models. The random structure only included by-participant random intercepts. Consistent with previous studies, we first explored the impact of delay on discrimination scores by conducting an initial statistical analysis on immediate and delayed go/no-go spoken recognition tasks, given that they were conducted in the same experimental condition. The most adjusted model included Type of pseudowords (close vs distant phonological distractive pseudowords), Session (immediate vs delayed), Congruency (congruent vs incongruent German words) and the interaction between Congruency and Session as fixed effects as well as by-participant random intercept (AIC = 252, $\chi 2(1) = 8.40$, $p = .004$). There was a main effect of the type of pseudowords, supporting that participants exhibited higher discrimination score between words and distant phonological distractors than for close phonological distractors (respectively, 1.69 vs 1.23, $t = 3.23$). The interaction between congruency and session was significant ($t = -2.89$) and was explored by computing separate models for congruent and incongruent German words as well as for both sessions. Interestingly, a significant main effect of session was reported for incongruent words ($t = -2.94$), supporting that participant had higher discriminative scores for incongruent items after delay compared to immediate session (respectively, 1.74 vs 1.05). For congruent words however, the main effect of session did not reach significance (respectively, 1.61 vs 1.48, $t <1$). Furthermore, the main effect of congruency only reached significance for immediate go/no-go spoken recognition task ($t = -3.24$), with higher discriminative scores for congruent items than for incongruent items (respectively, 1.61 vs 1.05).

Immediate vs Spontaneous testing:

The above statistical analysis revealed that a contribution of congruency on the accurate recognition of German words and the correct rejection of pseudowords, that was however restricted to immediate go/no-go spoken recognition task. Indeed, although participants exhibited lower discriminative scores for incongruent items immediately after learning session, this difference in performance was not retrieved after delay. The following analysis was conducted between immediate and “spontaneous” testing sessions to determine whether the contribution of congruency might be retrieved prior to re-exposure to spoken material. As a reminder, one-week delayed testing session started with the “spontaneous” go/no-go spoken recognition task. Here, the most adjusted model included Type of pseudowords (close vs distant phonological distractors) and Congruency as fixed effects as well as by-participants random intercepts (AIC = 266, $\chi2(1) = 4.07$, $p = .04$). Here again, there was a main effect of the type of pseudowords ($t = 3.26$), supporting that participants exhibited higher discriminative scores when discriminating between words and distant phonological distractors than for close phonological distractors (respectively, 1.68 vs 1.05). Furthermore, a significant main effect of congruency was reported ($t = -2.01$), with higher discriminative score for congruent items compared to incongruent items (respectively, 1.53 vs 1.21). Interestingly, the interaction between congruency and session did not led to a better adjusted model (AIC = 267, $\chi2(1) = 2.60$, $p = .11$).

***Summary**:*

Both statistical analyses conducted between immediate and delayed testing as well as between immediate and “spontaneous” testing session reported a main effect of the type of pseudowords, confirming that distant phonological distractors were more easily rejected than close phonological ones, leading thus to higher discriminative scores. There was however no further contribution of the type of items, as no interaction between type of pseudowords and congruency was highlighted. Furthermore, discriminative scores were higher for congruent items than for incongruent ones in immediate and spontaneous go/no-go spoken recognition task. The main effect of congruency was however not significant for delayed go/no-go spoken recognition task, supporting that discriminative scores for incongruent items finally caught up those for congruent items.

Response times:

Here again, go/no-go spoken recognition task was one of the sole experimental task with a speed criterion. Thus, we also conducted statistical analyses on response times. Response times were between 305 and 3000 milliseconds. Generalized mixed model were conducted on raw response times, given that these models are more efficient in satisfying normality assumptions than link-function transformations (Lo & Andrews, 2015).

The first statistical analysis was conducted on immediate and delayed go/no-go spoken recognition tasks. The most adjusted model only included by-participant and by-item random intercept (AIC = 538.51). Neither the inclusion of congruency (AIC = 540, $\chi 2$ (1) < 1, p =.87), nor of the inclusion of session (AIC = 539.5, $\chi 2(1)$ < 1, p =.32) led to a better adjusted model.

A follow-up analysis was performed on immediate and "spontaneous" session. Here, the most fitted model included Session as fixed effect as well as by-participant and by-item random intercepts (AIC = 472, $\chi 2$ (1) = 4.65, p =.03). The main effect of session supported slower response times during the "spontaneous" session compared to the immediate one (respectively, 1947 vs 1858 milliseconds, t = 2.16).

V. 1. 3. 4. Orthographic judgment task

Accuracy:

Statistical analyses were conducted on the remaining 15 participants. Measures of accuracy were analysed through mixed logistic models, given that accuracy was a binary outcome variable. The most adjusted model included by-participant and by-item random intercepts (AIC = 789.5). Neither the inclusion of congruency (AIC= 789.7, $\chi^2(1) = 1.74$, p = .19), nor the interaction between congruency and session (AIC= 792, $\chi^2(1) < 1$, p = .54) led to a better adjusted model, supporting that participants recognized the accurate spelling of German incongruent words as well as the ones of German congruent words (respectively, 69.44 % vs 64.2 %).

Pattern of errors:

For exploratory purpose, we also conducted statistical analyses on the pattern of committed errors to determine whether participants have been misled by grapheme-to-phoneme incongruences.

A 2x3 chi-squared homogeneity test conducted between congruency and the type of errors revealed that the proportion of errors were equally distributed across congruent and incongruent German words (χ^2 (2, 215) = 1.27, p = .53). Interestingly, more than half of the committed errors were made for close orthographic distractors regardless of the congruency (respectively, 58.27% for congruent and 60.33 % for incongruent German words).

V. 1. 3. 5. German spelling generalization task

Accuracy:

Statistical analyses were conducted using mixed logistic models, given that accuracy was a binary outcome variable. Through this experimental task, we explored whether participants were able to generalize letter-to-sound mappings to unlearned German words. In addition, we explored whether there was a switch on the graphotactic rules on which participants relied on before and after exposure to German during learning phase. Thus, given that the session variable (training, immediate and delayed sessions) was ordered, planned contrasts coding was implemented (training vs immediate session, immediate vs delayed session). Here, the most fitted model included Session, Congruency as well as the marginal interaction between Session and Congruency as fixed effects and by-participant, by-item random intercepts (AIC = 1368, $\chi 2$ = 3.77, p = .15). There was a main effect of congruency, with an odds of accurate spelling recognition 2.89 times higher for the congruent pseudowords than for the incongruent ones (respectively, 52.79 % vs 30.43 %, $p < .001$). In addition, a main effect of session was also reported for contrasting between training and immediate German spelling generalization tasks, with an odds of accurate spelling recognition 1.45 times higher for immediate session compared to the training one (respectively, 42.50 % vs 34.72 %, p =.02). However, when contrasting between immediate and delayed testing, the main effect of session did not reach significance (p =.22). There was a marginal interaction between session and congruency for training and immediate German spelling generalization task (p =.07), but not for immediate and delayed ones (p =. 84). This marginal interaction between congruency and session was explored by computing separate models for each modality of the congruency variable. Interestingly, a main effect of session was reported for incongruent pseudowords, with an odds of accurate incongruent spelling recognition 2.04 times higher for immediate German spelling generalization task compared to the training one (respectively, 33.33 % vs 20.56 %, p =.005). For the congruent pseudowords however, no main effect of session was reported (p = .59). In addition, a main effect of congruency was reported for training session (p =.001), with an odds of accurate pseudoword spelling recognition 4.35 times higher for congruent than for incongruent items. Although a significant effect was retrieved for immediate session (p =.02), the odds of accurate spelling recognition was then only 2.38 times higher congruent than for incongruent items, supporting that congruent items were spontaneously easier to recognize, even when participants had no prior exposure to German and its specific letter-to-sound mappings.

For exploratory purpose, we conducted a follow-up analysis to determine whether participants' enhanced recognition for incongruent items was observed for all the six selected grapheme-to-phoneme incongruences or whether it was restricted to some of them. To this end, descriptive analyses were conducted using paired Wilcoxon-signed-rank-test. They showed that immediately after learning, participants exhibited a higher accurate spelling recognition for pseudowords including either the <au> incongruence (respectively, 46.7 % for immediate spelling generalization task vs 6.7% for the training one, W = 72.50, p =.006), or the <ei> incongruence (respectively, 56.7% vs 30 %, W = 32.50, p = .04).

V. 1. 4. Discussion

The main objective of this study was to determine whether the benefit of orthography may be moderated by the degree of incongruent mapping between graphemes and phonemes. In addition, we explored whether the exposure to spoken and written information during learning helped children to transfer the L2 grapheme-to-phoneme correspondence rules to unlearned German (pseudo)words. The data inclusion started with fifth graders attending an orthographic learning method. However, due to the sanitary crisis, the interventions in elementary schools were cancelled before any inclusion of participants in the non-orthographic learning method. For this reason, the potential moderating effect of incongruent mapping between grapheme and phoneme on the benefit of orthography in L2 vocabulary learning could not be assessed, due to the absence of the control group, i.e., fifth graders attending a non-orthographic learning method.

Nonetheless, we explored whether fifth graders performed differently in testing tasks according to the degree of incongruent mapping between grapheme and phoneme. Interestingly, immediately after learning, participants were able to associate the spoken form correctly with its concept for about 19 of the 24 (79.4 %) German words, supporting, once again, that the paired-associate word learning paradigm was efficient to conduct L2 vocabulary learning studies. Again, this confirmed that our experimental setting, i.e., nine exposures to each of the 24 German words, was adapted to induce reliable L2 vocabulary learning among fifth graders.

V. 1. 4. 1. Evidence for a (limited) moderating effect of incongruent letter/sound mappings on L2 vocabulary learning

For two of the three testing tasks, i.e., forced-choice picture recognition task and orthographic judgment task, participants performed equivalently for congruent and incongruent German words. For the go/no-go spoken recognition task however, an interaction between congruency and session was observed, with larger discriminative performance for congruent German words compared to incongruent ones immediately after learning (respectively, 1.61 vs. 1.05). Indeed, fifth graders had a more conservative response strategy, i.e., tendency not to accept the spoken form when it was a word, for incongruent than for congruent German words (respectively, 59.2 % vs. 73.7% of accurate word recognition). For pseudowords however, they performed equivalently for both types of items. The moderating effect of incongruent letter/sound mapping was not retrieved after delay, supporting that fifth graders exhibited comparable discrimination scores for both congruent and incongruent L2 words. It should be mentioned that L1/L2 congruency only impacted performance to the pure phonological task and, thus, reflected the strong interplay between orthography and phonology. Indeed, the presence of orthography during learning contributed to map the spoken form with its written one, in line with the orthographic mapping theory in L1 (see., Ehri, 2014). Thus, the initial encoding of the spoken form relied on the L1 grapheme-to-phoneme correspondences, which was relatively adequate for congruent German words due to their large formal overlap between L1 and L2 GPC. However, for incongruent words, this may have contributed to the fuzzy encoding of the phonological form (mispronounced spoken forms), which in turn may be misremembered. Interestingly, given that participants exhibited comparable discriminative performance after delay, this suggests that the encoding of novel phonological forms may rely on a different time course according to their degree of grapheme-to-phoneme congruency with L1. We will discuss these preliminary results with regards to the ontogenesis model of L2 lexical representation (see., Bordag, Gor, & Opitz, 2021).

Although promising, further data inclusion are required to confirm these results. In addition, the inclusion of a control group, i.e., fifth graders who attend a non-orthographic learning method, may allow us to explore whether the orthographic facilitation is impacted by the degree of grapheme-to-phoneme congruency with L1.

V. 1. 4. 2. Evidence for a (limited) transfer of L2 letter/sound mappings on untrained items

The transfer of the L2 letter/sound correspondence rules has been assessed through a spelling generalization task before and after learning. We reported a marginal interaction between congruency and session. Indeed, before prior exposure to German, fifth graders already exhibited a larger proportion of accurate association between the spoken form and its related written form for congruent pseudowords compared to the incongruent ones (respectively, 49.1 % vs. 22.8 %). As expected, children stemmed on the L1 grapheme-to-phoneme correspondences to infer the accurate written form. This is consistent with the the orthographic skeleton hypothesis (Wegener et al., 2018), according to which children are able to predict the written form associated to a spoken form they heard to, by relying on the statistical orthotactics of their native language. Although restricted to six of the 12 (49.1%) congruent words, this decoding strategy was more efficient for the pseudowords whose letter/sound mapping was congruent with L1 (French) than for incongruent ones. Immediately after exposure to German words during learning, although children still exhibited larger accurate association between spoken and written forms for congruent compared to incongruent (German) pseudowords (respectively, 52.2 % vs. 35.5 %), we only reported an increased performance for incongruent pseudowords. Interestingly, this increased performance was restricted to two of the six types of incongruent grapheme-to-phoneme correspondences with L1, i.e., the bigrams <au> and <ei>. Taken together, these results support a relative acquisition of L2 letter/sound mappings as well as their generalization to unlearned items. However, these observations must be taken carefully, due to the restricted sample size as well as the marginally significant interaction between congruency and session. Further experimental inclusions are required to confirm these observations.

V. 1. 4. 3. Summary

In this study, the cross-linguistic dissimilarities associated with incongruent mapping between graphemes and phonemes has been only reported for the go/no-go spoken recognition task as well as for the spelling generalization task, two experimental tasks that explored the interplay between orthography and phonology in L2. Interestingly, both reported an initial disadvantage of incongruent letter/sound mappings with L1 on the accurate spoken recognition as well as for the accurate association between a spoken form and its related written form. These results provided some evidence that the phonological encoding was initially mediated by orthography through L1 grapheme to phoneme correspondence rules, which led to the creation of a fuzzy L2 phonological representation. We suggested that the encoding of L2 phonological representation relied on a different time course according to the degree of grapheme-to-phoneme congruency, as reflected by the ontogenesis model of L2 lexical representation (see., Bordag et al., 2021, see., General discussion for more details). Further data inclusion is required to confirm these preliminary observations.

In the next study, we will explore the contribution of cross-linguistic similarities conveyed by cognate words on the acquisition of novel vocabulary. The two previous studies focused on learning a foreign language through a traditional learning method. In the third study, we will determine whether learning a foreign language through a linguistic immersion program contributes to a facilitated learning of L3 vocabulary and whether this advantage was modulated by the degree of cross-linguistic similarities conveyed by cognateness.

Chapter VI. Extending the bilingual advantage on L3 vocabulary learning to children attending a linguistic immersion to L2

VI. 1. Study 3: Bilingual advantage in L3 vocabulary acquisition: evidence of a generalized learning benefit among classroom immersion children

VI. 1. 1. Introduction

In the context of a research mobility through an Indoc at the Cognitive psychology lab of the University of Strasbourg, I had the opportunity to conduct an experimental study which led to an accepted publication in Bilingualism: Language and Cognition[8] in September 2021.

The present study explored whether the bilingual advantage in L3 vocabulary learning may be retrieved in children attending a linguistic immersion to foreign language, i.e., German, at school. Whether this learning advantage may be associated with L2/L3 cross-linguistic similarities conveyed by cognate words was of particular interest. Given that this study was not focused on the contribution of orthography on vocabulary learning, a short overview of the literature will be provided above.

As we have seen in Chapter III, bilingualism has been long time associated with enhanced cognitive (executive) functioning (see. Barac et al., 2014), to account for the language switching and for the restricted interference associated with the non-target language in talk. However, recent studies failed to replicate these observations with experimental tasks involving comparable executive functions (see., Antoniou et al., 2019 for review). Despite a controversial impact on cognitive processing, the bilingual advantage has been relatively consistently documented for foreign language learning (and more especially vocabulary learning) in adults compared to monolinguals (Cenoz & Valencia, 1994; Kaushanskaya & Marian, 2009a, 2009b;

[8]Bilingual advantage in L3 vocabulary acquisition: evidence of a generalized learning benefit among classroom immersion children (Salomé, Casalis, & Commissaire, 2021).

Kaushanskaya & Rechtzigel, 2012; Kaushanskaya, Yoo & Van Hecke, 2013; Keshavarz & Astaneh, 2004; Papagno & Vallar, 1995; Sanz, 2000; Van Hell & Mahn, 1997).

Importantly, only half of these studies have adopted an experimental approach and used various word-learning paradigms to account for the bilingual advantage from the onset of L2/L3 vocabulary learning. In most of these studies, learning was either mediated by native language through background translation (Kaushanskaya & Marian, 2009a, 2009b; Kaushanskaya & Rechtzigel, 2012; Valente et al., 2018; see., RHM by Kroll & Stewart, 1994, presented in Chapter II-1) or characterized by a direct mapping with the concept through word-picture learning (Bartolotti & Marian, 2012a; Eviatar et al., 2018; Kaushanskaya et al., 2013; Kaushanskaya et al., 2014). Interestingly, these previous studies mostly focused on L2/L3 phonological learning (as well as its association with semantics), and one study explored the acquisition of L2 novel written forms (see., Bartolotti & Marian, 2018). In addition, none of them explored the contribution of a multimodal exposure to novel words, i.e., spoken and written form associated to their meaning, on the bilingual advantage. The present study will explore this issue by using a paired-associated word-learning paradigm, characterized by the simultaneous presentation of a word pronunciation, spelling and meaning, which was comparable to the learning paradigm used all along this doctoral work.

As presented in Chapter III, the bilingual advantage on L3 vocabulary learning has been consistently reported in adults with a large variability in their bilingual profiles in terms of age of acquisition, i.e., late bilinguals (e.g., Bogulski, Bice, & Kroll, 2019) or early bilinguals (e.g., Kaushanskaya & Marian, 2009a, 2009b), or on the context of L2 acquisition, i.e., environment-based bilinguals (e.g., Kaushanskaya & Marian, 2009a, 2009b) or classroom-based (Kaushanskaya et al., 2012; Van Hell & Mahn, 1997). However, only two studies have been conducted in bilingual children (Eviatar et al., 2018; Kaushanskaya et al., 2014). Indeed, Kaushanskaya and colleagues (2014) explored the bilingual advantage by contrasting learning performance between English monolingual first graders and children attending a dual-classroom immersion to both English and Spanish (on a 20%-80% ratio). They used a learning paradigm in which L3 (pseudo)words were paired with a familiar concept or with an unfamiliar one. As for the testing phase, learning was assessed through a forced-choice picture recognition task, for which participants had to select the picture that was associated with the spoken form they heard to. Classroom-immersion children outperformed their monolingual peers, supporting that the bilingual advantage in L3 vocabulary learning documented in adults may be extended to children.

To account for this bilingual advantage on L3 vocabulary learning, three main hypotheses have been suggested. i.e., enhanced short-term phonological memory (Papagno & Vallar, 1995; van Hell & Mahn, 1997), decreased sensibility to L1 interference (Bartolotti & Marian, 2012b; Kaushanskaya & Marian, 2009b; Meuter & Allport, 1999; Van Assche et al., 2013), and increased phonological discrimination abilities (Kaushanskaya et al., 2009a). Nevertheless, as it has been presented in Chapter III-3, experimental contradictory results have been reported for the two first hypotheses. Indeed, contrary to Papagno and Vallar (1995), who suggested that the bilingual advantage may be associated with larger short-term phonological memory abilities in bilinguals compared to monolinguals, this learning advantage persisted when participants were matched on their phonological memory skills (e.g., Kaushanskaya & Marian, 2009a; Kaushanskaya & Rechtzigel, 2012). In addition, Kaushanskaya and Marian (2009b) reported that bilingual adults still exhibited larger learning performance compared to monolinguals when both spoken and written wordforms were provided during learning phase. Given that this bimodal learning procedure may have confronted participants to incongruent letter/sound mappings, the authors suggested that bilinguals experienced a decreased sensibility to L1 interference compared to monolinguals (Kaushanskaya & Marian, 2009b; see also Bartolotti & Marian, 2012b on cross-language lexical interference). Still, this hypothesis cannot provide any satisfactory explanation for the persistence of the bilingual advantage when learning vocabulary in a language with a different written script (see., Kaushanskaya & Marian, 2009a). They, thus, suggested that the bilingual advantage may be accounted by the enhanced phonological discrimination skills, given that bilinguals are accustomed to deal with two different phonological systems. This may facilitate the acquisition of L3 novel phonological forms.

To these three complementary hypotheses, we also postulated that the bilingual learning advantage might be influenced by linguistic properties of words and thus, relied more precisely by the cross-linguistic similarities conveyed by cognate words. As a reminder, a cognate word is defined as a cross-linguistic translation equivalent that share a partial-to-complete orthographic overlap as well as an incomplete phonological overlap between languages. In this thesis, we dissociate identical cognate words (ex., baby in English and das Baby in German) from non-identical cognate words (ex., apple and der Apfel). Interestingly, as documented in Chapter II-2.1.2, the cognate facilitation effect has been well-documented in L2 word learning among adults (De Groot & Keijzer, 2000; Rogers, Webb & Nakata, 2015; Valente et al., 2018; Van Hell & Mahn, 1997) as well as among children (Comesaña et al., 2012b; Comesaña et al., 2019; Tonzar et al., 2009). Interestingly, Bartolotti and Marian (2017a) have reported a relative transfer from L3 to L1/L2 during learning that was driven by orthotactic probabilities. Indeed, given that they share a large overlap in written forms, they may lead to enhanced learning performance among bilinguals (see., Bartolotti & Marian, 2017a, 2017b). Nevertheless, due to the incomplete overlap in spoken forms, the cognate words may also confront children to conflicting letter/sound mappings with L1. Thus, it remains unsure whether learning L2/L3 cognate words may be facilitated among classroom-immersion children compared to monolingual children, a hypothesis to which there is no experimental evidence yet.

The present study explored whether the beneficial contribution of bilingualism might be retrieved in L3 vocabulary learning among children attending a dual-language immersion to foreign language and whether this learning advantage was modulated by the cross-linguistic similarities conveyed by cognate words. To do so, we contrasted the learning performance of 44 English words (two lists of 22 words) among two groups of fifth graders, including French monolingual children as well as children attending a dual-language immersion to German as a foreign language. We used a paired-associate learning paradigm, for which participants were simultaneously exposed to both L2/L3 spoken and written wordforms associated to their related concept. The dual-language immersion program was characterized by a balanced teaching time in both languages, i.e., half time in French (L1) and half time in German (L2), since preschool. Additionally, we were also interested in the locus of the bilingual advantage. Thus, we wondered whether this learning advantage was restricted to the cross-linguistic similarities conveyed by cognate words. In the learning lists, half of the English words were L2-German - L3-English non-identical cognate words (e.g., Apfel – apple) while the remaining half only included English non-cognate words (e.g., fork).

In light with the results of Kaushanskaya et al. (2014), we expected a rather general bilingual advantage, i.e., retrieved for all English words. Nonetheless, this general advantage might be reinforced by the presence of L2/L3 cognate words. If so, this would indicate that L2 was activated early during L3 vocabulary learning, and in children considered as emergent bilinguals.

Word learning performance were assessed immediately as well as one week after learning by using the same three experimental tasks as for the two previous studies, i.e., forced-choice picture recognition task, go/no-go spoken recognition task, and orthographic judgment task. Consistent with Kaushanskaya et al. (2014), we expected that classroom-immersion children may outperform their monolingual peers on the forced-choice picture recognition task. In addition, a bilingual advantage on L3 vocabulary learning was expected for both orthographic and phonological learning. Furthermore, the learning of L3 written forms may be even more facilitated among classroom-immersion children due to the large form overlap with L2. For phonological learning however, it is still unclear whether the bilingual advantage may be impacted by the cross-linguistic similarities conveyed by cognate words, given that phonology is less stable across languages (see., Marian et al., 2012).

VI. 1. 2. Methodological part

VI. 1. 2. 1. Participants

Eighty-nine fifth-graders were recruited from two schools in the Grand Est region, France. All were French native speakers. Among them, 41 children (mean age = 10.42 years; SD = .24) had been attending a classroom-immersion program to German since kindergarten. Attending this bilingual immersion program did not depend on children's academic performance or on any suggestion of the headmaster, but rather on familial and cultural history. Indeed, many families make this decision, because of the cross-border situation with Germany and the existence of a local patois, Alsatian, which is now only spoken by some elders from this region of France and bears some similarities with German. These linguistic immersion classes were conducted in traditional elementary schools and teaching was carried out in German for half of the school time. Thus, classroom-immersion children had a robust exposure to German as a L2. The remaining 48 participants (mean age = 10.25 years; SD = .24) were monolinguals enrolled in the same elementary schools as the immersion group. Despite no measure of parents' socio-economic status (SES), we expected no such differences in SES within and between groups, as all participants came from the same catchment area. Eighteen participants (11 monolinguals vs. 7 immersion children) did not complete all sessions and were removed, leaving 34 classroom-immersion children and 37 monolinguals for analysis; the two groups were matched on chronological age (t (69) = -1.06, p =.29). Importantly, children had no exposure to English either at school, or at home before the study. All children and their parents signed a written consent form for this study, which was approved by the Ethics and

Research Committee of the University of Strasbourg (accreditation number: Unistra/CER/2020-14).

Cognitive and language control tests:

Participants' abilities in French were assessed using standardized tests to ensure that any difference between groups were not attributed to better general cognitive or linguistic skills of the classroom-immersion children. Non-verbal and verbal intelligence were assessed respectively through the colored progressive RAVEN matrices (Raven, 1981) and the vocabulary subtest of WISC IV (Wechsler, 2005) that requires participants to define orally a list of French words with decreasing frequency and increasing difficulty. Phonological-short term memory was controlled through the pseudoword repetition task subset of the NEPSY II (Korkman, Kirk & Kemp, French adaptation ECPA, 2012) due to its correlation with vocabulary learning (Gupta et al., 2003). In addition, given our interest for the contribution of orthography and phonology on learning novel words, we also measured several L1-related linguistic skills. Reading accuracy and fluency were measured by using the Alouette task (Lefavrais, 1967; 2005), which consists in reading aloud a French text composed of unpredictable words within three minutes. Phonological awareness was assessed with the phoneme deletion subset of the EVALEC (Sprenger-Charolles et al., 2005). Finally, German (L2) expressive vocabulary was assessed using a French-English translation task, adapted to German (Casalis et al., 2015), to ensure that classroom-immersion children exhibited a larger L2 vocabulary size compared to monolinguals. Participants' scores on these tests are presented in Table 25. Independent sample t-tests were conducted to ensure that participants were matched on language and cognitive tests. While classroom-immersion children outperformed monolinguals in the pseudoword repetition task (p =.05), groups were matched on all other cognitive and language tasks (all *p-values* >.10). Importantly, we also checked that the classroom-immersion group knew the German translations of the English material to be learned by asking them to complete a picture naming task - using the picture material used in the learning sessions - in German (L2). If no answer was provided, a German forced-choice recognition task was performed, in which participants had to choose the correct form corresponding to the picture, between three spoken items. These tasks showed that the classroom-immersion children already knew 85 % (about 37.4 out of the 44 German words) of the German equivalents[2] on average. Therefore, the German translation equivalents of both L2/L3 cognate and non-cognate English words were already known by classroom-immersion children.

Table 25. *Summary of the participants' performances to cognitive and linguistic background tasks.*

	Classroom-immersion		Monolingual		*t*-test	*p*-value	Cohen's d
	M	SD	**M**	SD			
Reading fluency	385.20	83.45	352.50	92.79	1.54	.13	
Reading accuracy	96.90	1.42	96.28	2.41	1.29	.20	
Phon. deletion (/12)	10.97	1.09	10.97	1.27	0.01	.99	
NWRT (/40)	36.39	3.20	34.53	3.89	2.15	.04	.52
RAVEN matrices (/36)	26.50	4.00	26.05	5.73	0.37	.71	
L1Vocabulary (/68) (WISC-IV)	37.24	4.19	35.02	7.34	1.33	.19	
L2 Vocabulary (%)	54.62	24.62	6.12	6.48	10.95	<.001	2.85

Note—Reading measures were obtained at the Alouette test (Lefavrais, 1967; 2005): Reading fluency scores reflect the number of words that would have been read in three minutes (reading fluency score higher than 265 means that the participant have read the whole text in less than three minutes); Reading accuracy was calculated by multiplying by 100 the ratio between the number of words read accurately compared to the number of words read; Phon. Deletion: phoneme deletion subset of the EVALEC (Sprenger-Charolles et al., 2005); NWRT: Nonword repetition task subtest of NEPSY II (Korkman et al., French adaptation ECPA, 2012) and assessed short-term phonological memory skills; RAVEN matrices were used as a measure of non-verbal reasoning skills (Raven, 1981); L1(French) Vocabulary subtest of Wechsler Intelligence Scale for Children (WISC IV; Wechsler, 2005); L2 (German) Vocabulary test was assessed using a French-English translation task, adapted to German (Casalis et al., 2015) .

VI. 1. 2. 2. Learning and testing phases

This study was split into two learning sessions and four testing sessions. Each learning session was immediately followed by a testing session. A delayed testing took place one week after each learning session. The second learning session took place two weeks after the first one. The experimental design is illustrated in Figure 8. Both learning and testing sessions took place in elementary schools.

Figure 8. *Organization of the learning and testing sessions for Study 3.*

Day 1:

- Learning session 1
- Immediate testing session:
  - Forced-choice picture recognition task
  - Go/no-go spoken recognition task
  - Orthographic judgment task

Day 7:

- Delayed testing session:
  - Go/no-go spoken recognition task (spontaneous session)
  - Forced-choice picture recognition task
  - Go/no-go spoken recognition task (delayed session)
  - Orthographic judgment task

Day 15:

- Learning session 2
- Immediate testing session:
  - Forced-choice picture recognition task
  - Go/no-go spoken recognition task
  - Orthographic judgment task

Day 22:

- Delayed testing session:
  - Go/no-go spoken recognition task (spontaneous session)
  - Forced-choice picture recognition task
  - Go/no-go spoken recognition task (delayed session)
  - Orthographic judgment task
- Cognitive and linguistic background tasks

VI. 1. 2. 2. 1. Learning phase

Stimuli. Forty-four English words were selected from the SUBTLEX-US-database (Brysbaert & New, 2009). The English words were between three and eight letters long (mean = 4.76, SD= 1.2). Half of these words were English-German non-identical cognate words (e.g., swan - Schwan). The other half were non-cognate English words. The words were selected according to their concreteness and imageability to ensure participants would directly retrieve the concept associated with the picture. We ensured that they were highly frequent in German, using lexical frequencies provided for native German children speakers by the childLex-database (Schroeder et al., 2015) and by asking participants' teachers to determine whether the German translation equivalents were already known by their students (in both written and spoken modalities). According to them, the German words were already known by the participants (5.78 for the spoken form and 5.22 for the written form on a 6-point scale). The learning material is available in Appendices, please see Appendix 16.

Independent sample t-tests showed that English-German cognate words and English non-cognate words were matched on several variables in English: lexical frequency (p =.89), orthographic (p =.28) and phonological length (p =.66), concreteness (p =.45) and imageability (p =.18). Furthermore, minimal bigram frequencies, as well as cross-language orthographic and phonological similarities of selected English words with French and German were estimated by using CLEARPOND database (Marian et al., 2012). Learning material was matched on minimal bigram frequency (p=.20) as well as on the frequency of their German translation equivalents (p =.42). We reported the degree of orthographic and phonological overlap with German translation equivalents for all items by using the Orthographic and the Phonological Levenshtein Distance, respectively, which were calculated using the vwr-package (Keuleers, 2013) on R-Software (R Core Team, 2017); the phonemes were transcribed into the phonetics alphabet using a X-SAMPA converter. Cognate English-German words exhibited a smaller orthographic (M =2.36; SD= .85) and phonological distance from German (M = 3.32; SD = 1.9) compared to the English non-cognates (M =5.32, SD= .84, and M = 6.64, SD = 1.6, for orthographic and phonological distance, respectively, both *p-values* <.001).

A set of corresponding black-and-white pictures were selected from the MULTIPIC-database (Duñabeitia et al., 2018). Each selected word was pronounced by two English native speakers and recorded using AUDACITY software (Team, 2015) to ensure that participants heard different speakers for each learning and testing session. The audio stream was normalized across each word and we performed a noise attenuation procedure.

Procedure. Twenty-two English words were learned during each learning session. The order of the two learning sessions was counterbalanced across participants and, within each session, the presentation order of these words was randomized among participants. Before learning, we ensured that pictures were recognized by participants using a French naming task. We also ensured that they did not already know their English translation equivalents. For each trial, the spoken and written form of an English word were provided by the computer and associated with their related picture. Each English word was visually presented in a random order for at least three seconds (with no time limit) and participants were then allowed to move to the next word. The spoken information was only displayed once for each trial. Thus, children were exposed nine times to each English word during the learning session. This ensured a significant exposure to the learning material. Participants were exposed to both speakers for each item, as a switch occurred every three repetitions. Learning sessions lasted between 20 and 35 minutes long.

VI. 1. 2. 2. 2. Testing phase

Both the immediate and the one-week delayed testing phases comprised three computerized experimental tasks, i.e., a forced-choice recognition task, a go/no-go auditive recognition task and an orthographic judgment task. Testing material is available in Appendices, please see Appendix 17 for the forced-choice recognition task, Appendix 18 for the go/no-go auditive recognition task and Appendix 19 for the orthographic judgment task. These tasks were displayed in the order presented above for immediate and one-week delayed testing. However, the delayed session started with an additional 'spontaneous' go/no-go auditive recognition task to assess participants' recognition performance with no re-exposure to the spoken material. The speaker's voice was switched after each experimental task. Immediate and one-week delayed testing lasted between 25 to 45 minutes including experimental tasks and linguistic and cognitive background tests.

Forced-choice recognition task:

For each trial, four pictures were presented simultaneously on the computer screen while participants heard one of the learned words in spoken form. Using the computer mouse, participants had to select the picture corresponding to the spoken English word, presented alongside three distractive pictures chosen among those used in the same learning phase. The position of the target word and that of the distractive pictures was randomized across sessions. For the same experimental item presented during the immediate and delayed sessions, two out of three distractive pictures were identical. One of them was substituted by another one to avoid familiarization with the distractive pictures. Accuracy was recorded for each trial.

Go/no-go auditive recognition task:

Stimuli. Besides the 44 learned English words, two lists of 44 pseudowords were constructed using WUGGY software (Keuleers, & Brysbaert, 2010). They were close phonological distractors to the learning material (one phoneme different from the real words, like *furk* for the item *fork*). The same two native speakers pronounced the word and its corresponding pseudoword to ensure overall comparable pronunciation of the two items (and accent). The first list of pseudowords was used for immediate and delayed testing, whereas the second one was displayed for the spontaneous go/no-go task presented at the start of the delayed session.

Procedure. Participants were instructed that, for each trial, an item (word or pseudoword) would be presented in the headphones only. Children had to press the button as fast as possible when they recognized a learned English word and to refrain from giving any response when the spoken form was a pseudoword. The up-coming items were displayed immediately after pressing the Space key or after a three-second delay. This response time interval allowed sufficient time for participants to produce an answer. Accuracy and response times were recorded for each trial. Contrary to the immediate testing, two go/no-go auditive recognition tasks were conducted during the delayed testing session further called as delayed and spontaneous go/no-go auditive recognition tasks. The delayed go/no-go task was presented at the same time in the testing sequence as for the immediate testing and thus included the same pseudowords. The spontaneous one however was presented at the start of the one-week delayed testing and included novel pseudowords, to prevent any familiarization effect to the spoken pseudowords for the delayed go/no-go task. Through this experimental design, we explored whether the bilingual advantage for spoken discriminative performance could persist spontaneously after delay, without re-exposure to spoken material. Nonetheless, the bilingual advantage could possibly emerge, only if re-exposure to spoken material, i.e., through the experimental tasks, was provided in similar conditions to those of the immediate session.

Orthographic judgment task:

Stimuli. Three types of distractors were created for each of the 44 experimental stimuli: close and distant orthographic distractors, and phonological distractors. The close orthographic distractors were created by a one-letter transposition (horse-hosre) when possible, or by a one-letter substitution (duck-dulk). The distant ones shared a small orthographic overlap with the target word. This overlap was restricted to one-to-three graphemes (horse-hopan), depending on word size. The phonological distractors were homophonic[3] to the real words when using French grapheme-to-phoneme correspondences (duck-deuque). We designed the orthographic judgment task this way in order to identify whether and to what extent participants paid attention to the English spellings during the learning phase.

Procedure. The target word was presented alongside its three distractors on each corner of the screen. Participants were asked to select the correct written transcription for each of the learned English words among the four different stimuli displayed. For each session, the position of the various written transcriptions was randomized. Accuracy was recorded as well as the pattern of distractive errors, i.e., the selection of one of the distractive spellings.

VI. 1. 3. Results

VI. 1. 3. 1. Data analysis

Accuracy was analyzed for each experimental task. Although response times were recorded for each task, we analyzed them only for the go/no-go auditive recognition task, which was the only task with a speed criterion and statistical analyses on response times are available in Supplementary material; please see Appendix S6. Statistical analyses were conducted for each experimental task following the same procedure. Mixed model analyses were conducted on R software (R Core Team, 2017), using lmer and glmer functions from the lme4 package (Bates et al., 2015). Indeed, through these models, the potential variability across participants, items and schools was considered for each experimental task through random intercepts: the random effect structure model included at least random intercepts for participants and for items. The modelling of random effects was a compromise between the maximal random structure (Barr et al., 2013), in order to alleviate the lack of model convergence, and the parsimonious one (Bates et al., 2015).

For each experimental task, we then adjusted the model by including the fixed effects: session (immediate vs. delayed), group (classroom-immersion vs. monolingual children) and cognateness (L2/L3 cognate vs. non-cognate words). We used a model comparison approach by progressively entering each fixed main and interaction effects, by comparing each model with the previous one, and eventually including the variables that led to the most adjusted model. At each step, Chi-squared were calculated to test the significant adjustment differences across models; p-values were determined using the lmertest package (Kuznetsova et al., 2017). This led to the selection of the most adjusted model, i.e., with the smallest Akaike Information Criteria (AIC). This statistical approach seemed very relevant, given that the existing scientific literature did not give us a clear idea of how some of our variables would contribute or not to learning performance. We used treatment contrasts for these analyses. In the event of interaction, we conducted post-hoc analyses including a Bonferroni correction. The best fitted model for each task is presented below. Furthermore, descriptive statistics for all three experimental tasks are reported in Table 26. Given that participants were not matched on their phonological short-term memory skills, we conducted statistical analyses both with and without a non-word repetition task as a covariate. They did not reveal any significant statistical difference, thus, we chose to present the analysis with no covariate to minimize the number of factors included in the models.

Table 26. *Participants' performance for all three experimental tasks according to Group (classroom-immersion vs monolingual children), cognateness (cognate vs. non-cognate words) and session (immediate vs. delayed sessions; and vs. spontaneous session).*

	Classroom-immersion children				Monolingual children			
	Cognate		Non cognate		Cognate		Non cognate	
	M	SD	**M**	SD	**M**	SD	**M**	SD
Forced-choice recognition task (accuracy in percent)								
Immediate	95.3	8.6	92.8	11.3	89.8	12.2	88.8	15.4
Delayed	93.7	15.5	92.8	17.7	84.3	16.6	80.1	18.5
Go no go auditive recognition task (discrimination score)								
Immediate	1.54	0.67	1.24	0.58	1.36	0.73	1.13	0.56
Spontaneous	1.50	0.65	1.29	0.67	1.10	0.57	0.87	0.58
Delayed	1.88	0.63	2.01	0.97	1.42	0.42	1.39	0.67
Orthographic judgment task (accuracy in percent)								
Immediate	83.9	16.3	79.9	18.2	81.6	16.3	79.9	19.4
Delayed	85.9	16.0	80.2	17.9	82.2	17.0	82.2	15.4

Furthermore, we needed to ensure that the classroom- immersion group was familiar with the German translations of the cognate material learned in order to properly investigate any potential cognate effect. Unlike to the teacher's questionnaire, we found that some German words were unknown for the classroom-immersion group, as indicated by the German naming post-test measure. Given that classroom-immersion children experienced difficulties in spontaneously naming the German translation equivalents, the identification of unknown cognate and German translation equivalents words was conducted on the German recognition task. Therefore, we removed the unknown German translation equivalents, whether there were cognate words or not, corresponding to the removal of 15% of the remaining data for all the experimental tasks[4]. The average number of known items was 18.5 out 22 (84%) for the cognates and 19 out 22 (86%) for the German translation equivalents. Statistical analyses were conducted on known (cognate and non-cognate) items but as they did not reveal any significant statistical differences with the analyses conducted with all the items, we only report the latter one, to keep a maximum number of items in our analyses. Importantly, given the lack of previous conducted meta-analyses, we could not estimate our a-priori statistical power. Nonetheless, following the recommendations of Brysbaert and Stevens (2018), the statistical power depends on the total number of observations, i.e., the number of participants and of items, with at least 1600 observations by group (40 participants x 40 observations), as data are not averaged when using generalized mixed model analyses. Here, for each experimental task, there was at least 2992 observations by group, supporting a rather high statistical power.

VI. 1. 3. 2. Forced-choice recognition task

The accuracy data were analyzed using mixed logistic models since the dependent variable is binary. The best-fitted model included Session, Group, interaction between Session and Group as fixed effects, and by-participant, by-item and by-school random intercepts (AIC=

3465, $\chi^2(1) = 8.25$, $p = .004$, OR= .57). This model and its parameter estimates are reported in Table 27.

Table 27. *Summary of the logistic mixed model analysis for variables predicting accuracy in forced-choice recognition task.*

Predictors	Estimate	SE	95% CI		*t*-value	*p*-value
			LL	UL		
Intercept	3.618	0.295	3.040	4.197	12.265	<.001
Session (immediate vs delayed)	-.147	0.156	-.452	.158	-0.943	.35
Group (classroom-immersion vs monolinguals)	-.804	0.360	-1.510	-.098	-2.233	.03
Session x Group	-.567	0.192	-.944	-.190	-2.948	.003

Model = glmer (forced_choice$Accuracy~Session+Group+Session:Group+(1|participant) + (1|item)+(1|school), data=forced_choice,family=binomial(link=logit),control=glmerControl(optimizer="bobyqa"))

Higher accurate performances were observed among classroom-immersion participants compared to monolinguals (respectively, 94% vs. 86%, t (3123) = 10.27, $p < .001$, Cohen's d = .26). However, the proportion of correct associations between picture and spoken form significantly decreased after delay among the monolingual children (respectively, 89% vs. 82%, t (1627) = 6.96, $p < .0001$, $d = 0.17$), whereas the performance of classroom-immersion children remained stable across sessions (respectively, 94% vs. 93%, t (1495) = 1.04, $p = .30$). The inclusion of the cognate status factor did not fit the model better to the data (χ^2 (1) = 2.62, p = .11).

VI. 1. 3. 3. Go / No-go auditive recognition task

Discrimination score:

Nine participants (four classroom-immersion and five monolingual children) did not complete all go/no-go tasks and were removed from the analysis. Thus, the statistical analyses were conducted on the 62 remaining participants, i.e. 30 classroom-immersion children and 32 monolinguals. Surprisingly, our participants made a large amount of false recognition for five pseudowords (hirse, hulmet, swun, upple and wetch). After having listened to them again, we realized they were phonologically too ambiguous for being recognized by participants and, thus, were removed from the analysis. In total, the summed deleted data reached 3.76% for this task. The proportion of accurate recognition for words and rejection for pseudowords according to group and session (immediate, delayed, and "spontaneous") is presented in Table 28. The nature of the go/no-go auditive recognition task could led to potential response strategies, i.e. pressing the space key for all items or for none, thus, we calculated d' score for sensibility further termed as discrimination score in this article. Hit rates and false alarms were calculated for each participant for both the cognate and non-cognate items. Discrimination scores were obtained by the difference between the z-transformed distribution of correct word identification (hits) and those of the incorrect acceptance of pseudowords (false alarms). A preliminary transformation was conducted on the extreme recognition scores, using Macmillan & Kaplan's (1985) requested transformation. Scores equal to 1 were transformed following the (*n-0.5/n*) equation (with *n* defined as the number of items). Null scores were recalculated using the (*0.5/n*) correction.

Table 28. *Summary of the accurate recognition of words and pseudowords in the go/no-go auditive recognition task according to group (classroom-immersion vs. monolingual children) and session (immediate vs. spontaneous vs. delayed).*

	Classroom-immersion children				Monolingual children			
	Cognate		Non cognate		Cognate		Non cognate	
	M	SD	**M**	SD	**M**	SD	**M**	SD
Words (in percent)								
Immediate	79.6	13.2	70.6	14.1	74.7	15.2	68.3	13.2
Spontaneous	80.7	9.7	71.7	17.0	72.1	17.6	63.1	17.0
Delayed	87.4	9.3	79.2	16.8	83.5	12.6	77.5	15.1
Pseudowords (in percent)								
Immediate	70.9	15.2	72.4	12.6	70.9	15.2	71.7	14.6
Spontaneous	69.2	17.6	71.7	12.4	64.1	14.8	67.8	17.2
Delayed	72.1	13.9	79.2	16.8	61.8	11.1	66.8	18.7

Discrimination scores were analyzed for immediate and delayed sessions using generalized mixed models. Due to the calculation of the discrimination scores, the random structure included by-participant random intercepts. First, only immediate and delayed scores were considered in the analysis. This design gave us a measure of discriminative performance after a one-week delay, for the go/no-go task conducted in the same condition for immediate and delayed testing. The best-fitted model included Session (immediate vs delayed session), Group, as well as the interaction between Session and Group, Cognateness and the interaction between Session and Cognateness as a fixed effect and by-participant random intercepts (AIC= 417, χ^2 (1) = 8.08, p = .005). Despite no significant differences in discriminative performance across group in immediate testing (t (122) = 1.27, p = .21), classroom-immersion children outperformed their monolingual peers after delay (respectively, 1.95 vs 1.41, *t* (122) =4.34, *p*<.001, Cohen's d =.78). Furthermore, classroom-immersion children exhibited larger discriminative performance in delayed compared to immediate testing (respectively, 1.95 vs 1.39, *t* (118) =4.18, *p*<.001, Cohen's d =.76), whereas the monolinguals did not (respectively, 1.41 vs 1.21, *t* (126) =1.54, *p*=.13). Surprisingly, participants exhibited larger discriminative performance for cognate items compared to non-cognate ones but restricted to immediate testing (respectively, 1.45 vs 1.18, *t* (122) =2.35, *p*=.02, Cohen's d =0.42). Indeed, no difference in discriminative performance was retrieved between cognate and non-cognate words in delayed session (respectively, 1.64 vs 1.69, *t* (122) =-0.37, *p*=.71). Furthermore, larger discrimination scores were retrieved for non-cognate words in delayed session compared to the immediate one (respectively, 1.69 vs 1.18, *t* (122) =3.67, *p*= 0004, Cohen's d =0.66). The interaction between Group and Cognateness (AIC= 419, χ^2 (1) = 0.16, *p* = .69), as well as the one between Group, Session and Cognateness did not reach significance (AIC= 420, χ^2 (1) = 1.10, *p* = .29). The parameter estimates for this model are reported in Table 29.

Table 29. *Summary of the mixed linear regression analysis for variables predicting discrimination scores in the go/no-go auditive recognition task in the analysis including immediate and delayed sessions.*

Predictors	Estimate	SE	95% CI		*t*-value	*p*-value
			LL	UL		
Intercept	1.922	0.114	-0.415	-0.159	16.836	< .001
Session	-0.398	0.098	-0.001	0.248	-4.075	.001
Group	-0.519	0.150	-0.295	0.036	-3.460	.001
Cognateness	0.049	0.079	0.182	0.383	0.627	.532
Group x Session	0.392	0.112	0.053	0.338	3.513	.001
Cognateness x Session	-0.317	0.112	-0.255	0.023	-2.843	.005

Model=lmer(go_nogo$Discrimination_score~Session+Group+Cognateness+Group:Session+Cognateness:Session+(1|participant),data=go_nogo)

Follow-up analyses. The bilingual advantage emerged after delay, with classroom-immersion children outperforming their monolingual peers for discriminative scores. We further conducted a statistical analysis to compare discriminative performance between immediate and “spontaneous” session. As a reminder, the “spontaneous” go/no go task took place at the beginning of the delayed testing to determine whether the bilingual advantage would arise in the absence of re-exposure to the spoken material. Discriminative differences between the immediate and the “spontaneous” go/no-go on tasks were investigated through a linear mixed model.

Here, the best-fitted model included Session (immediate vs. spontaneous session), Cognateness, Group, and the interaction between Session and Group as fixed effects and by-participant random intercepts (AIC =410, $\chi^2(1) = 5.36$, $p = .02$). This model and its parameters are presented in Table 30. Discriminative scores were higher among the classroom-immersion children compared to the monolingual ones, but for spontaneous session only (respectively, 1.40 vs 0.98, t (122) = 3.66, p=.0004, Cohen’s d =.66). However, monolinguals’ discriminative performance decreased significantly in the spontaneous session compared to the immediate one (respectively, 0.98 vs 1.24, t (126) =2.37, p=.02, Cohen’s d =.42) whereas classroom-immersion children did not exhibit differences in discriminative performance between immediate and spontaneous sessions (respectively, 1.39 vs 1.40, t (118) =-.03, p=.97). Once again, larger discriminative scores were retrieved for cognate compared to non-cognate words (respectively, 1.37 vs 1.13, t (246) =3.00, p=.003, Cohen’s d =0.37).

Table 30. *Summary of the mixed linear regression analysis for variables predicting discrimination scores in the go/no-go auditive recognition task in the analysis including immediate and spontaneous sessions.*

Predictors	Estimate	SE	95% CI		*t*-value	*p*-value
			LL	UL		
(Intercept)	1.513	0.102	1.313	1.712	14.867	< .001
Session	0.004	0.082	-0.156	0.165	0.05	.96
Cognateness	-0.244	0.057	-0.356	-0.133	-4.292	<.001
Group	-0.125	0.137	-0.393	0.143	-0.918	.36
Group x Session	-0.264	0.114	-0.487	-0.040	-2.313	.02

Model = glmer(go_nogo$Discrimination_score~Session+Cognateness+Group+Group:Session+(1|participant), data=go_nogo)

Summary. Classroom-immersion children exhibited higher discriminative scores than the monolinguals at delayed testing. This discriminative difference was retrieved, even when participants were not re-exposed to the spoken and written material. Nonetheless, the bilingual advantage was reinforced after re-exposure to the spoken material.

VI. 1. 3. 4. Orthographic judgment task

Three classroom-immersion children did not complete the whole task and were removed from the analysis. Furthermore, response files from three monolingual children were corrupted and were not included for the analysis. Thus, analyses were conducted on the remaining 65 participants, including 31 classroom-immersion and 34 monolingual children. The summed deleted data amounts 9% for this task.

Accuracy. Measures of accuracy were analyzed through mixed logistic models, given that this variable is binary. The best-fitted model included Session, Cognateness, Group and the interaction between Cognateness and Group as fixed effects, as well as by-participant and by-item random intercepts (AIC = 4633, $\chi^2(1) = 5.21$, $p = .02$, OR = 1.39). The parameter estimates are reported in Table 31. Recognition performance remained stable between immediate and delayed session (respectively, 81.3 % vs 82.6 %, t (5718) = 1.3, p=.19). Post-hoc analyses showed that classroom-immersion children exhibited a higher recognition rate for cognate words compared to non-cognates (respectively, 84.9 % vs. 80.1 %, t (2694) = 3.33, p = .001, d = 0.10), whereas monolingual children did not (respectively, 81.9 % vs 81.1 %, p =.57). Furthermore, despite no significant differences between groups for non-cognate words (t (2822) = -0.69, p = .49), classroom-immersion children outperformed monolinguals for cognates (t (2857) = 2.17, p = .03, d = 0.14).

Table 31. *Summary of the logistic regression analysis for variables predicting accuracy in the orthographic judgment task.*

Predictors	Estimate	SE	95% CI		*z*-value	*p*-value
			LL	UL		
Intercept	2.315	0.273	1.781	2.851	8.48	<.001
Session	-0.111	0.076	-0.259	0.037	-1.47	.14
Group	-0.404	0.301	-0.995	0.186	-1.34	.18
Cognateness	-0.429	0.246	-0.912	0.053	-1.74	.08
Group x Cognateness	0.350	0.152	0.052	0.648	2.31	.02

Model=glmer(ortho_judgment$Accuracy~Session+Group+ Cognateness+ Group: Cognateness+(1|participant)+(1|item), data=ortho_judgment, family=binomial(link=logit), control=glmerControl(optimizer="bobyqa"))

VI. 1. 4. Discussion

The present study explored the potential benefit of linguistic immersion in a foreign language on L3 vocabulary learning, as evidenced among bilingual adults (see., Kaushanskaya & Marian, 2012a, 2012b). Additionally, we wondered whether this learning advantage might be generalized to all items or whether it was restricted by the cross-linguistic similarities conveyed by cognate words, an issue little addressed so far. Indeed, most alphabetic languages share a large amount of cognate words. L2 on L3 vocabulary learning. Therefore, cumulated experience with close related languages might help children to learn novel vocabulary. To this purpose, we contrasted the learning performance of English words between classroom-immersion fifth graders and monolingual children, whose exposure to foreign language remained quite limited (traditional foreign language learning at school). In addition, we also compared whether classroom-immersion children exhibited larger learning performance for L2/L3 (non-identical) cognate words compared to non-cognate words. Importantly, we ensured that the selected English words did not share any orthographic nor phonological overlap with participants' native language, i.e., French, to minimize effect of L1/L3 typology on learning performance. Indeed, Schepens, Van der Silk and Van Hout (2016) have documented a larger influence of L1 on L3 rather than the L2/L3 typology, regardless of the interlinguistic distance.

VI. 1. 4. 1. Evidence of a generalized bilingual advantage on L3 vocabulary learning

The results revealed that classroom-immersion children outperformed their monolingual peers on two of the three experimental tasks, i.e., forced-choice spoken recognition task and go/no-go spoken recognition task. For the orthographic judgment task however, the bilingual advantage was only reported for cognate words. Indeed, there was no significant difference in written word recognition between classroom-immersion and monolingual fifth graders for non-cognate words. Still, we did not report any significant interaction between group (classroom-immersion vs. monolingual fifth graders) and cognateness (non-identical cognate vs. non-cognate words), suggesting that the bilingual advantage was rather generalized to all items among classroom-immersion children. In addition, this bilingual advantage persisted after a one-week delay. Still, the monolingual children were able to correctly associate a spoken form to its related concept for about 39 of the 44 (89%) English words, suggesting that participants reached a relatively high learning after nine exposure to the English words, consistent with the previous results reported in Study 1c. These results are particularly consistent with the lexical quality hypothesis (Perfetti & Hart, 2002), showing once again that the multimodal sources of information displayed during learning were sufficient to induce a robust vocabulary learning. Importantly, our results are consistent with the two previous studies that reported a bilingual advantage on L3 vocabulary learning in children attending a linguistic immersion to L2 (see., Eviatar et al., 2018; Kaushanskaya et al., 2014). Nonetheless, to our knowledge, this is the first study that explored the bilingual advantage on L3 vocabulary learning on both spoken and written modalities by using a paired-associate learning paradigm.

VI. 1. 4. 2. Evidence for a facilitated L3 phonological learning among classroom-immersion children

Despite no cognate facilitation on L3 phonological learning, we still reported a bilingual advantage on the acquisition of L3 spoken forms. Indeed, classroom-immersion children outperformed their monolingual peers in the go/no-go spoken recognition task immediately after learning (respectively, 1.39 vs. 1.25). Raw data showed that both groups performed equivalently for pseudowords (71.7 % vs. 71.3 %), but higher word recognition was retrieved among classroom-immersion compared to monolingual children (respectively, 75.1 % vs. 71.5 %). This learning advantage persisted after delay, even without any re-exposure to the spoken material (respectively, 1.40 vs. 0.99), given that monolinguals experienced some decay in both accurate word recognition (67.6%) and correct rejection for pseudowords (66%). Interestingly, although both groups experienced a benefit of re-exposure to the spoken material, classroom-immersion children still outperformed their monolingual peers (respectively, 1.95 vs. 1.41). This is consistent with the bilingual advantage on L3 phonetic learning evidenced in adults (see., Antoniou, Liang, Ettlinger, & Wong, 2015) and the bilingual advantage reported for classroom-immersion children may be explained by the fact that children had to deal with two phonological systems early in life.

VI. 1. 4. 3. Evidence for a limited cognate facilitation on the bilingual advantage

In this study, the bilingual advantage was only modulated by the cross-linguistic similarities conveyed by cognate words for the orthographic judgment task. Interestingly, this was the only pure orthographic task, i.e., for which no additional source of information was displayed. For this task, fifth graders had to select the correct German written form presented along with three distractive written forms, i.e., a close and a distant orthographic distractor, and a phonological distractor (homophonic when using L1 letter/sound mappings). In this task, classroom-immersion fifth graders outperformed their monolinguals peers for cognate words (respectively, 84.9 % vs. 81.9 %), but not for non-cognate words (respectively, 80.1 % vs. 81.1 %). These results are consistent with previous studies that reported a cognate facilitation on L2 vocabulary learning among children (see., Comesaña et al., 2012; Tonzar et al., 2009; Valente et al., 2018). Thus, although limited to the orthographic judgment task, our results suggested that L2 was activated during the early steps of L3 vocabulary learning, thus, facilitating the recognition of L2/L3 cognate words, even if they only shared an incomplete orthographic overlap with the foreign language (ex., Spinne – spider). Such an assumption is consistent with the scaffolding model of L3 acquisition, according to which L3 novel forms are linked to their translation equivalents in another language. Thus, the weak language is then anchored to a more experienced one, which helped children to acquire novel wordforms. In the present study, the acquisition of novel written forms was thus linked to L2 German, given that they shared a (relative) orthographic overlap with the L2 words. For non-cognate words however, it is likely that L3 words were glued to the L1; an assumption which is consistent with the strong contribution of L1 typology on L3 learning (see., Schepens et al., 2016).

VI. 1. 4. 4. Limitations and future directions

Although we did not report any cognate facilitation for two of the three experimental tasks, it is possible that this lack of effect could be attributed to several potential biases associated, such as the degree of cognate awareness, unknown German translation equivalents, and the scarce cross-linguistic phonological overlap for cognate words. However, all these potential limitations will be mentioned and developed in the General discussion part.

Future research is required to determine whether the bilingual advantage in L3 vocabulary learning may be reinforced by cognateness, when increasing the phonological overlap in cognates. In addition, it appears relatively interesting to determine which amount of linguistic immersion to foreign language is required for the bilingual advantage to arise.

VI. 1. 4. 5. Summary

In this study, we have evidenced a generalized bilingual advantage on L3 vocabulary learning that could be extended to classroom-immersion children. Interestingly, this bilingual advantage was rather not modulated by cognateness for phonological and semantic (through the connection between L2 phonology and semantics) learning. However, for orthographic learning, the bilingual advantage was only retrieved for non-identical cognate words, suggesting that L2 was already activated during early steps of L3 vocabulary learning. These results gave some credit for the scaffolding account for the L3 vocabulary learning (see., Bartolotti & Marian, 2016).

GENERAL DISCUSSION

Overview of the theoretical background and of the research questions

This thesis work explored the contribution of orthography on vocabulary learning in a foreign language among children, an issue little addressed so far. Indeed, although previous studies reported a consistent orthographic advantage on learning L1 novel words as well as pseudowords, their conclusions could not be transferred to L2 word learning. Two main differences should be mentioned: first, most children start learning their foreign language in an academic context, which is characterized by a scarce exposure to the spoken form and a predominance of the written form in secondary schools. There, the exposure to foreign language remains quite limited (around 1.5 hour per week). In elementary schools however, children are not exposed to L2 written modality until Grade 5. Second, word learning in L1 requires children to acquire its meaning as well as both its spoken and written forms and to build connections between each of the three representations. On the contrary, L2 word learning (at school) occurs after the development of L1. Therefore, the semantic representation, which is shared across languages, is already acquired prior to the learning of the novel written and spoken forms that are specific to L2 (see the parasitic model of foreign language acquisition, Hall, 2002). In this thesis work, we thus conducted three main studies to provide some experimental evidence of the contribution of orthography on L2 vocabulary learning. The first aim was to determine whether orthography benefited to word learning. Word learning was assessed here through three aspects: spoken word form recognition, written word form recognition, (reciprocal) L2 phonology to semantics connexion (Study 1). In addition, we wondered whether this learning advantage was modulated by the degree of reading skills, as well as by the learning load. The second aim was to determine whether the orthographic benefit on L2 vocabulary learning would be modulated by the degree of grapheme-to-phoneme congruency with L1 letter/sound mapping (Study 2). In addition, we explored whether children were able to acquire and transfer the grapheme-to-phoneme correspondence rules that are specific to L2 to novel words. These two main aims were explored among the first two studies for which children were exposed to spoken and written forms in L2 prior to initial experience with traditional foreign-language learning at school. For these studies, two learning methods were contrasted, an orthographic learning method, i.e., characterized by the simultaneous presentation of a spoken word and its written form in association with its concept and a non-orthographic learning method, for which orthography was substituted by a bench of non-decodable symbols.

The third aim was to determine whether a linguistic-immersion to foreign language may facilitate the learning of L3 vocabulary, as reported in previous studies among bilingual adults (e.g., Kaushanskaya & Marian, 2012a, 2012b; Kaushanskaya & Rechtzigel, 2012; Kaushanskaya et al., 2013) and among bilingual children (Kaushanskaya et al., 2014). Additionally, this study explored whether this learning advantage may be modulated by the cross-linguistic similarities conveyed by (non-identical) cognate words (Study 3). Contrary to the two previous studies, the third one was conducted among children who attended a classroom-immersion to German as a foreign language. Vocabulary learning in L3 was conducted by using an orthographic learning method, for which L3 written and spoken forms were associated to their related concept. Importantly, we manipulated the influence of cross-linguistic similarities conveyed by L2/L3 non-identical cognate words on L3 vocabulary learning. Methodological challenges associated to word learning abilities and required exposure to written and spoken wordforms have been investigated.

Overview and discussion about the learning and testing designs

In the following paragraphs, we will expose the arguments associated with our experimental procedure for learning phase as well as with the task selection for the testing phase. As a reminder, during learning phase, participants were simultaneously exposed to a spoken form, i.e., pronounced by a native speaker of German, a visual form (corresponding to the associated written form or to unrelated symbols, i.e., orthographic vs. non-orthographic conditions) as well as their related picture (semantics). We ensured that, between each learning block (after six, nine and twelve exposures to learning material), there was a switch in German speaker. This strategy relied on two main arguments. First, the exposure to several native speakers prevented participants to rely on specific prosodic indices (tone, pitch or accentuation) to complete the experimental tasks during the testing phases. Second, in addition to an ecological language learning environment, participants had to flexibly adjust their phonological representation for each German speaker to allow them to generalize their recognition of the German spoken forms. Indeed, in spoken language, there is some variability in spoken language production, given that no utterance or word are pronounced in the exact same way, even by the same speaker (e.g., Harrington, 2010). In addition, previous studies also reported some evidences for the benefit of the variability of the spoken input displayed during learning among adults (see., Brosseau-Lapré, Rvachew, Clayards, & Dickson, 2011; Welby, Spinelli, & Bürki, 2021). In their study, Brosseau-Lapré and colleagues (2011) made English native speakers learn minimal pairs of French words that included a vowel contrast (ex., /ə/ vs. /ø/). Participants either learned these L2 words with multiple French native speakers (with voices resynthesized) or with an only speaker (control conditions). During learning, novel words were presented in both written and spoken modality. Participants who learned the French novel words with multiple speakers outperformed those in the only speaker condition in novel word pair identification. Recently, Welby et al. (2021) explored the effect of speaker-based variability on learning performance among French monolingual adults who were learning English novel words through a unimodal (audio-only) or a bimodal (audio + orthography) learning method (Welby et al., 2021). Importantly, novel-words were either learned with multiple speakers or with only one. As for the testing phase, participants had to complete a picture naming task, for which faster response times were reported in participants that were exposed to the multiple sources of spoken information compared to those who were not. However, the effect of speaker-based variability was restricted to the unimodal (audio only) learning method. These results suggested that the orthographic advantage on L2 vocabulary learning overlapped the one associated with the speaker-based variability. With regards to our experimental work, these studies provided a strong support for our learning procedure, given that exposure to multiple native speakers of German may have favored learning performance, especially for the forced-choice picture recognition task and the go/no-go spoken recognition task among participants who attended a non-orthographic learning method. Therefore, whether the benefit of orthography was consistently reported across experimental tasks and studies, this should be really informative on the strong contribution of written information on L2 vocabulary learning.

In addition to the learning phase, the selection (and creation) of our testing tasks also relied on experimental grounds. Previous studies used productive tasks to explore their participants' learning performance, such as the picture naming task for semantic and phonological learning and spelling dictation for orthographic learning. In our studies, we decided to focus on recognition measures, which are associated with lower cognitive costs. We opted for a forced-choice picture recognition task to explore the connection between semantic and phonological representations, although ceiling effects were largely reported in studies that explored L1 vocabulary learning. In our study, the forced-choice picture recognition task was designed to assess learning performance among both groups of participants. Importantly, despite third graders performed less accurately than the fifth graders, they still were able to associate the spoken form correctly to its meaning for about 17.5 of the 24 German words (73.3%) when they were exposed to orthography, suggesting that a robust word learning was reached after twelve exposure to the German words, when children were exposed to orthography during learning.

Given that semantic and phonological learning are both intricated in the forced-choice picture recognition task, we also explored the acquisition of L2 German spoken forms more directly through a go/no-go spoken recognition task. This task required participants to detect the correct phonological forms of the German/English words among spoken distractors, which were either close phonological distractors (see Study 1, Study 2, and Study 3) or distant phonological ones (see Study 2). As exposed previously, although previous L1 vocabulary learning studies used a picture naming task (see., Colenbrander et al., 2019 for a systematic review), we have opted for this spoken recognition task, which is a pure phonological task to assess children's phonological learning for several reasons. First, we expected that children would have performed at a floor level when using a productive task, given that pronouncing a L2 word involves higher linguistic skills than its (passive) spoken recognition, such as the ability to adapt previous L1 phonetic categories to L2 specific ones. Furthermore, a large variability in children's production would have been expected across participants. Second, this task was more adapted in assessing spoken abilities compared to yes/no (spoken) lexical decision task among developing readers (see., Moret-Tatay & Perea, 2011). In addition, the go/no-go spoken recognition task allowed us to explore the quality of the L2 phonological representation by using close phonological distractors (ex, /bɪrk/) which only differed from the German target word by one to two phonemes (ex, /bɛrk/, <Berg>). By using close phonological distractors, we explored whether the spoken form was accurately discriminated, thus, supporting that participants encoded the phonological form in a rather complete way.

Orthographic learning was assessed using an orthographic judgment task, which required children to detect the correct spelling of the L2 German words (but see Study for L3 English words) among orthographic distractors, with no additional cue, i.e., spellings were displayed on the computer screen with no additional information. Thus, the orthographic judgment task was a pure orthographic task for which distractive pseudowords were created to prevent any decoding strategy to be successful as long as participants relied on the L1 French grapheme-to-phoneme correspondences. In the following paragraphs, we will summarize the main experimental observations reported in these studies, which documented the contribution of orthography on L2/L3 vocabulary learning.

Overview of the main experimental results

In summary, the presence of orthography contributed to an enhanced word learning in L2, which was consistently reported for orthographic and phonological learning. Semantic learning, i.e., connection between the phonological representation and its associated concept, was also facilitated when the written information had been displayed during learning. This orthographic facilitation has been reported among both third and fifth graders, although the latter did not exhibit any orthographic advantage for the go/no-go auditive recognition task in the 16-item condition only (see Study 1a). Nonetheless, when the learning load increased (Study 1b), we reported an orthographic learning advantage for the go/no-go spoken recognition task among fifth graders too. These observations are consistent with studies that documented the benefit of orthography on novel word learning in L1 (e.g., Rosenthal & Ehri, 2008) as well as on pseudoword learning (e.g., Ricketts et al., 2009). Nonetheless, in their study, pseudowords were associated to novel semantic referents and their spoken form relied on the L1-English preexisting phonemes. Thus, in this context, pseudoword learning cannot give a full account of L2 vocabulary learning for which participants had to learn novel spoken and written forms and to associate them with their pre-existing concept. Furthermore, in this thesis work, we replicated the orthographic advantage in L2 vocabulary learning when increasing the learning load (eight additional German concrete words compared to the 16 initial ones), suggesting both that the paired-associate learning paradigm was efficient to conduct replicable word learning studies, but also, and more importantly, that the beneficial contribution of orthography on L2 vocabulary learning was not impacted by the increased memorization load during learning phase.

Cross-linguistic dynamics associated to L2/L3 word learning, i.e., grapheme-to-phoneme incongruencies vs. cross-linguistic similarities conveyed by cognate words, have also been explored to determine whether they modulated the contribution of orthography on L2/L3 vocabulary learning. The moderating effect of incongruent letter/sound mapping has been investigated among fifth graders who learned 24 German words, half of which included at least one grapheme to phoneme incongruency with L1-French. Preliminary results reported no significant effect of congruency in two out of three experimental tasks, i.e., the forced-choice picture recognition task and the orthographic judgment task. For the go/no-go auditive recognition task however, initial discrimination between German words and their associated phonological distractors was lower for those that included incongruent grapheme-to-phoneme correspondences. Interestingly, this disadvantage disappeared after a one-week delay, given that fifth graders performed similarly for congruent and incongruent words in the delayed session. Although promising, these results have to be confirmed by the future data inclusion and the inclusion of a non-orthographic learning method as a control group. For the cross-linguistic similarities between L2 and L3, we also reported a limited contribution of L2/L3 cognateness on L3 vocabulary learning (Study 3). Indeed, we found no specific cognate facilitation on L3 vocabulary learning among fifth graders who attended a linguistic-immersion to German as a foreign language in two out of three experimental tasks, i.e., forced-choice picture recognition task and go/no-go auditive recognition task. Nevertheless, for the orthographic judgment task, there was a cognate facilitation effect on the accurate recognition of English spellings for cognate compared to non-cognate words. In light with these two studies, cross-linguistic dynamics had a quite restricted moderating effect on the orthographic facilitation associated with L2/L3 vocabulary learning. These results are however inconsistent with previous studies, which reported a cognate facilitation effect on L2 vocabulary learning (e.g., Comesaña et al., 2012; Tonzar et al., 2009; Valente et al., 2018), but an interfering contribution of familiar but incongruent grapheme-to-phoneme correspondences (see. Barrios & Schowalter, 2021 for a systematic review).

To our knowledge, this thesis work is the first one to explore the contribution of orthography on word learning in a foreign language by focusing on the acquisition of all three formal dimensions, i.e., semantics, phonology and orthography. For all three studies, we reported that the presence of orthography during learning led children to encode a large amount of L2 words in memory. Furthermore, one-week delayed testing reported no significant decay in word memory, suggesting that mediating the learning of L2/L3 vocabulary by orthography contributed to form deep lexical representations. These observations are consistent with the lexical quality hypothesis (Perfetti & Hart, 2002).

In the following sections, we will discuss our results in regards to the nature of the reported orthographic facilitation on L2 vocabulary learning. We will then focus on the mechanisms underlying the benefit of orthography on L2 vocabulary learning as well as on the nature of the orthographic encoding during learning. Then, orthographic advantage on L2 phonological learning to report the strong interplay between L2 orthography and phonology. Then, we will address the degree of orthographic overlap between the L2 encoded orthographic representation and its associated written wordform. The relationship between L1 linguistic skills and grade will be discussed. We will start by the (indirect) contribution of L2 orthography on access to semantic representation.

On the nature of the orthographic advantage on L2 vocabulary learning

In this thesis work, we reported a (rather) consistent benefit of orthography on L2 vocabulary learning, i.e., orthographic, phonological and semantic learning. We suggest that this learning facilitation could be attributed to several explanations that we shall detail in the following paragraphs.

Visual advantage vs orthography:

Consistently in our studies, we reported that children who were exposed to orthography during learning exhibited a larger proportion of accurate (written and spoken) recognition compared to those who were not.. Some experimental evidences have been provided by Hulme et al. (2007), who reported a larger learning advantage for a visual-visual paired-associated learning paradigm compared to both a visual-verbal and verbal-verbal ones, supporting that learning the association between two visual information was easier compared to the others. Previous L1 studies also reported a consistent orthographic facilitation for L1 spelling to dictation tasks (see., Ricketts et al., 2009; Rosenthal & Ehri, 2008) as well as for forced-choice spelling recognition task (e.g., Valentini et al., 2018). Importantly, contrary to these previous studies, we ensured that the difference between the two learning groups would be explained by the presence of the written form per se, and not by the mere presence of a visual cue. To do so, we substituted the written word form by a series of undecodable symbols for children assigned to the non-orthographic learning method. The presence of these non-orthographic information during learning did not led to comparable learning effect than orthography, which supported that the presentation of a pure visual clue was not sufficient enough to trigger learning facilitation. This suggests that the orthographic advantage might not be resumed to a pure visual effect. However, it should be underlined that these symbols were not visually discriminant across trials compared to spellings. It has also been suggested that the presence of non-orthographic visual indices may interfere with word learning performance by confusing participants (see., Ricketts et al., 2015). Therefore, further studies are thus required to ensure that the orthographic advantage on L2 vocabulary learning may not be confounded with a visual one, when using discriminant visual clues across trials.

Several recent experimental evidences came from pseudoword learning studies that were conducted among monolingual adults. Indeed, Escudero, Smit, and Angwin (2021) made 39 students learn nonsense novel words through a cross-situational word learning study. The learning phase was characterized by the presentation of two word-picture pairings. The nonsense pseudowords were either presented in their written form (orthographic method) or pronounced by an Autralian native speaker (phonological method). The pseudowords included a minimal difference on their initial consonant (ex., <BON> /bɔn/ vs. <DON> /dɔn/) or on their vowel (ex., <DEET> /dit/ vs. DIT /dɪt/). As for testing task, learning performance were assessed through a picture spoken word recognition, for which the target nonword was pronounced four times at each trial and presented along with a distractive picture. They contrasted between minimal-pairs trials (ex., <BON> /bɔn/ vs. <DON> /dɔn/) and non-minimal pairs ones (ex., <BON> /bɔn/ vs. <DEET> /dit/). They reported higher performance on picture spoken word recognition for participants assigned to the orthographic learning method compared to those that attended a phonological learning method. These results showed that the learning benefit on learning performance was indeed attributed on the presence of orthography, providing some evidences against a pure visual effect. Nonetheless, due to the Covid sanitary crisis, the authors reported that data inclusion was restricted to 11 monolingual adults for the phonological learning method. Thus, future studies are required to confirm these preliminary results in L1 vocabulary studies and to extent them to L2 learning ones. In addition, it is important to determine whether these observations might be retrieved among children.

Double coding:

Another possible explanation to account for the orthographic advantage on L2 vocabulary learning relies on the double coding associated with the orthographic learning method in our studies. Indeed, consistent with the double-coding theory (Paivio, 1975; Paivio & Lambert, 1981; Sadoski, 2005), children were exposed to both written and spoken wordform during learning, whereas they were only exposed to the word pronunciation in the non-orthographic learning method. Thus, according to this theory, the learning benefit associated with the presence of the written form may not rely on orthography per se, but on the additional source of information provided during learning. To test this assumption, Pattamadilok, Welby, & Tyler (2021) made French native speaker adults learn minimal pairs of English words that included a specific minimal phonemic contrast (i.e., /θ/-/f/) by contrasting three different modalities of exposure to learning material: exposure to the spoken form only, exposure to spoken words with their associated articulatory gestures, and exposure to both spoken and written wordforms. Immediately after learning phase, a picture naming task was performed which reported comparable accurate word pronunciation regardless of the learning method. Nevertheless, after a one-day delay, participants assigned to the orthographic learning method (exposure to both spoken and written words during learning) outperformed the two other groups, supporting a delayed but stronger lexical consolidation once a word has been encoded through orthography and phonology. These results are consistent with the lexical quality hypothesis, according to which the multimodal sources of information provided during learning helped L2 learners to build a strong lexical representation. In addition, this lends credence to the strong association between written and spoken codes for vocabulary learning. Although future studies are required to determine whether these preliminary results may be extended to L2 vocabulary learning among children, the benefit of orthography cannot be restricted to a dual-coding of information but seems to be associated with orthography per se.

Thus, if the orthographic facilitation could be associated with orthography per se, it appears interesting to explore the quality of the encoded orthographic representation. This would provide us some information on the processing of the written form during learning. As a reminder, the benefit of orthography on the acquisition of L2 written forms has been consistently shown in Study 1, with a larger accurate recognition of the L2 spelling presented along with its associated distractors among participants who attended an orthographic learning method compared to those who did not. The orthographic judgment task was a pure orthographic task, i.e., no additional source of information was provided to participants. Interestingly, more than two third of the L2 written forms were accurately recognized by participants who were assigned to an orthographic learning method, supporting that participants paid attention to the orthographic information displayed during learning.

Nevertheless, the binary coding associated with the accuracy measure, i.e., correct vs. incorrect recognition of the target written form, is not precise enough to explore the quality of the encoded orthographic representation. Thus, we included three different distractive written forms to determine to what extent children paid attention to the written form during learning. The close orthographic distractor was characterized by a large orthographic overlap with the target word and was characterized by one-letter substitution or transposition. The distant orthographic distractor shared a weak orthographic overlap with the target word, i.e., restricted to the one or two initial letters. If participants chose the close orthographic distractor, this supported an incomplete encoding of the written form, although the orthographic representation shared a large orthographic overlap with the target written word. On the contrary, the selection of the distant orthographic distractor suggested that participants did not paid attention to the written form at all during learning. The third type of distractor is a homophonic one when using the French letter/sound mapping. Interestingly, the analyses conducted on the pattern of errors revealed that participants committed a larger amount of close orthographic errors when they were exposed to orthography. On the contrary, in Study 1 (Study 1a and Study 1b), the homophonic distractor was preferred by participants who learned L2 words without orthography. Thus, these results supported that, in the absence of written information, children (both third and fifth graders) relied on the L1 grapheme-to-phoneme correspondence rules. This strategy was particularly misleading, especially for words with incongruent mapping between letters and sounds. On the contrary, the presence of the L2 written form shaped the encoding of German words, still the memorized orthographic representation was characterized by an incomplete form overlap with the German written wordform for some of the learning material. Therefore, given that the difference between the written form and the close orthographic distractor was restricted to one grapheme (substitution or transposition), the orthographic representation had to be fully specified to accurately discriminate between these two spellings. Interestingly, despite no differences in the pattern of committed errors according to grade for participants who were exposed to orthography during learning, we reported that fifth graders preferentially selected the close orthographic distractors rather than the distant ones, compared to third graders in the non-orthographic learning method. Thus, fifth graders could have been aware that grapheme-to-phoneme correspondences varied across languages, due to their ongoing experience with English as a foreign language in both a school and an out-of-school context (see., De Wilde et al., 2020), which confronted them with incongruent letter/sound and sound/letter mappings as well as with novel English specific phonemes (ex, the English bigram <th> whose associated phoneme /ð/ does not exist in French). Some evidences have been provided by Study 2 (although preliminary), which showed that fifth graders committed preferentially close orthographic errors irrespective of the degree of grapheme to phoneme congruency between L2 and L1. Therefore, in light with these results, children were able to learn novel written forms after a scarce exposure to orthography during learning. Furthermore, they were able, at least among the fifth graders, not to rely on L1 grapheme-to-phoneme correspondence rules. These interpretations have to be taken with caution and further studies are required to confirm our results. However, the degree of orthographic overlap between the encoded orthographic representation and the written word form is still unknown. It is indeed possible that children encoded a partial orthographic representation when they were exposed to the written wordform. Future studies are required to explore this processing more precisely. Using a spelling task would have allowed us to look exactly to the encoded orthographic representation. Unfortunately, it required to pronounce the word to spell, and thus, additional mechanisms would be involved and it may be difficult to disentangle between them. To explore this, it could be considered to expose children to partially masked written forms, by presenting them either to the first initial graphemes (Gl####) or the last ones (####ke) during learning and to compare their learning performance to those of participants exposed to the complete orthographic form (Glocke).

A further explanation of the orthographic advantage might be related to the strong interplay of the orthographic code with phonology, which will be explored through the orthographic facilitation on L2 phonological learning.

Orthographic facilitation on L2 phonological learning

The benefit of orthography on L2 phonological learning has been assessed through a go/no-go spoken recognition task for all the experimental studies of this doctoral work. As discussed above, this was a pure phonological task that required participants to discriminate between German spoken forms and their associated close (Study 1, Study 2 and Study 3) and distant (Study 2) phonological distractors. For the go/no-go spoken recognition task, an orthographic advantage on L2 spoken recognition was consistently reported among third graders immediately after learning, characterized by a higher discrimination score, i.e., between German words and close phonological pseudowords in the orthography-present group compared to the non-orthographic group. Such an observation evidenced that orthography helped Grade 3 children to learn L2 novel phonological forms, an assumption that has been consistently reported in L1 studies for pronunciation learning (see., Ricketts et al., 2009; Rosenthal & Ehri, 2008), but not for phonological recognition (see., Valentini et al., 2018). These results are in line with the orthographic mapping of phonological information (Ehri, 2014), according to which the presence of the (L2) written form secured the memorization of its associated spoken form. For the fifth graders however, contradictory results have been reported between Study 1a and Study 1b. Indeed, despite larger discriminative performance compared to the third graders, orthography did not contribute to enhance L2 phonological learning in Study 1a. Nevertheless, in Study 1b, the benefit of orthography on L2 phonological learning has been retrieved in fifth graders. Thus, in the following paragraph, we will explore some explanatory hypotheses relative to 1) the degree of incongruent letter/sound mapping, 2) to the nature of the experimental task as well as the increased learning load.

Therefore, in Study 1a, the lack of orthographic facilitation was surprising, given that fifth graders had larger linguistic (and cognitive) skills compared to the third graders. Interestingly, raw data showed that, although participants in the orthographic method performed less accurately for German word recognition compared to those in the non-orthographic one (73.3 % vs 76.7 % respectively), they committed a lower proportion of false alarm (17.4% vs 23.9 % respectively), suggesting a more conservative strategy of response. Two hypotheses might support this absence of orthographic facilitation on L2 spoken recognition. First, we suggested that fifth graders relied on a complete orthographic encoding during learning, which might have confronted them to incongruencies in grapheme/phoneme mapping. In this particular context, orthography may have played a distracting effect on phonological learning. Indeed, given that our selected words included both congruent and incongruent grapheme-to-phoneme correspondences when using the L1 letter/sound mapping, it may be possible that the orthographic advantage for L2 phonological learning was neutralized/hidden, due to combination of facilitation and interference effects. On the one hand, the presence of orthography may have facilitated the recognition of spoken words that included congruent grapheme/phoneme mapping with L1. Thus, according to the orthographic mapping theory (e.g., Ehri, 2014), the written form was glued to the spoken one, leading to its memorization in the lexicon. However, on the other hand, for the German words with an incongruent letter/sound mapping, orthography may have contributed to encode a “mispronounced” phonological form, which may lead to misremembered spoken forms of German words and thus, hindered the recognition of L1-L2 incongruent spoken forms previously learned, an assumption that has been formulated in L2 phonological learning studies conducted among adults (see., Escudero et al., 2014; Hayes-Harb et al., 2010; Showalter, 2018). This hypothesis has however not been statistically tested due to the restricted number of German words (eight congruent vs eight incongruent German words) in the Study 1a, but, raw data showed comparable accurate word recognition and rejection for pseudowords between congruent and incongruent items (respectively, 72.3% vs. 77.4% for words and 80.8% vs. 82.8% for pseudowords). Thus, the impact of grapheme-to-phoneme congruency seemed quite limited to account for the absence of orthographic facilitation in phonological learning among fifth graders, which led us to formulate a second hypothesis to account for these “surprising” results. Indeed, given that the go/no-go spoken recognition task was a pure phonological task, it is possible that fifth graders did not rely on orthography to perform accurately, especially when the learning load was relatively low (Study 1a, for learning 16 German words). When the learning load increased (see Study 1b), the orthographic advantage on L2 phonological learning was significant, with fifth graders outperforming their peers on L2 spoken recognition once they were exposed to written information during learning. Interestingly, the raw data reported that fifth graders in the non-orthographic group had lower accurate recognition of German words compared to the orthographic one (69% vs 73% respectively), and they committed a higher proportion of false alarm (27% vs. 22% for the non-orthographic vs. the orthographic group respectively). Thus, discrimination between words and their close phonological distractors was less accurate when participants were not exposed to orthography during learning. Importantly, as a reminder, fifth graders exhibited comparable discriminative performance in the 16-item study, whether they were exposed to orthography or not. In light of these results, we suggested that, until a “critical” learning load was not reached, it was possible for participants to perform as well irrespective of the learning method. However, as soon as the learning load overcame children’ phonological short-term memory abilities, then, the benefit of orthography was reported among fifth graders. For third graders, given that their cognitive and linguistic skills are lower than those of fifth graders, the benefit of orthography was retrieved regardless of the learning load. These results confirmed the close relationship between orthography and phonology, consistent with the orthographic mapping (Ehri, 2014). Thus, exposure to the written wordform seemed to help children secure the phonological form in memory. Indeed, we supposed that participants tried to directly decode the written word presented along with its spoken form during learning and thus, orthographic and phonological information were glued together. Similarly, most studies conducted on L1 learning documented the benefit of orthography on the acquisition of novel (pseudo)word pronunciation (see., Colenbrander et al., 2019 for a systematic review).

Interestingly, comparable results were also observed among monolingual adults learning novel English words (see., Welby et al., 2021). Indeed, they reported a specific orthographic facilitation on L2 phonological learning, evidenced by faster response times for the picture naming task (production) and for the picture matching task (spoken recognition) after a three-day delayed testing (no immediate testing) when participants attended an orthographic method (audio + ortho) compared to a non-orthographic one (audio-only). Nonetheless, they also reported that participants stemmed on the L1 grapheme-to-phoneme correspondence rules to pronounce L2 English pseudowords. This strategy might be relatively efficient for L2 words whose grapheme-to-phoneme correspondences are congruent with L1, but could lead to interfering effects for learning novel phonological forms with incongruent letter/sound mapping.

Limited evidence of a moderating effect of incongruent grapheme-to-phoneme correspondences on L2 phonological learning

In this doctoral work, the moderating effect of incongruent grapheme-to-phoneme correspondences on L2 vocabulary learning has been explored in two studies, i.e., Study 1b and Study 2. To this purpose, we exposed children to 12 incongruent and 12 congruent German words. We did not report any significant contribution of congruency on orthographic, phonological nor on semantic learning in Study 1; this lack of congruency effect could be attributed to the difficult manipulation of this variable, given that, by nature, none of the L2 word could be considered as fully congruent with L1 letter/sound mappings. As an example, the final grapheme is usually pronounced in German, but silent in French (ex, Birne, Glocke, Hose, Kette, Lippe). In addition, among the incongruent German words, we observed that some of them only included one grapheme-to-phoneme incongruency (ex, Hand, Stern, Tafel). Thus, the distinction between the congruent and the incongruent selected words may not be salient enough to allow us to disentangle potential learning disadvantage associated with exposure to

L2 written forms. Importantly, it should be mentioned that the statistical analyses conducted on the impact of congruency on the orthographic advantage on L2 vocabulary learning have been reported for exploratory purpose, given that, initially, this was not an experimental purpose of the princeps study. Therefore, for Study 2, we selected highly incongruent German words that included between two and four (2.5 incongruences in average) incongruent letter/sound mappings with L1. Due to the Covid sanitary crisis, data inclusion was restricted to 19 participants (15 ones who attended both testing sessions) who attended an orthographic learning method. A significant effect of congruency was only reported for the go/no-go spoken recognition task at immediate testing, with higher discriminative score for congruent words compared to incongruent ones (respectively, 1.61 vs 1.05). Interestingly, participants performed equivalently on the correct rejection of congruent and incongruent pseudowords (respectively, 74.1% vs 77.2%), a lower proportion of incongruent words were accurately recognized compared to the congruent ones (respectively, 59.2 % vs. 73.7%), suggesting that participants used a more conservative strategy for the German words with incongruent grapheme-to-phoneme correspondences with French. However, after a one-week delay, discriminative performance for incongruent items reached those for the congruent ones (respectively, 1.60 vs. 1.44). Although discriminative performance remained stable across sessions for the congruent items, participants exhibited larger accurate word recognition and rejection for pseudoword after delay (respectively, 72.7% for words and 75.8%) for pseudowords). These results suggest that the encoding of novel phonological forms may rely on a different time course according to their degree of grapheme-to-phoneme congruency with L1. We will discuss these preliminary results with regards to the ontogenesis model of L2 lexical representation (see., Bordag, Gor, & Opitz, 2021), which focuses on the initial stages in (L1 and L2) learning, i.e., orthographic, phonological and semantic learning as well as their mappings. It should be mentioned that we will not provide an exhaustive description of this model (see., Bordag et al., 2021 for the detailed presentation of the ontogenesis model of L2 lexical representation). The central property of this model posits a relative fuzziness of L2 (early) lexical representation (see., Gor, 2018; Kapnoula, 2021) which refers to an inexact or incomplete encoding of formal dimensions, especially for L2 phonological representations. According to this model, the L2 lexical representations are thought to remain fuzzy until each lexical dimension reaches its “optimum”, i.e., the highest level of its acquisition (which is specific for each lexical dimension and between languages). This gradual increase in the acquisition of a lexical representation (from its initial fuzzy encoding to its optimum) is represented through an ontogenetic curve. This is also consistent with the offline sleep consolidation evidenced in children (see., Brown et al., 2012; Henderson et al., 2012). Thus, initial exposure to L2 spoken forms leads to an incomplete encoding of its pronunciation which includes some temporarily incorrect mapping between graphemes and phonemes, especially for incongruent L2 words. Indeed, given that incongruent L2 spoken form is less familiar with L1 grapheme-to-phoneme mappings compared to the congruent ones, the slope of its ontogenetic curve is thought to be lower than those of the more familiar ones. Therefore, the encoding of L2 congruent phonological forms occurred faster than those of L2 incongruent ones, as evidenced by the difference in discrimination performance in the go/no-go spoken recognition task at immediate testing. In addition, we hypothesized that participants reached a relative peak in their L2 phonological learning for congruent words, given that their discriminative performance remained stable after delay. Interestingly, for incongruent German words, the increased discriminative performance suggested a benefit of offline sleep consolidation (see., Brown et al., 2012; Henderson et al., 2012) on the memorization of L2 incongruent phonological forms. Further experimental evidence have been provided by studies that explored L2 (pseudoword) phonological learning among adults (see., Bakker et al., 2014; Bakker, Takashima, van Hell, Janzen & McQueen, 2015). However, despite some promising preliminary results reported for Study 2, it is still unclear whether the delayed accurate word recognition and rejection for (close and distant) pseudowords for incongruent items could be attributed to the presence of orthography during learning only or to offline-sleep consolidation or to both. To do so, supplementary data inclusion is required and will take place in schools in the next months. A control group, i.e., fifth graders attending a non-orthographic learning method, will be also included.

In light of our results, there were relatively strong connections between orthography and phonology in L2 vocabulary learning, as evidenced by the benefit of the presence of written form on the acquisition and memorization of L2 spoken forms. Our studies focused on recognition measures and participants were not asked to pronounce the novel spoken forms. Nonetheless, the simultaneous presentation of spoken and written forms during learning could also limit the accurate acquisition of L2 pronunciation due to the interference from the written form. Indeed, Bürki et al. (2019) reported that the presence of written information during L2 phonological learning led to production that were more L1-like, given that participants relied on their L1 letter/sound mappings to pronounce the novel forms.

In addition, it is still unclear whether the exposure to L2 spoken and written forms during learning helped children to extract the L2 specific grapheme-to-phoneme correspondence rules and whether they could be transferred to untrained German (pseudo)words, a research question that will be addressed in the following section.

Exploring the transfer of L2 letter/sound mappings to untrained L2 (pseudo)words

In light with the previous results, it should be relatively interesting to consider whether children were able to generalize (and transfer) some of the L2 specific mappings between letters and sounds, i.e., to which they were not exposed during learning. In Study 2, we used a spelling generalization task, for which participants had to link a novel spoken form to its associated written form, for items including both congruent and incongruent grapheme-to-phoneme correspondences with L1. Preliminary results suggested that, prior to learning phase, participants were already able to associate the spoken form with its related written form for congruent pseudowords. These results supported that fifth graders were able to stem on their L1 grapheme/phoneme correspondences to infer/predict L2 orthographic form, giving some more credence to the orthographic skeleton hypothesis (see., Wegener et al., 2018). As a reminder, this hypothesis relies on the ability for children to map together orthographic and phonological form early during reading acquisition (e.g., Savage & Stuart, 2006; Ventura, Morais & Kolinsky, 2007). Through cumulated experience with written language, children may be able to have some expectations about the spelling of spoken forms. For incongruent spellings, we observed a relative increase in accurate association between spoken and written forms immediately after learning (and after a one-week delayed) that was however restricted to two out of the six selected grapheme-to-phoneme incongruencies between German and French, i.e., <au> which is associated with the phoneme /aʊ̯/ in German and /o/ in French and <ei> (/aɪ̯/ in German and /ɛ̃/[9] in French). This supported that participants were able to acquire and extent some of the L2 specific mappings between grapheme and phoneme from the early steps of L2 learning. Nonetheless, these promising preliminary observations have to be replicated with a larger sample of participants, but also with different pairs of languages. Indeed, the specific interplay between L1 and L2 orthographic depth may impact the relative acquisition of L2 words. Indeed, in a previous study, Erdener and Burnham (2005) reported that the presence of the orthographic input helped adults to learn L2 phonological forms, although this benefit was modulated by L1 and L2 degree of orthographic transparency. Orthography played a larger benefit among Turkish native speakers (a transparent language) when they had to learn Spanish (transparent) phonological forms compared to Irish ones (opaque). On the contrary, when L1 had an opaque orthography, i.e., Australian English, participants performed equivalently for Spanish (transparent) and Irish languages. Here, in our studies, we chose to expose French

[9] In French, the bigram <ei> does not exist per se, but is retrieved among the trigrams <eil> and <ein>. Thus, the phoneme associated to the artificial bigram <ei> was selected among the production of a panel of French native speakers that were asked to decode the German pseudowords when relying on letter/sound correspondences.

children to German as a foreign language, given its relative orthographic transparency in both reading and writing. This allowed us to manipulate the degree of grapheme-to-phoneme congruency with L1 for German words (one phoneme was associated to one grapheme and conversely in German). We reported a relative consistent orthographic advantage on L2 (transparent) vocabulary learning. Therefore, one can wonder to what extent the consistency of the orthography of the language to be learned explain these effects, an issue that has to be documented in future researches.

On the direct vs indirect contribution of orthography on access to semantic representation

In the following section, we will address the debate between a direct and an indirect contribution of orthography on access to semantic representation. Consistent with Ricketts et al. (2009), we used a forced-choice picture recognition task as a measure of accurate access to the semantic representation, for which participants, i.e., third vs. fifth graders, exhibited an orthographic advantage on correct meaning retrieval. This experimental task explored the creation of the connection between L2 phonological representation and its associated semantic representation. As a result, the access to the semantic representation was thus mediated by phonology, and we cannot disentangle whether orthography played a direct access to semantics through a connection between orthography and semantics, or whether it is mediated through phonology on the basis of this experimental task. Nonetheless, the presence of the L2 written form led to reinforce the building of a strong connection between L2 spoken form and its associated meaning, as evidenced by enhanced accurate picture recognition reported for the orthographic learning method compared to the non-orthographic one. Such a result is consistent with the lexical quality hypothesis (Perfetti & Hart, 2002), which postulates that a lexical representation could be considered of high quality, when the exposure to one (of the three) constituent of the lexical representation drives the activation of all the other ones. In this context, the orthographic facilitation is explained as a matter of higher lexical quality, given that participants were exposed to orthography, phonology and concept during learning, leading them to build a three-element lexical representation against a two-element one when orthography was substituted by a bench of symbols.

Given that this thesis work focused on the acquisition of two L2 formal dimensions, i.e., spoken and written forms, and their connection to semantics shared across languages, we ensured that L2 vocabulary learning was experienced without stemming (explicitly) on L1. Therefore, the acquisition of L2 word meaning could only be conducted through the evaluation of the phono-semantic or the ortho-semantic links, leaving no room to determine whether L2 orthography played a direct facilitation on semantic learning. Discriminating between these two alternatives may provide some further evidence for the direct/indirect connection between orthography and semantic. Recently, Krepel, de Bree, and de Jong (2020) explored the orthographic facilitation in L2 word learning by using both a forward (L1 to L2) and a backward (L2 to L1) translation learning paradigm among sixth graders. In their study, they made Dutch monolinguals learn 12 (abstract) English words, half of which included an incongruent mapping between letter and sound. The 2x2x2 factorial design included thus two learning methods (orthographic vs. non-orthographic learning method), two different direction of translation (backward learning vs. forward learning) and two modalities of the degree of letter/sound mapping (congruent vs. incongruent). During the learning phase, the L2 spoken form was either associated with its related L2 written form, i.e., orthographic learning method or not, i.e., non-orthographic learning method. For the forward translation learning, the L1 written translation equivalent was presented before the L2 written and spoken form, whereas it was displayed after the L2 ones for the backward translation learning. As for the testing phase, the learning of word meaning was assessed using a forward (pronouncing the L2 English word associated to the L1 Dutch word presented on the computer screen) and a backward (typing the spelling of the L1 Dutch word associated with the L2 English spoken word) translation task, which revealed enhanced performance among children who learned English words with orthography compared to those who did not. Interestingly, contrasting between backward and forward translation allowed to disentangle between a direct and an indirect advantage of orthography on access to semantic. Indeed, the forward translation task required participants to pronounce the L2 spoken form from the L1 written form, whereas for the background task, they had to type the L2 word associated with the L1 spoken form. Importantly, the orthographic advantage on L2 pronunciation learning was impacted by grapheme-to-phoneme congruency, with larger accurate performance for congruent over incongruent words. This was however restricted to the forward translation task. This suggested an indirect connection between orthography and meaning, through a mediation by L2 phonology. These results are not consistent with the connectionist triangle framework, according to which there is a direct connection between orthography and semantics (Harm & Seidenberg, 2004). Such results may be also inconsistent with the lexical quality hypothesis (Perfetti & Hart, 2002), which assumed that exposure to the written form led to the direct retrieval of its meaning. However, it is still possible that the presence of orthography during learning led to an altered encoding of novel phonological forms for which there was an incongruent mapping between letters and sounds. This might have contributed to a decreased accurate pronunciation of L2 words in the forward translation task compared to congruent L2 words. Additional evidence came from the early production of L2 novel phonological form for incongruent English words during forward translation learning phase. Indeed, a recent study reported a detrimental encoding of novel phonological forms, if they were pronounced immediately during the learning phase (see., Kapnoula & Samuel, in prep). Thus, further studies are required to confirm whether L2 orthography has a direct connection to semantics or not.

In the previous sections, we have documented the contribution of orthography on the acquisition of written and spoken wordforms as well as their connections with semantics. In the following part of the General discussion, we will address the modulation of the orthographic facilitation on L2 vocabulary learning by L1 linguistic skills as well as by level of school instruction, to which we will refer as grade level.

On the contribution of L1 linguistic skills vs. grade on L2 vocabulary learning

In this doctoral work, we explored whether the benefit of orthography was modulated by the degree of L1 mastery as well as by the grade level. Importantly, in Study 1, fifth graders outperformed the third graders on the three testing tasks, i.e., forced-choice picture recognition task, go/no-go spoken recognition task and orthographic judgment task. Importantly, although fifth graders outperformed the third graders on all three experimental tasks, we did not report any interaction between the learning method and grade, except for the go/no-go spoken recognition task in Study 1a. Therefore, although fifth graders outperformed the third graders on all three experimental tasks in Study 1, the benefit of orthography was not modulated by the grade level. In addition, we explored more specifically whether the benefit of orthography was associated with L1 reading and vocabulary skills. Indeed, previous L1 vocabulary studies reported a relative significant correlation between reading skills and the orthographic facilitation. For example, Ricketts et al. (2009) reported that better readers among their group of third graders benefitted more from orthography during learning. In the Study 1 however, we failed to report a systematic (and significant) correlation between L1 reading skills and performance to the testing tasks, especially for spoken and written recognition tasks, among both groups of third and fifth graders. These results have to be taken with caution, due to the nature of the reading task. Indeed, contrary to previous studies that used the Test of Word Reading Efficiency (TOWRE; Torgesen, Wagner, & Rashotte, 1999) to assess their participants' word and nonword reading skills, we opted for the Alouette task (Lefavrais, 1967; 2005) which is composed of an unpredictable text that included 265 French words, and required participants to use the sublexical procedure, i.e., decoding, rather than the lexical one (see, DRC; Coltheart et al., 2001). In addition, this text is included in an opaque context that may mislead participants during reading. The Alouette task is particularly appropriate for screening dyslexia (Cavalli et al., 2018).

Although surprising, these results are in line with the literature in L1 vocabulary learning that reported no systematic relationship between L1 reading skills and learning performance. As a reminder, the benefit of orthography on L1 (pseudoword) learning has also been documented among children suffering from developmental language disorders (Ricketts et al., 2015) or dyslexia (Baron et al., 2018). In light with these evidences, we suggested that a minimal orthographic knowledge is required to support L2 word learning. The benefit of orthography arose early during L2 learning and was rather retrieved independently of participants linguistic and cognitive skills. However, further studies are required to confirm these assumptions by using more reliable L1 linguistic background tests.

We thus explored the contribution of L1 reading abilities on L2 vocabulary learning. In addition, it is also possible that the (relative) mastery of two spoken and written systems may also impact the vocabulary learning dynamics. This assumption will be addressed in the following section, to explore whether being a bilingual led to a facilitated acquisition of L3 vocabulary.

Evidence for a generalized bilingual advantage on L3 vocabulary learning extended to classroom-immersion children

In Study 3, we reported that classroom-immersion children outperformed their monolingual peers on two of the three experimental tasks, i.e., forced-choice picture recognition task and go/no-go spoken recognition task. This suggests that, except for orthographic learning, the bilingual advantage could be generalized for all items. It does not seem to be modulated by or restricted to the form and meaning overlap between the English words to be learnt and German words. For the orthographic judgment task however, the bilingual advantage was restricted to L2/L3 (German/English) non-identical cognate words. This supported that foreign language was already activated in early steps of L3 vocabulary acquisition, an observation which is consistent with the scaffolding account for L3 word learning (e.g., Bartolotti & Marian, 2016, see., Chapter III-3.3.3, for additional experimental evidence). The scaffolding account posits that a novel language acquisition is mediated by one of the pre-existing languages, by anchoring the "weak" language to one more experienced one. Interestingly, here, the learning of L3 written forms seemed to be glued to L2 written ones, supporting that the bilingual advantage was restricted to the learning of L2/L3 cognate words.

The lack of cognate facilitation for two of the three experimental tasks was nonetheless surprising and could be explained by two complementary hypotheses. First, in our study, the cognate facilitation might have been hindered by the differential degree of overlap between orthography and phonology. Indeed, L3 words had a larger overlap between L2 and L3 in written rather than in spoken modality (mean Levenshtein distance: 2.36 vs 3.32 respectively). Given that words were displayed in both modalities during learning, this may have impaired the cognate facilitation effect. This hypothesis is consistent with Valente et al. (2018), who reported that the amplitude of the cognate facilitation was modulated by the degree of phonological overlap with L1. Indeed, the cognate advantage decreased with increasing distance between L2/L3 cross-linguistic orthographic and phonological forms. Second, it is also possible that participants had no previous knowledge of some of the L2 translation equivalents associated to the L2/L3 cognate words. Although we ensured that the L2 translation equivalents of the selected L3 English words were already known by participants prior to the study through a questionnaire addressed to their teachers, we observed at post-test that classroom-immersion children had some difficulties in spontaneously naming the German words when using a L2 picture naming task. Nonetheless, statistical analyses conducted on "known" items did not reveal any significant cognate facilitation effect. In addition, we did not emphasize the presence of L2/L3 cognate words during learning, which could have impaired the vocabulary learning advantage in classroom-immersion children. Indeed, the cognate facilitation effect could be dependent of participants' cognate awareness, i.e., the explicit knowledge of shared formal overlap (in spoken and in written overlap) and meaning of a novel word with an already-known one in another language (see., Malabonga et al., 2008). However, a recent study reported tht cognate awareness did not lead to facilitated learning of L1/L2 cognate words, supporting that cognate facilitation in vocabulary learning does not necessary rely on explicit learning to arise (see., Otwinowska et al., 2020). Future studies require to assess the cognate facilitation on L3 vocabulary learning by using more frequent cognate words. Furthermore, additional exposure to foreign language may be required for such a cognate facilitation to arise.

Pending contradictory results, these observations thus suggested a limited contribution of L2/L3 cognateness on L3 vocabulary learning, suggesting that the bilingual advantage cannot be accounted by the cross-linguistic similarities conveyed by cognate words. Nonetheless, in light with our results and consistent with Kaushanskaya and Marian (2009a), the bilingual advantage on L3 vocabulary learning, i.e., phonological and semantic (through the connection between spoken form and its associated meaning), could be attributed to the enhanced phonological discrimination skills among bilinguals, given that they had to deal with two phonological systems early in life.

Importantly, to date, only two studies reported a bilingual advantage on L3 vocabulary learning among children, conducted with rather young aged children exposed to an L2 since kindergarten and with an average cumulated exposure to L2 of seven to eight months (Eviatar et al., 2018) and two years (Kaushanskaya et al., 2014). In the Study 3, classroom-immersion children were exposed to German as a foreign language for five years. Nonetheless, although the participants have had a longer exposure to foreign language in time compared to those in Kaushanskaya et al. (2014), it is important to note that the participants had an equivalent exposure to both L1 and L2 at school. For Kaushanskaya et al. (2014) however, children attending a dual-language immersion to foreign language were mainly exposed to L2 on a 80 % - 20 % L2/L1 ratio. Therefore, our study provided us some evidence that the bilingual advantage on L3 vocabulary learning could be extended to children attending a classroom-immersion to foreign language. In addition, we reported comparable conclusions compared to the two previous studies conducted among children, but for a different type of linguistic immersion program. This aimed for a generalized bilingual advantage in children considered as emergent bilinguals.

Setting of the experimental parameters

Throughout this doctoral dissertation, we sought to set the "optimal" experimental parameters, i.e., the size of the learning list and the number of exposures to each item, that are required to conduct a replicable L2 vocabulary learning study by using a paired-associate word learning paradigm. As a reminder, several studies conducted on L1 vocabulary learning were unable to address the orthographic facilitation on semantic learning due to ceiling effects in the word-picture matching task (see., Chambré et al., 2017; Jubenville et al., 2014; Rosenthal & Ehri, 2008; Valentini et al., 2018). We had seen that these effects could be associated to the limited size of the learning list as well as the repeated exposure to learning material. Thus, it was necessary to define a compromise to ensure that the children's learning abilities were not overcome but also to avoid the ceiling effects associated with the restricted number of items. When contrasting between two learning loads, i.e., 16 vs. 24 German words, we observed a comparable proportion of learning performance among third and fifth graders. Furthermore, the benefit of orthography was retrieved for both modalities of the size of the learning list.

We also set the required number of exposures to each item during the learning phase that led to the highest learning performance. As a reminder, according to Chambré et al. (2017), the presence of orthography during learning fastened the acquisition of L1 vocabulary and thus reduced the number of exposures required to reach the maximal proportion of word learning.

Indeed, they reported that first graders performed accurately after only six exposures to the learning material. Nonetheless, it should be underlined that children were only exposed to six L1 pseudowords. Thus, the required exposure to items might be also dependent of the size of the learning list. In Study 1c, we reported that participants reached a learning peak after nine exposure to each German word with an accurate association between spoken form and picture for about 15.6 (65%) and 17.5 (73%) out of the 24 German words among third and fifth graders. Supplementary exposure to German words did not led to significant higher performance to the forced-choice picture recognition task, for which we reported a glass ceiling in the word learning performance. Interestingly, this glass ceiling was reported among all our experimental studies regardless of participants' cognitive and linguistic skills, but to which we cannot provide any explanation yet.

Importantly, the benefit of orthography was already marginally significant after six exposures to the German words but reached significance from nine repetitions. Therefore, we set the optimal experimental parameters, i.e., 24 items and nine required exposure to each item, on which we stemmed to explore the contribution of orthography on L2 vocabulary learning. Interestingly, supplementary support of the adequation of our experimental setting with L2/L3 word learning studies when using a paired-associate word learning paradigm came from Study 3 for which monolingual children were able to associate the spoken form correctly with its concept for about 39 of the 44 English (89%) words after nine exposure to each word during learning phase.

Implications for (cognitive) developmental models of bilingualism

In light of our results, there was a consistent benefit of orthography on the acquisition and memorization of L2 vocabulary, i.e., orthographic, phonological and semantic learning, in early steps of foreign language acquisition. To date, there were only two developmental models of bilingualism, i.e., RHM (Kroll & Stewart, 1994, see, Chapter I-1.2, for its presentation) and BIAd (Grainger et al., 2010, see., Chapter I-1.5 for its detailed presentation) to account for the initial steps of foreign language acquisition. However, these models in their current version do not include lexical nor sublexical levels to account for the early processing of orthography (and phonology) in L2 vocabulary learning. Recently, the ontogenesis model of L2 lexical representation (see Bordag et al., 2021) has been proposed to account for the development of lexical representations from the initial exposure to foreign language. In this model, the early lexical representation in foreign language are assumed to be relatively fuzzy (incomplete and partially incorrect), but, with growing experience with L2, the degree of lexical acquisition for each dimension (orthography, phonology and semantic and their connections) may increase to reach its optimum. This model is also consistent with the lexical quality hypothesis (e.g., Perfetti & Hart, 2002). However, contrary to the previous cognitive models of bilingualism, the ontogenesis model is focused within the lexical level and, thus, cannot provide information on the interlinguistic dynamics between L1 and L2. In addition, following the adagium "no model should be left behind" (Kroll et al., 2010) and in light with our experimental observations, the pre-existing (developmental) cognitive models of bilingualism should be updated to include sublexical and lexical dimensions to account for the (early) benefit of orthography on L2 learning.

Implications for the teaching of foreign languages?

This doctoral work provided the first evidence of an orthographic advantage on L2 vocabulary learning. In light with our studies, there was a strong relationship between orthography and phonology for learning L2 vocabulary. The simultaneous presentation of both (multiple sources of) spoken form and written form favored the acquisition and memorization of orthographic, phonological and semantic (through the connection between phonology and semantics) representation in L2.

Interestingly, we focused on an explicit learning of L2 words in the experimental studies, although no direct attention to written information was driven during learning. Nonetheless, there is no consensus in the literature about the distinction between explicit and implicit learning. Indeed, most of the studies that investigated the orthographic facilitation on L2 vocabulary learning through a paired-associate word-learning paradigm referred to implicit learning (Ehri & Wilce, 1979; Jubenville et al., 2014; Ricketts et al., 2009, 2015; Rosenthal & Ehri, 2008). Contrary to our explicit learning, Krashen (1981, 1982, 1992) supported that implicit learning was the optimal way to acquire a foreign language, especially for grammatical rules learning.

Nonetheless, although it would be too hasty to address some implications of our results for the teaching of foreign languages, the dual coding of spoken and written information seems promising to help children (and adults) acquiring early vocabulary knowledge in L2 without stemming explicitly on L1 and future studies should be conducted to complete our initial researches. This position is in line with Rosenthal and Ehri (2007) who preconized to include orthography in the theories of (L1) vocabulary learning. To conclude, although learning a foreign language goes beyond vocabulary learning, it should be mentioned that word learning is crucial for oral communication as well as for speech comprehension. It is also associated with the learning and mastering of written language as well as for academic success.

Conclusion

In the present doctoral work, we have reported that the presence of written information helped children to learn vocabulary in a foreign language. Our results are in line with the previous studies conducted on L1 (pseudo)word learning (see Colenbrander et al., 2019 for review). More especially, to our knowledge, this is the first research work that documented the benefit of orthography on learning two formal representations, i.e., L2 orthographic and L2 phonological representation, as well as the reciprocal L2 phonological to semantics connection. Importantly, this orthographic facilitation was consistently retrieved in Study 1 and was independent of the grade level, thus supporting that this learning advantage appears at the early steps of foreign language acquisition.

Furthermore, the contribution of orthography on L2 word learning was not impacted by the L1 linguistic skills, supporting that a minimal orthographic knowledge was required for children to rely on orthography to drive novel word learning. These results are consistent with previous studies that reported a benefit of orthography on L1 vocabulary learning among children with dyslexia (see Baron et al., 2018) or with developmental language disorder (Ricketts et al., 2015). Nonetheless, we identified some limitations associated with our linguistic background measures and future studies are required to explore the potential mediating impact of L1 reading skills on L2 vocabulary learning. Importantly, although there was an effect of the grade level on L2 learning performance, it did not modulate the amount of orthographic facilitation between fifth and third graders, supporting once again, that the benefit of orthography did not require participants to have mastered reading to arise.

In this doctoral work, we also explored the nature of the orthographic facilitation by dissociating between a pure orthographic advantage and a visual advantage. The presence of visual (undecodable) symbols during learning did not help children to enhance their learning performance compared to the ones attending an orthographic learning method. Nonetheless, it is necessary to explore more precisely this assumption by modifying the visual clues provided during learning. Interestingly, the benefit of orthography during learning could also be attributed to the dual-coding, given that both spoken and written information were provided during learning, in line with the lexical quality hypothesis (Perfetti & Hart, 2002). However, recent findings did not support this assumption (Pattamadilok et al., 2021).

In addition, we also explored the moderating effect of incongruent letter/sound mappings on the benefit of orthography on L2 vocabulary learning. Unfortunately, due to the sanitary crisis, data collection was prematurely stopped and we could only provide some preliminary results for the orthographic learning method. Nonetheless, we only reported an impact of grapheme/phoneme incongruency for the go/no-go spoken recognition task immediately after learning. However, after a one-week delay, fifth graders performed equally well for both congruent and incongruent German words. These results supported that the encoding of novel phonological forms relied on a different time-course according to the degree of letter/sound congruency. Our results were interpreted through the ontogenetic model of L2 lexical representation (Bordag et al., 2021), as well as in terms of lexical fuzziness (Kapnoula, 2021). However, we cannot dissociate whether this delayed acquisition of incongruent phonological forms relies exclusively on an orthographic recoding (see Ehri, 2014 for the orthographic mapping) or one offline-sleep consolidation (see Brown et al., 2012; Henderson et al., 2012). Thus, future data collection is required to confirm these preliminary results as well as to include a non-orthographic learning method to explore the presence (or absence) of orthographic facilitation when learning incongruent L2 words.

Furthermore, along this doctoral work, we ensured to set the experimental parameters that were optimal for children to learn L2 vocabulary, i.e., the size of the learning list and the degree of exposure to each item that we applied to all our studies. This ensured us to minimize the potential methodological bias associated with the selection of these parameters. In addition, we used a (consistent) paired-associate word-learning paradigm which was particularly adapted to conduct L2 vocabulary learning studies.

To conclude, although this doctoral work has provided some (consistent) evidences for a benefit of orthography on L2 vocabulary learning, it has also left the room open for multiple research questions that we hope to be able to explore in future studies.

References

Abu-Rabia, S., & Sanitsky, E. (2010). Advantages of bilinguals over monolinguals in learning a third language. *Bilingual Research Journal*, *33*(2), 173-199. https://doi.org/10.1080/15235882.2010.502797

Adler, M. K. (1977). *Collective and individual bilingualism: A sociolinguistic study*. Hamburg: Buske.

Altarriba, J., & Mathis, K. M. (1997). Conceptual and lexical development in second language acquisition. *Journal of memory and language, 36*(4), 550-568. https://doi.org/10.1006/jmla.1997.2493

Anglin, J. M. (1993). Vocabulary development: A morphological analysis. Monographs of the Society for Research in Child Development, 58(10, Serial No. 238), i-186

Anglin, J. M., & Miller, G. A. (2000). Vocabulary development: A morphological analysis. Wiley-Blackwell.

Antoniou, M. (2019). The advantages of bilingualism debate. *Annual Review of Linguistics*, *5*, 395-415. https://doi.org/10.1146/annurev-linguistics-011718-011820

Baker, C., & Wright, W. E. Foundations of Bilingual Education and Bilingualism.

Bakker, I., Takashima, A., van Hell, J. G., Janzen, G., & McQueen, J. M. (2014). Competition from unseen or unheard novel words: Lexical consolidation across modalities. *Journal of Memory and Language*, *73,* 116-130. https://doi.org/10.1016/j.jml.2014.03.002

Bakker, I., Takashima, A., Van Hell, J. G., Janzen, G., & McQueen, J. M. (2015). Changes in theta and beta oscillations as signatures of novel word consolidation. *Journal of cognitive neuroscience*, *27*(7), 1286-1297. https://doi.org/10.1162/jocn_a_00801

Balota, D. A., Yap, M. J., Hutchison, K. A., Cortese, M. J., Kessler, B., Loftis, B., ... & Treiman, R. (2007). The English lexicon project. *Behavior research methods*, *39*(3), 445-459. https://doi.org/10.3758/BF03193014

Barac, R., & Bialystok, E. (2012). Bilingual effects on cognitive and linguistic development: Role of language, cultural background, and education. *Child development*, *83*(2), 413-422. https://doi.org/10.1111/j.1467-8624.2011.01707.x

Barac, R., Bialystok, E., Castro, D. C., & Sanchez, M. (2014). The cognitive development of young dual language learners: A critical review. *Early childhood research quarterly*, *29*(4), 699-714. https://doi.org/10.1016/j.ecresq.2014.02.003

Baron, L. S., Hogan, T. P., Alt, M., Gray, S., Cabbage, K. L., Green, S., & Cowan, N. (2018). Children with dyslexia benefit from orthographic facilitation during spoken word learning. *Journal of Speech, Language, and Hearing Research*, *61*(8), 2002-2014. https://doi.org/10.1044/2018_JSLHR-L-17-0336

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of memory and language*, *68*(3), 255-278. https://doi.org/10.1016/j.jml.2012.11.001

Barrios, S. L., & Hayes-Harb, R. (2020). Second language learning of phonological alternations with and without orthographic input: Evidence from the acquisition of a German-like voicing alternation. *Applied Psycholinguistics*, *41*(3), 517-545. https://doi.org/10.1017/S0142716420000077

Bartolotti, J., & Marian, V. (2012a). Language learning and control in monolinguals and bilinguals. *Cognitive science*, *36*(6), 1129-1147. https://doi.org/10.1111/j.1551-6709.2012.01243.x

Bartolotti, J., & Marian, V. (2012b). Bilingual memory: structure, access, and processing. *Memory, language, and bilingualism: Theoretical and applied approaches*, 7-47.

Bartolotti, J., & Marian, V. (2014). Wordlikeness and novel word learning. In *Proceedings of the Annual Meeting of the Cognitive Science Society* (Vol. 36, No. 36).

Bartolotti, J., & Marian, V. (2017a). Bilinguals' existing languages benefit vocabulary learning in a third language. *Language learning*, *67*(1), 110-140. https://doi.org/10.1111/lang.12200

Bartolotti, J., & Marian, V. (2017b). Orthographic knowledge and lexical form influence vocabulary learning. *Applied psycholinguistics*, *38*(2), 427-456. https://doi.org/10.1017/S0142716416000242

Bassetti, B. (2017). Orthography affects second language speech: Double letters and geminate production in English. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *43*(11), 1835. https://doi.org/10.1037/xlm0000417

Bassetti, B., Sokolović-Perović, M., Mairano, P., & Cerni, T. (2018). Orthography-induced length contrasts in the second language phonological systems of L2 speakers of English: Evidence from minimal pairs. *Language and speech*, *61*(4), 577-597. https://doi.org/10.1177/0023830918780141

Bates, D., Kliegl, R., Vasishth, S., & Baayen, H. (2015). Parsimonious mixed models. *arXiv preprint arXiv:1506.04967*.

Beck, I., & McKeown, M. (2002). Bringing Words to Life: Robust Vocabulary Instruction.

Bialystok, E., & Viswanathan, M. (2009). Components of executive control with advantages for bilingual children in two cultures. *Cognition*, *112*(3), 494-500. https://doi.org/10.1016/j.cognition.2009.06.014

Bialystok, E. (2001). *Bilingualism in development: Language, literacy, and cognition*. Cambridge University Press.

Bialystok, E., Luk, G., & Kwan, E. (2005). Bilingualism, biliteracy, and learning to read: Interactions among languages and writing systems. *Scientific studies of reading*, *9*(1), 43-61. https://doi.org/10.1207/s1532799xssr0901_4

Biemiller, A., & Boote, C. (2006). An effective method for building meaning vocabulary in primary grades. *Journal of educational psychology*, *98*(1), 44. https://doi.org/10.1037/0022-0663.98.1.44

Biemiller, A., & Slonim, N. (2001). Estimating root word vocabulary growth in normative and advantaged populations: Evidence for a common sequence of vocabulary acquisition. *Journal of educational psychology*, *93*(3), 498. https://doi.org/10.1037/0022-0663.93.3.498

Biemiller, A. (2003). Vocabulary: Needed if more children are to read well. *Reading psychology*, *24*(3-4), 323-335. https://doi.org/10.1080/02702710390227297

Bijeljac-Babic, R., Biardeau, A., & Grainger, J. (1997). Masked orthographic priming in bilingual word recognition. *Memory & Cognition*, *25*(4), 447-457. https://doi.org/10.3758/BF03201121

Birdsong, D. (Ed.). (1999). *Second language acquisition and the critical period hypothesis*. Routledge.

Bogulski, C. A., Bice, K., & Kroll, J. F. (2019). Bilingualism as a desirable difficulty: Advantages in word learning depend on regulation of the dominant language. *Bilingualism: Language and Cognition*, *22*(5), 1052-1067. https://doi.org/10.1017/S1366728918000858

Bonin, P., Méot, A., & Bugaiska, A. (2018). Concreteness norms for 1,659 French words: Relationships with other psycholinguistic variables and word recognition times. *Behavior research methods*, *50*(6), 2366-2387. https://doi.org/10.3758/s13428-018-1014-y

Bordag, D., Gor, K., & Opitz, A. (2021). Ontogenesis Model of the L2 Lexical Representation. *Bilingualism: Language and Cognition*, 1-17. https://doi.org/10.1017/S1366728921000250

Bosse, M. L., Chaves, N., Largy, P., & Valdois, S. (2015). Orthographic learning during reading: the role of whole-word visual processing. *Journal of Research in Reading*, *38*(2), 141-158. https://doi.org/10.1111/j.1467-9817.2012.01551.x

Brosseau-Lapré, F., Rvachew, S., Clayards, M., & Dickson, D. (2011). Stimulus variability and perceptual learning of nonnative vowel categories. *Applied Psycholinguistics*, *34*(3), 419-441. https://doi.org/10.1017/S0142716411000750

Brown, H., Weighall, A., Henderson, L. M., & Gaskell, M. G. (2012). Enhanced recognition and recall of new words in 7-and 12-year-olds following a period of offline consolidation. *Journal of experimental child psychology*, *112*(1), 56-72. https://doi.org/10.1016/j.jecp.2011.11.010

Brysbaert, M., & Duyck, W. (2010). Is it time to leave behind the Revised Hierarchical Model of bilingual language processing after fifteen years of service?. *Bilingualism:*

Language and cognition, *13*(3), 359-371. https://doi.org/10.1017/S1366728909990344

Brysbaert, M., Van Wijnendaele, I., & Duyck, W. (2002). On the temporal delay assumption and the impact of non-linguistic context effects. *Bilingualism: Language and Cognition*, *5*(3), 199-201. https://doi.org/10.1017/S1366728902213012

Bürki, A., Welby, P., Clément, M., & Spinelli, E. (2019). Orthography and second language word learning: Moving beyond “friend or foe?”. *The Journal of the Acoustical Society of America*, *145*(4), EL265-EL271. https://doi.org/10.1121/1.5094923

Castles, A., & Nation, K. (2008). Learning to be a good orthographic reader. *Journal of Research in Reading*, *31*(1), 1-7. https://doi.org/10.1111/j.1467-9817.2007.00367.x

Castles, A., Bates, T., Coltheart, M., Luciano, M., & Martin, N. G. (2006). Cognitive modelling and the behaviour genetics of reading. *Journal of Research in Reading*, *29*(1), 92-103. https://doi.org/10.1111/j.1467-9817.2006.00294.x

Cavalli, E., Colé, P., Leloup, G., Poracchia-George, F., Sprenger-Charolles, L., & El Ahmadi, A. (2018). Screening for dyslexia in French-speaking university students: An evaluation of the detection accuracy of the Alouette test. *Journal of learning disabilities*, *51*(3), 268-282. https://doi.org/10.1177/0022219417704637

Cenoz, J., & Valencia, J. F. (1994). Additive trilingualism: Evidence from the Basque country. *Applied psycholinguistics*, *15*(2), 195-207. https://doi.org/10.1017/S0142716400005324

Cerni, T., Bassetti, B., & Masterson, J. (2019). Effects of orthographic forms on the acquisition of novel spoken words in a second language. *Frontiers in Communication*, *4*, 31. https://doi.org/10.3389/fcomm.2019.00031

Chambré, S. J., Ehri, L. C., & Ness, M. (2017). Orthographic facilitation of first graders' vocabulary learning: Does directing attention to print enhance the effect?. *Reading and Writing*, *30*(5), 1137-1156. https://doi.org/10.1007/s11145-016-9715-z

Chambrè, S. J., Ehri, L. C., & Ness, M. (2020). Phonological decoding enhances orthographic facilitation of vocabulary learning in first graders. *Reading and Writing*, *33*(5), 1133-1162. https://doi.org/10.1007/s11145-019-09997-w

Christophersen, P. (1948). Bilingualism.

Clark EV (2009) First language acquisition. Cambridge University Press.

Colenbrander, D., Miles, K. P., & Ricketts, J. (2019). To see or not to see: How does seeing spellings support vocabulary learning?. *Language, speech, and hearing services in schools*, *50*(4), 609-628. https://doi.org/10.1044/2019_LSHSS-VOIA-18-0135

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: a dual route cascaded model of visual word recognition and reading aloud. *Psychological review*, *108*(1), 204.

Comesaña, M., Perea, M., Piñeiro, A., & Fraga, I. (2009). Vocabulary teaching strategies and conceptual representations of words in L2 in children: Evidence with novice learners. *Journal of Experimental Child Psychology*, *104*(1), 22-33. https://doi.org/10.1016/j.jecp.2008.10.004

Comesaña, M., Soares, A. P., Sánchez-Casas, R., & Lima, C. (2012). Lexical and semantic representations in the acquisition of L2 cognate and non-cognate words: Evidence from two learning methods in children. *British Journal of Psychology*, *103*(3), 378-392. https://doi.org/10.1111/j.2044-8295.2011.02080.x

Comesaña, M., Ferré, P., Romero, J., Guasch, M., Soares, A. P., & García-Chico, T. (2015). Facilitative effect of cognate words vanishes when reducing the orthographic overlap: The role of stimuli list composition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *41*(3), 614. https://doi.org/10.1037/xlm0000065

Comesaña, M., Moreira, A. J., Valente, D., Hernández-Cabrera, J. A., & Soares, A. P. (2019). List composition effect on cognate and non-cognate word acquisition in children. *Linguistic Approaches to Bilingualism*, *9*(2), 289-313. https://doi.org/10.1075/lab.16034.com

Comesaña, M., Soares, A. P., Sánchez-Casas, R., & Lima, C. (2012). Lexical and semantic representations in the acquisition of L2 cognate and non-cognate words: Evidence from two learning methods in children. *British Journal of Psychology*, *103*(3), 378-392. https://doi.org/10.1111/j.2044-8295.2011.02080.x

Commissaire, E., Duncan, L. G., & Casalis, S. (2014). Grapheme coding in L2: How do L2 learners process new graphemes?. *Journal of Cognitive Psychology*, *26*(7), 725-739. https://doi.org/10.1080/20445911.2014.951363

Cunningham, A. E., Perry, K. E., Stanovich, K. E., & Share, D. L. (2002). Orthographic learning during reading: Examining the role of self-teaching. *Journal of experimental child psychology*, *82*(3), 185-199. https://doi.org/10.1016/S0022-0965(02)00008-5

Davis, M. H., Di Betta, A. M., Macdonald, M. J., & Gaskell, M. G. (2009). Learning and consolidation of novel spoken words. *Journal of cognitive neuroscience, 21*(4), 803-820. https://doi.org/10.1162/jocn.2009.21059

De Groot, A. M., & Keijzer, R. (2000). What is hard to learn is easy to forget: The roles of word concreteness, cognate status, and word frequency in foreign-language vocabulary learning and forgetting. *Language learning*, *50*(1), 1-56. https://doi.org/10.1111/0023-8333.00110

De Groot, A. M., & Nas, G. L. (1991). Lexical representation of cognates and noncognates in compound bilinguals. *Journal of memory and language*, *30*(1), 90-123. https://doi.org/10.1016/0749-596X(91)90012-9

de Groot, A. M. (1992). Determinants of word translation. *Journal of Experimental Psychology: Learning, memory, and cognition*, *18*(5), 1001. https://doi.org/10.1037/0278-7393.18.5.1001

de Groot, A. M., Dannenburg, L., & Vanhell, J. G. (1994). Forward and backward word translation by bilinguals. *Journal of memory and language*, *33*(5), 600-629. https://doi.org/10.1006/jmla.1994.1029

de Groot, A. M. (1989). Representational aspects of word imageability and word frequency as assessed through word association. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *15*(5), 824.

de Jong, P. F., & Share, D. L. (2007). Orthographic learning during oral and silent reading. *Scientific Studies of Reading*, *11*(1), 55-71. https://doi.org/10.1207/s1532799xssr1101_4

De Wilde, V., Brysbaert, M., & Eyckmans, J. (2020). Learning English through out-of-school exposure. Which levels of language proficiency are attained and which types of input are important?. *Bilingualism: Language and Cognition*, *23*(1), 171-185.

Diekelmann, S., & Born, J. (2010). The memory function of sleep. *Nature Reviews Neuroscience*, *11*(2), 114-126. https://doi.org/10.1038/nrn2762

Dijkstra, T., Grainger, J., & Van Heuven, W. J. (1999). Recognition of cognates and interlingual homographs: The neglected role of phonology. *Journal of Memory and language*, *41*(4), 496-518. https://doi.org/10.1006/jmla.1999.2654

Dijkstra, T., & Kroll, J. F. (2005). Bilingual visual word recognition and lexical access. *Handbook of bilingualism: Psycholinguistic approaches*, *178*, 201.

Dijkstra, T., Miwa, K., Brummelhuis, B., Sappelli, M., & Baayen, H. (2010). How cross-language similarity and task demands affect cognate recognition. *Journal of Memory and language*, *62*(3), 284-301. https://doi.org/10.1016/j.jml.2009.12.003

Dijkstra, T., & Van Heuven, W. J. (2002). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and cognition*, *5*(3), 175-197. https://doi.org/10.1017/S1366728902003012

Dijkstra, T., Van Jaarsveld, H., & Ten Brinke, S. (1998). Interlingual homograph recognition: Effects of task demands and language intermixing. *Bilingualism: Language and cognition*, *1*(1), 51-66. https://doi.org/10.1017/S1366728998000121

Dijkstra, T., Wahl, A., Buytenhuijs, F., Van Halem, N., Al-Jibouri, Z., De Korte, M., & Rekké, S. (2018). Multilink: a computational model for bilingual word recognition and word translation. *Bilingualism: Language and Cognition*, *22*(4), 657-679. https://doi.org/10.1017/S1366728918000287

Dodd, B. J., So, L. K., & Lam, K. K. (2008). Bilingualism and learning: The effect of language pair on phonological awareness abilities. *Australian Journal of Learning Difficulties*, *13*(2), 99-113.

Dong, Y., Gui, S., & MacWhinney, B. (2005). Shared and separate meanings in the bilingual mental lexicon. *Bilingualism: Language and Cognition*, *8*(3), 221-238.

Duff, F. J., & Hulme, C. (2012). The role of children's phonological and semantic knowledge in learning to read words. *Scientific Studies of Reading*, *16*(6), 504-525. https://doi.org/10.1080/10888438.2011.598199

Dufour, R., & Kroll, J. F. (1995). Matching words to concepts in two languages: A test of the concept mediation model of bilingual representation. *Memory & Cognition*, *23*(2), 166-180. https://doi.org/10.3758/BF03197219

Gaskell, M. G., & Dumay, N. (2003). Lexical competition and the acquisition of novel words. *Cognition*, *89*(2), 105-132. https://doi.org/10.1016/S0010-0277(03)00070-2

Duñabeitia, J. A., & Carreiras, M. (2015). The bilingual advantage: Acta est fabula. *Cortex*, *73*, 371-372. https://doi.org/10.1016/j.cortex.2015.06.009

Duñabeitia, J. A., & Vidal-Abarca, E. (2008). Children like dense neighborhoods: Orthographic neighborhood density effects in novel readers. *The Spanish journal of psychology*, *11*(1), 26-35. https://doi.org/10.1017/S113874160000408X

Duñabeitia, J. A., Crepaldi, D., Meyer, A. S., New, B., Pliatsikas, C., Smolka, E., & Brysbaert, M. (2018). MultiPic: A standardized set of 750 drawings with norms for six European languages. *Quarterly Journal of Experimental Psychology*, *71*(4), 808-816. https://doi.org/10.1080/17470218.2017.1310261

Duyck, W., & Brysbaert, M. (2004). Forward and backward number translation requires conceptual mediation in both balanced and unbalanced bilinguals. *Journal of Experimental Psychology: Human Perception and Performance*, *30*(5), 889. https://doi.org/10.1037/0096-1523.30.5.889

Ehri, L. C., & Wilce, L. S. (1979). The mnemonic value of orthography among beginning readers. *Journal of Educational Psychology*, *71*(1), 26. https://doi.org/10.1037/0022-0663.71.1.26

Ehri, L. C. (1995). Phases of development in learning to read words by sight. *Journal of research in reading*. https://doi.org/10.1111/j.1467-9817.1995.tb00077.x

Ehri, L. C. (1998). Grapheme—phonerne knowledge is essential for learning to read words in English. *Word recognition in beginning literacy, 1*.

Ehri, L. C. (2005). Learning to read words: Theory, findings, and issues. *Scientific Studies of reading*, *9*(2), 167-188. https://doi.org/10.1207/s1532799xssr0902_4

Ehri, L. C. (2014). Orthographic mapping in the acquisition of sight word reading, spelling memory, and vocabulary learning. *Scientific Studies of Reading*, *18*(1), 5-21. https://doi.org/10.1080/10888438.2013.819356

Elbro, C., & De Jong, P. F. (2017). Orthographic learning is verbal learning. *Theories of reading development*, 169-189.

Erdener, V. D., & Burnham, D. K. (2005). The role of audiovisual speech and orthographic information in nonnative speech production. *Language Learning*, *55*(2), 191-228. https://doi.org/10.1111/j.0023-8333.2005.00303.x

Escudero, P. (2015). Orthography plays a limited role when learning the phonological forms of new words: The case of Spanish and English learners of novel Dutch words. *Applied Psycholinguistics*, *36*(1), 7-22. https://doi.org/10.1017/S014271641400040X

Escudero, P., Hayes-Harb, R., & Mitterer, H. (2008). Novel second-language words and asymmetric lexical access. *Journal of Phonetics*, *36*(2), 345-360.

Escudero, P., Simon, E., & Mulak, K. E. (2014). Learning words in a new language: Orthography doesn't always help. *Bilingualism: language and cognition*, *17*(2), 384-395. https://doi.org/10.1017/S1366728913000436

Escudero, P., & Wanrooij, K. (2010). The effect of L1 orthography on non-native vowel perception. *Language and speech*, *53*(3), 343-365. https://doi.org/10.1177/0023830910371447

Eviatar, Z., Taha, H., & Shwartz, M. (2018). Metalinguistic awareness and literacy among semitic-bilingual learners: a cross-language perspective. *Reading and Writing*, *31*(8), 1869-1891. https://doi.org/10.1007/s11145-018-9850-9

Fenson, L., Dale, P. S., Reznick, J. S., Bates, E., Thal, D. J., Pethick, S. J., ... & Stiles, J. (1994). Variability in early communicative development. *Monographs of the society for research in child development*, i-185. https://doi.org/10.2307/1166093

Figueredo, L. (2006). Using the known to chart the unknown: A review of first-language influence on the development of English-as-a-second-language spelling skill. *Reading and writing*, *19*(8), 873-905. https://doi.org/10.1007/s11145-006-9014-1

Franke, T. M., Ho, T., & Christie, C. A. (2011). The chi-square test: Often used and more often misinterpreted. *American Journal of Evaluation*, *33*(3), 448-458. https://doi.org/10.1177/1098214011426594

Gathercole, S. E., & Baddeley, A. D. (1989). Evaluation of the role of phonological STM in the development of vocabulary in children: A longitudinal study. *Journal of memory and language*, *28*(2), 200-213. https://doi.org/10.1016/0749-596X(89)90044-2

Genesee, F., & Lindholm-Leary, K. (2013). Two case studies of content-based language education. *Journal of Immersion and Content-based language Education*, *1*(1), 3-33. https://doi.org/10.1075/jicb.1.1.02gen

Gerena, L. (2011). Parental voice and involvement in cultural context: Understanding rationales, values, and motivational constructs in a dual immersion setting. *Urban Education*, *46*(3), 342-370. https://doi.org/10.1177/0042085910377512

Giacchino-Baker, R., & Piller, B. (2006). Parental motivation, attitudes, support, and commitment in a Southern Californian two-way immersion program. *Journal of Latinos and Education*, *5*(1), 5-28. https://doi.org/10.1207/s1532771xjle0501_2

Gollan, T. H., Montoya, R. I., Fennema-Notestine, C., & Morris, S. K. (2005). Bilingualism affects picture naming but not picture classification. *Memory & cognition*, *33*(7), 1220-1234. https://doi.org/10.3758/BF03193224

Goodman, N. R. (1963). Statistical analysis based on a certain multivariate complex Gaussian distribution (an introduction). *The Annals of mathematical statistics*, *34*(1), 152-177.

Gor, K. (2018). Phonological priming and the role of phonology in nonnative word recognition. *Bilingualism: Language and Cognition*, *21*(3), 437-442. https://doi.org/10.1017/S1366728918000056

Grainger, J., Midgley, K., & Holcomb, P. J. (2010). Re-thinking the bilingual interactive-activation model from a developmental perspective (BIA-d). *Language acquisition across linguistic and cognitive systems*, *52*, 267-283.

Grondin, R., Lupker, S. J., & McRae, K. (2009). Shared features dominate semantic richness effects for concrete concepts. *Journal of Memory and Language*, *60*(1), 1-19. https://doi.org/10.1016/j.jml.2008.09.001

Grosjean, F. (1988). Exploring the recognition of guest words in bilingual speech. *Language and cognitive processes*, *3*(3), 233-274. https://doi.org/10.1080/01690968808402089

Gross, J., Treiman, R., & Inman, J. (2000). The role of phonology in a letter detection task. *Memory & cognition*, *28*(3), 349-357. https://doi.org/10.3758/BF03198550

Gupta, P., MacWhinney, B., Feldman, H. M., & Sacco, K. (2003). Phonological memory and vocabulary learning in children with focal lesions. *Brain and language*, *87*(2), 241-252. https://doi.org/10.1016/S0093-934X(03)00094-4

Gupta, P., Lipinski, J., Abbs, B., Lin, P. H., Aktunc, E., Ludden, D., ... & Newman, R. (2004). Space aliens and nonwords: Stimuli for investigating the learning of novel word-meaning pairs. *Behavior Research Methods, Instruments, & Computers*, *36*(4), 599-603. https://doi.org/10.3758/BF03206540

Gupta, P., & Tisdale, J. (2009). Word learning, phonological short-term memory, phonotactic probability and long-term memory: towards an integrated framework. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1536), 3755-3771. https://doi.org/10.1098/rstb.2009.0132

Han, J. I., & Choi, T. H. (2016). The influence of spelling on the production and storage of words with allophonic variants of/h/in Korean. *Applied Psycholinguistics*, *37*(4), 757-780. https://doi.org/10.1017/S0142716415000235

Harm, M. W., & Seidenberg, M. S. (2004). Computing the meanings of words in reading: cooperative division of labor between visual and phonological processes. *Psychological review*, *111*(3), 662. https://doi.org/10.1037/0033-295X.111.3.662

Hayes-Harb, R., & Barrios, S. (2021). The influence of orthography in second language phonological acquisition. *Language Teaching*, 1-30. https://doi.org/10.1017/S0261444820000658

Hayes-Harb, R., Brown, K., & Smith, B. L. (2017). Orthographic input and the acquisition of German final devoicing by native speakers of English. *Language and speech, 61*(4), 547-564. https://doi.org/10.1177/0023830917710048

Hayes-Harb, R., Nicol, J., & Barker, J. (2010). Learning the phonological forms of new words: Effects of orthographic and auditory input. *Language and Speech, 53*(3), 367-381. https://doi.org/10.1177/0023830910371460

Heeringa, W. J. (2004). *Measuring dialect pronunciation differences using Levenshtein distance* (Doctoral dissertation, University Library Groningen][Host]).

Henderson, L., Devine, K., Weighall, A., & Gaskell, G. (2015). When the daffodat flew to the intergalactic zoo: Off-line consolidation is critical for word learning from stories. *Developmental psychology*, *51*(3), 406. https://doi.org/10.1037/a0038786

Henderson, L. M., Weighall, A. R., Brown, H., & Gareth Gaskell, M. (2012). Consolidation of vocabulary is associated with sleep in children. *Developmental science*, *15*(5), 674-687. https://doi.org/10.1111/j.1467-7687.2012.01172.x

Hesse, H. G., Göbel, K., & Hartig, J. (2008). *Sprachliche Kompetenzen von mehrsprachigen Jugendlichen und Jugendlichen nicht-deutscher Erstsprache* (pp. 208-230). https://10.25656/01:3155

Hevia-Tuero, C., Incera, S., & Suárez-Coalla, P. (2021). Does English orthography influence bilingual Spanish readers? The effect of grapheme crosslinguistic congruency and complexity on letter detection. *Cognitive Development*, *59*, 101074. https://doi.org/10.1016/j.cogdev.2021.101074

Hirosh, Z., & Degani, T. (2018). Direct and indirect effects of multilingualism on novel language learning: An integrative review. *Psychonomic bulletin & review*, *25*(3), 892-916. https://doi.org/10.3758/s13423-017-1315-7

Horst, M., Cobb, T., & Meara, P. (1998). Beyond a clockwork orange: Acquiring second language vocabulary through reading.

Houston-Price, C., Howe, J. A., & Lintern, N. J. (2014). Once upon a time, there was a fabulous funambulist…: What children learn about the "high-level" vocabulary they encounter while listening to stories. *Frontiers in psychology*, *5*, 75. https://doi.org/10.3389/fpsyg.2014.00075

Hu, G. (2008). The misleading academic discourse on Chinese–English bilingual education in China. *Review of Educational research*, *78*(2), 195-231. https://doi.org/10.3102/0034654307313406

Hulme, C., Goetz, K., Gooch, D., Adams, J., & Snowling, M. J. (2007). Paired-associate learning, phoneme awareness, and learning to read. *Journal of experimental child psychology*, *96*(2), 150-166. https://doi.org/10.1016/j.jecp.2006.09.002

James, E., Gaskell, M. G., Weighall, A., & Henderson, L. (2017). Consolidation of vocabulary during sleep: The rich get richer?. *Neuroscience & Biobehavioral Reviews, 77,* 1-13. https://doi.org/10.1016/j.neubiorev.2017.01.054

James, E., Gaskell, M. G., & Henderson, L. M. (2019). Offline consolidation supersedes prior knowledge benefits in children's (but not adults') word learning. *Developmental science*, *22*(3), e12776. https://doi.org/10.1111/desc.12776

Jared, D., & Kroll, J. F. (2001). Do bilinguals activate phonological representations in one or both of their languages when naming words?. *Journal of memory and language*, *44*(1), 2-31. https://doi.org/10.1006/jmla.2000.2747

Jubenville, K., Sénéchal, M., & Malette, M. (2014). The moderating effect of orthographic consistency on oral vocabulary learning in monolingual and bilingual children. *Journal of Experimental Child Psychology*, *126,* 245-263. https://doi.org/10.1016/j.jecp.2014.05.002

Kalashnikova, M., Escudero, P., & Kidd, E. (2018). The development of fast-mapping and novel word retention strategies in monolingual and bilingual infants. *Developmental Science*, *21*(6), e12674. https://doi.org/10.1111/desc.12674

Kapnoula, E. C. (2021). On the locus of L2 lexical fuzziness: Insights from L1 spoken word recognition and novel word learning. *Frontiers in Psychology*, *12,* 2770. https://10.3389/fpsyg.2021.689052

Kaushanskaya, M., Gross, M., & Buac, M. (2014). Effects of classroom bilingualism on task-shifting, verbal memory, and word learning in children. *Developmental science*, *17*(4), 564-583. https://doi.org/10.1111/desc.12142

Kaushanskaya, M., & Marian, V. (2009). The bilingual advantage in novel word learning. *Psychonomic Bulletin & Review*, *16*(4), 705-710. https://doi.org/10.3758/PBR.16.4.705

Kaushanskaya, M., & Marian, V. (2009). Bilingualism reduces native-language interference during novel-word learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*(3), 829. https://doi.org/10.1037/a0015275

Kaushanskaya, M., Park, J. S., Gangopadhyay, I., Davidson, M. M., & Weismer, S. E. (2017). The relationship between executive functions and language abilities in children: A latent variables approach. *Journal of Speech, Language, and Hearing Research*, *60*(4), 912-923. https://doi.org/10.1044/2016_JSLHR-L-15-0310

Kaushanskaya, M., & Rechtzigel, K. (2012). Concreteness effects in bilingual and monolingual word learning. *Psychonomic bulletin & review*, *19*(5), 935-941. https://doi.org/10.3758/s13423-012-0271-5

Kaushanskaya, M., Yoo, J., & Van Hecke, S. (2013). Word learning in adults with second-language experience: Effects of phonological and referent familiarity. https://doi.org/10.1044/1092-4388(2012/11-0084

Keshavarz, M. H., & Astaneh, H. (2004). The impact of bilinguality on the learning of English vocabulary as a foreign language (L3). *International Journal of Bilingual Education and Bilingualism*, *7*(4), 295-302. https://doi.org/10.1080/13670050408667814

Kessler, B. (2005). Phonetic comparison algorithms 1. *Transactions of the Philological Society*, *103*(2), 243-260. https://doi.org/10.1111/j.1467-968X.2005.00153.x

Keuleers, E. (2013). vwr: Useful functions for visual word recognition research. R package version 0.3. 0. *Neuropsychological rehabilitation*, *27*.

Keuleers, E., & Brysbaert, M. (2010). Wuggy: A multilingual pseudoword generator. *Behavior research methods*, *42*(3), 627-633. https://doi.org/10.3758/BRM.42.3.627

Keuleers, E., Diependaele, K., & Brysbaert, M. (2010). Practice effects in large-scale visual word recognition studies: A lexical decision study on 14,000 Dutch mono-and disyllabic words and nonwords. *Frontiers in psychology*, *1*, 174. https://doi.10.3389/fpsyg.2010.00174

Korkman M, Kirk U and Kemp S (2012) NEPSY II-Bilan Neuropsychologique de l'Enfant, 2de Édn. Adaptation française Paris: Editions ECPA.

Krashen, S. (1981). Second language acquisition. *Second Language Learning*, *3*(7), 19-39.

Krashen, S. D. (1982). Acquiring a second language. *World Englishes*, *1*(3), 97-101.

Krashen, S. D. (1992). *Fundamentals of language education*. Torrance, CA: Laredo Publishing Company.

Krepel, A. (2020). Word watching: Understanding and enhancing word learning in English as a foreign language.

Krepel, A., de Bree, E. H., & de Jong, P. F. (2021). Does the availability of orthography support L2 word learning?. *Reading and Writing*, *34*(2), 467-496. https://doi.org/10.1007/s11145-020-10078-6

Kroll, J. F., & Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. *Journal of memory and language*, *33*(2), 149-174. https://doi.org/10.1006/jmla.1994.1008

Kroll, J. F., Van Hell, J. G., Tokowicz, N., & Green, D. W. (2010). The Revised Hierarchical Model: A critical review and assessment. *Bilingualism: Language and Cognition*, *13*(3), 373-381. https://doi.org/10.1017/S136672891000009X

Kuppens, A. H. (2010). Incidental foreign language acquisition from media exposure. *Learning, Media and Technology*, *35*(1), 65-85. https://doi.org/10.1080/17439880903561876

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. (2017). lmerTest package: tests in linear mixed effects models. *Journal of statistical software*, *82*(1), 1-26. https://doi.org/10.18637/jss.v082.i13

Lange, M. (2002). Activation of multiple phoneme associates of graphemes in visual word recognition. *Brain and Language*, *81*(1-3), 610-620. https://doi.org/10.1006/brln.2001.2551

Lavaur, J. M., & Font, N. (1998). Représentation des mots cognats et non cognats en mémoire chez les bilingues français-espagnol. *Psychologie française*, *43*(4), 329-338.

Leach, L., & Samuel, A. G. (2007). Lexical configuration and lexical engagement: When adults learn new words. *Cognitive psychology*, *55*(4), 306-353. https://doi.org/10.1016/j.cogpsych.2007.01.001

Lété, B., Sprenger-Charolles, L., & Colé, P. (2004). MANULEX: A grade-level lexical database from French elementary school readers. *Behavior Research Methods, Instruments, & Computers*, *36*(1), 156-166. https://doi.org/10.3758/BF03195560

Lee, J. (2011). Size matters: Early vocabulary as a predictor of language and literacy competence. *Applied Psycholinguistics*, *32*(1), 69-92. https://doi.org/10.1017/S0142716410000299

Lefavrais, P. (1967). Test de L'Alouette, Manuel et tests. *Éditions du Centre de Psychologie Appliquée (ECPA). Paris*.

Lefavrais, P. (2005). *Alouette-R: test d'analyse de la vitesse en lecture à partir d'un texte*. Éditions du centre de psychologie appliquée.

Lefever, S. C. (2010). English skills of young learners in Iceland:"I started talking English when I was 4 years old. It just bang… just fall into me.".

Lemhöfer, K., & Dijkstra, T. (2004). Recognizing cognates and interlingual homographs: Effects of code similarity in language-specific and generalized lexical decision. *Memory & cognition*, *32*(4), 533-550. https://doi.org/10.3758/BF03195845

Lenneberg, E. H. (1967). The biological foundations of language. *Hospital Practice*, *2*(12), 59-67. https://doi.org/10.1080/21548331.1967.11707799

Levenshtein, V. I. (1966, February). Binary codes capable of correcting deletions, insertions, and reversals. In *Soviet physics doklady* (Vol. 10, No. 8, pp. 707-710).

Li, H., Zhang, J., Ehri, L., Chen, Y., Ruan, X., & Dong, Q. (2016). The role of orthography in oral vocabulary learning in Chinese children. *Reading and Writing*, *29*(7), 1363-1381. https://doi.org/10.1007/s11145-016-9641-0

Loizou, M., & Stuart, M. (2003). Phonological awareness in monolingual and bilingual English and Greek five-year-olds. *Journal of Research in Reading*, *26*(1), 3-18. https://doi.org/10.1111/1467-9817.261002

López, M. M. (2013). Mothers choose: Reasons for enrolling their children in a two-way immersion program. *Bilingual Research Journal*, *36*(2), 208-227. https://doi.org/10.1080/15235882.2013.818595

Lotto, L., & De Groot, A. M. (1998). Effects of learning method and word type on acquiring vocabulary in an unfamiliar language. *Language learning*, *48*(1), 31-69. https://doi.org/10.1111/1467-9922.00032

Lucas, R., & Norbury, C. F. (2014). Orthography facilitates vocabulary learning for children with autism spectrum disorders (ASD). *Quarterly Journal of Experimental Psychology*, *67*(7), 1317-1334. https://doi.org/10.1080/17470218.2013.859714

Macmillan, N. A., & Kaplan, H. L. (1985). Detection theory analysis of group data: estimating sensitivity from average hit and false-alarm rates. *Psychological bulletin*, *98*(1), 185. https://doi.org/10.1037/0033-2909.98.1.185

MacWhinney, B. (2008). *A unified model*. Routledge/Taylor & Francis Group.

Majerus, S., Poncelet, M., Van der Linden, M., & Weekes, B. S. (2008). Lexical learning in bilingual adults: The relative importance of short-term memory for serial order and phonological knowledge. *Cognition*, *107*(2), 395-419. https://doi.org/10.1016/j.cognition.2007.10.003

Malabonga, V., Kenyon, D. M., Carlo, M., August, D., & Louguit, M. (2008). Development of a cognate awareness measure for Spanish-speaking English language learners. *Language Testing*, *25*(4), 495-519. https://doi.org/10.1177/0265532208094274

Marian, V., Bartolotti, J., Chabal, S., & Shook, A. (2012). CLEARPOND: Cross-linguistic easy-access resource for phonological and orthographic neighborhood densities. https://doi.org/10.1371/journal.pone.0043230

Marian, V., & Shook, A. (2012, September). The cognitive benefits of being bilingual. In *Cerebrum: the Dana forum on brain science* (Vol. 2012). Dana Foundation.

McClelland, J. L., & Elman, J. L. (1986). The TRACE model of speech perception. *Cognitive psychology*, *18*(1), 1-86. https://doi.org/10.1016/0010-0285(86)90015-0

McClelland, J. L., McNaughton, B. L., & O'Reilly, R. C. (1995). Why there are complementary learning systems in the hippocampus and neocortex: insights from the successes and failures of connectionist models of learning and memory. *Psychological review*, *102*(3), 419. https://doi.org/10.1037/0033-295X.102.3.419

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: I. An account of basic findings. *Psychological review*, *88*(5), 375. https://doi.org/10.1037/0033-295X.88.5.375

McKague, M., Pratt, C., & Johnston, M. B. (2001). The effect of oral vocabulary on reading visually novel words: A comparison of the dual-route-cascaded and triangle frameworks. *Cognition*, *80*(3), 231-262. https://doi.org/10.1016/S0010-0277(00)00150-5

McLaughlin, B. (1995). Assessing Language Development in Bilingual Preschool Children. NCBE Program Information Guide Series No. 22.

Mengoni, S. E., Nash, H., & Hulme, C. (2013). The benefit of orthographic support for oral vocabulary learning in children with Down syndrome. *Journal of Child Language*, *40*(1), 221-243. https://doi.org/10.1017/S0305000912000396

Meuter, R. F., & Allport, A. (1999). Bilingual language switching in naming: Asymmetrical costs of language selection. *Journal of memory and language*, *40*(1), 25-40. https://doi.org/10.1006/jmla.1998.2602

Miles, K. P., Ehri, L. C., & Lauterbach, M. D. (2016). Mnemonic value of orthography for vocabulary learning in monolinguals and language minority English-speaking college students. *Journal of College Reading and Learning*, *46*(2), 99-112. https://doi.org/10.1080/10790195.2015.1125818

Moradi, H. (2014). An investigation through different types of bilinguals and bilingualism. *International Journal of Humanities & Social Science Studies*, *1*(2), 147-154.

Morales, J., Gómez-Ariza, C. J., & Bajo, M. T. (2013). Dual mechanisms of cognitive control in bilinguals and monolinguals. *Journal of Cognitive Psychology*, *25*(5), 531-546. https://doi.org/10.1016/j.neuropsychologia.2014.11.014

Moret-Tatay, C., & Perea, M. (2011). Is the go/no-go lexical decision task preferable to the yes/no task with developing readers?. *Journal of experimental child psychology*, *110*(1), 125-132. https://doi.org/10.1016/j.jecp.2011.04.005

Nation, K., & Cocksey, J. (2009a). The relationship between knowing a word and reading it aloud in children's word reading development. *Journal of experimental child psychology*, *103*(3), 296-308. https://doi.org/10.1016/j.jecp.2009.03.004

Nation, K., & Snowling, M. J. (1998). Semantic processing and the development of word-recognition skills: Evidence from children with reading comprehension difficulties. *Journal of memory and language*, *39*(1), 85-101. https://doi.org/10.1006/jmla.1998.2564

Nation, K., & Snowling, M. J. (2004). Beyond phonological skills: Broader language skills contribute to the development of reading. *Journal of research in reading*, *27*(4), 342-356. https://doi.org/10.1111/j.1467-9817.2004.00238.x

Nazzi, T. (2005). Use of phonetic specificity during the acquisition of new words: Differences between consonants and vowels. *Cognition*, *98*(1), 13-30. https://doi.org/10.1016/j.cognition.2004.10.005

Nazzi, T., Paterson, S., & Karmiloff-Smith, A. (2003). Early word segmentation by infants and toddlers with Williams syndrome. *Infancy*, *4*(2), 251-271. https://doi.org/10.1207/S15327078IN0402_06

Nazzi, T., & Ramus, F. (2003). Perception and acquisition of linguistic rhythm by infants. *Speech communication*, *41*(1), 233-243. https://doi.org/10.1016/S0167-6393(02)00106-1

Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. (1998). The University of South Florida word association, rhyme, and word fragment norms. 1998.

O'Reilly, R. C., & Norman, K. A. (2002). Hippocampal and neocortical contributions to memory: Advances in the complementary learning systems framework. *Trends in cognitive sciences*, *6*(12), 505-510. https://doi.org/10.1016/S1364-6613(02)02005-3

Ohayon, M. M., Carskadon, M. A., Guilleminault, C., & Vitiello, M. V. (2004). Meta-analysis of quantitative sleep parameters from childhood to old age in healthy individuals: developing normative sleep values across the human lifespan. *Sleep*, *27*(7), 1255-1273. https://doi.org/10.1093/sleep/27.7.1255

Otwinowska, A., Foryś-Nogala, M., Kobosko, W., & Szewczyk, J. (2020). Learning Orthographic Cognates and Non-Cognates in the Classroom: Does Awareness of Cross-Linguistic Similarity Matter?. *Language Learning*, *70*(3), 685-731. https://doi.org/10.1111/lang.12390

Otwinowska, A., & Szewczyk, J. M. (2017). The more similar the better? Factors in learning cognates, false cognates and non-cognate words. *International Journal of Bilingual Education and Bilingualism*. https://doi.org/10.1080/13670050.2017.1325834

Ouellet, M. (1990). *Synthese historique de l'immersion francaise au Canada suivie d'une biblographie selective et analytique (Historical Synthesis of French Immersion in Canada Followed by a Selective and Analytic Bibliography).*

Ouellette, G. P. (2006). What's meaning got to do with it: The role of vocabulary in word reading and reading comprehension. *Journal of educational psychology*, *98*(3), 554. https://doi.org/10.1037/0022-0663.98.3.554

Paap, K. R., Johnson, H. A., & Sawi, O. (2015). Bilingual advantages in executive functioning either do not exist or are restricted to very specific and undetermined circumstances. *Cortex*, *69*, 265-278. https://doi.org/10.1016/j.cortex.2015.04.014

Paivio, A., & Lambert, W. (1981). Dual coding and bilingual memory. *Journal of verbal learning and verbal behavior*, *20*(5), 532-539. https://doi.org/10.1016/S0022-5371(81)90156-0

Paivio, A. (1975). Coding distinctions and repetition effects in memory. In *Psychology of learning and motivation* (Vol. 9, pp. 179-214). Academic press. https://doi.org/10.1016/S0079-7421(08)60271-6

Papagno, C., & Vallar, G. (1995). Verbal short-term memory and vocabulary learning in polyglots. *The Quarterly Journal of Experimental Psychology Section A*, *48*(1), 98-107. https://doi.org/10.1080/14640749508401378

Pattamadilok, C., Welby, P., & Tyler, M. (2021). The contribution of visual articulatory gestures and orthography to speech processing: Evidence from novel word learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. https://doi.org/10.1037/xlm0001036

Perea, M., & Estévez, A. (2008). Transposed-letter similarity effects in naming pseudowords: Evidence from children and adults. *European Journal of Cognitive Psychology*, *20*(1), 33-46. https://doi.org/10.1080/09541440701306941

Perfetti, C. A., & Hart, L. (2002). The lexical quality hypothesis. *Precursors of functional literacy*, *11*, 67-86.

Poarch, G. J., Van Hell, J. G., & Kroll, J. F. (2015). Accessing word meaning in beginning second language learners: Lexical or conceptual mediation?. *Bilingualism: Language and Cognition*, *18*(3), 357-371. https://doi.org/10.1017/S1366728914000558

Poltrock, S., & Nazzi, T. (2015). Consonant/vowel asymmetry in early word form recognition. *Journal of Experimental Child Psychology*, *131*, 135-148. https://doi.org/10.1016/j.jecp.2014.11.011

Poulin-Dubois, D., Bialystok, E., Blaye, A., Polonia, A., & Yott, J. (2013). Lexical access and vocabulary development in very young bilinguals. *International Journal of Bilingualism*, *17*(1), 57-70. https://doi.org/10.1177/1367006911431198

Ramos, F. (2007). What do parents think of two-way bilingual education? An analysis of responses. *Journal of Latinos and Education*, *6*(2), 139-150. https://doi.org/10.1080/15348430701304807

Raven JC (1981) Progressive Matrices, Issy-les-Moulineaux, EAP, Scientifiques et Psychologiques.

Reder, F., Daigle, D., & Demont, E. (2012). Metalinguistic development in French learners enrolled in an immersion programme: A longitudinal study. *European Journal of Developmental Psychology*, *10*(4), 476-494. https://doi.org/10.1080/17405629.2012.734132

Reder, F., Marec-Breton, N., Gombert, J. E., & Demont, E. (2013). Second-language learners' advantage in metalinguistic awareness: A question of languages' characteristics. *British Journal of Educational Psychology*, *83*(4), 686-702. https://doi.org/10.1111/bjep.12003

Ricketts, J., Bishop, D. V., & Nation, K. (2009). Orthographic facilitation in oral vocabulary acquisition. *Quarterly journal of experimental psychology*, *62*(10), 1948-1966. https://doi.org/10.1080/17470210802696104

Ricketts, J., Bishop, D. V., Pimperton, H., & Nation, K. (2011). The role of self-teaching in learning orthographic and semantic aspects of new words. *Scientific Studies of Reading*, *15*(1), 47-70. https://doi.org/10.1080/10888438.2011.536129

Ricketts, J., Dockrell, J. E., Patel, N., Charman, T., & Lindsay, G. (2015). Do children with specific language impairment and autism spectrum disorders benefit from the presence of orthography when learning new spoken words?. *Journal of Experimental Child Psychology*, *134*, 43-61. https://doi.org/10.1016/j.jecp.2015.01.015

Ricketts, J., Nation, K., & Bishop, D. V. (2007). Vocabulary is important for some, but not all reading skills. *Scientific Studies of Reading*, *11*(3), 235-257. https://doi.org/10.1080/10888430701344306

Rogers, J., Webb, S., & Nakata, T. (2015). Do the cognacy characteristics of loanwords make them more easily learned than noncognates?. *Language Teaching Research*, *19*(1), 9-27. https://doi.org/10.1177/1362168814541752

Roodenrys, S., & Hinton, M. (2002). Sublexical or lexical effects on serial recall of nonwords?. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *28*(1), 29. https://doi.org/10.1037/0278-7393.28.1.29

Rosenthal, J., & Ehri, L. C. (2008). The mnemonic value of orthography for vocabulary learning. *Journal of educational psychology*, *100*(1), 175. https://doi.org/10.1037/0022-0663.100.1.175

Roth, F. P., Speece, D. L., & Cooper, D. H. (2002). A longitudinal analysis of the connection between oral language and early reading. *The Journal of Educational Research*, *95*(5), 259-272. https://doi.org/10.1080/00220670209596600

Sadoski, M. (2005). A dual coding view of vocabulary learning. *Reading & Writing Quarterly*, *21*(3), 221-238. https://doi.org/10.1080/10573560590949359

Saletta, M., Goffman, L., & Brentari, D. (2016). Reading skill and exposure to orthography influence speech production. *Applied psycholinguistics*, *37*(2), 411-434. https://doi.org/10.1017/S0142716415000053

Sanders, M., & Meijers, G. (1995). English as L3 in the elementary school. *ITL-International Journal of Applied Linguistics*, *107*(1), 59-78.

Sanz, C. (2000). Bilingual education enhances third language acquisition: Evidence from Catalonia. *Applied psycholinguistics*, *21*(1), 23-44. https://doi.org/10.1017/S0142716400001028

Savage, R., & Stuart, M. (2006). A developmental model of reading acquisition based upon early scaffolding errors and subsequent vowel inferences. *Educational Psychology*, *26*(1), 33-53. https://doi.org/10.1080/01443410500340983

Savaiano, M. E., Compton, D. L., Hatton, D. D., & Lloyd, B. P. (2016). Vocabulary word instruction for students who read braille. *Exceptional Children*, *82*(3), 337-353. https://doi.org/10.1177/0014402915598774

Schepens, J., Dijkstra, T., & Grootjen, F. (2012). Distributions of cognates in Europe as based on Levenshtein distance. *Bilingualism: Language and Cognition*, *15*(1), 157-166. https://doi.org/10.1017/S1366728910000623

Schepens, J., Dijkstra, T., Grootjen, F., & Van Heuven, W. J. (2013). Cross-language distributions of high frequency and phonetically similar cognates. *PloS one*, *8*(5), e63006. https://doi.org/10.1371/journal.pone.0063006

Schoonbaert, S., Duyck, W., Brysbaert, M., & Hartsuiker, R. J. (2009). Semantic and translation priming from a first language to a second and back: Making sense of the findings. *Memory & cognition*, *37*(5), 569-586. https://doi.org/10.3758/MC.37.5.569

Schwanenflugel, P. J., & Shoben, E. J. (1983). Differential context effects in the comprehension of abstract and concrete verbal materials. *Journal of Experimental Psychology: Learning, memory, and cognition*, *9*(1), 82. https://doi.org/10.1037/0278-7393.9.1.82

Schwartz, A. I., Kroll, J. F., & Diaz, M. (2007). Reading words in Spanish and English: Mapping orthography to phonology in two languages. *Language and Cognitive processes*, *22*(1), 106-129. https://doi.org/10.1080/01690960500463920

Scott, D., & Beadle, S. (2014). *Improving the effectiveness of language learning: CLIL and computer assisted language learning*. ICF GHK.

Scott, G. G., Keitel, A., Becirspahic, M., Yao, B., & Sereno, S. C. (2019). The Glasgow Norms: Ratings of 5,500 words on nine scales. *Behavior research methods*, *51*(3), 1258-1270. https://doi.org/10.3758/s13428-018-1099-3

Share, D. L. (1995). Phonological recoding and self-teaching: Sine qua non of reading acquisition. *Cognition, 55*(2), 151-218. https://doi.org/10.1016/0010-0277(94)00645-2

Share, D. L. (1999). Phonological recoding and orthographic learning: A direct test of the self-teaching hypothesis. *Journal of experimental child psychology*, *72*(2), 95-129. https://doi.org/10.1006/jecp.1998.2481

Showalter, C. E., & Hayes-Harb, R. (2015). Native English speakers learning Arabic: The influence of novel orthographic information on second language phonological acquisition. *Applied psycholinguistics, 36*(1), 23-42. https://doi.org/10.1017/S0142716414000411

Showalter, C. E. (2018). Impact of Cyrillic on native English speakers' phono-lexical acquisition of Russian. *Language and Speech, 61*(4), 565-576. https://doi.org/10.1177/0023830918761489

Smith, S. L., Kindermans, P. J., Ying, C., & Le, Q. V. (2017). Don't decay the learning rate, increase the batch size. *arXiv preprint arXiv:1711.00489*.

Snow, C. E., Burns, M. S., & Griffin, P. (1998). Preventing reading difficulties in young children. Washington, DC: National Academy Press.

Spiegel, C., & Halberda, J. (2011). Rapid fast-mapping abilities in 2-year-olds. *Journal of experimental child psychology*, *109*(1), 132-140. https://doi.org/10.1016/j.jecp.2010.10.013

Sprenger-Charolles, L., Siegel, L. S., & Béchennec, D. (1997). Beginning reading and spelling acquisition in French: A longitudinal study. *Learning to spell: Research, theory, and practice across languages*, 339-359.

Stanovich, K.E. (1986). Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. Reading Research Quarterly, 21, 360–407.

Storkel, H. L., Armbrüster, J., & Hogan, T. P. (2006). Differentiating phonotactic probability and neighborhood density in adult word learning. https://doi.org/10.1044/1092-4388(2006/085)

Stuart, M., & Coltheart, M. (1988). Does reading develop in a sequence of stages?. *Cognition*, *30*(2), 139-181. https://doi.org/10.1016/0010-0277(88)90038-8

Suggate, S., Schaughency, E., McAnally, H., & Reese, E. (2018). From infancy to adolescence: The longitudinal links between vocabulary, early literacy skills, oral narrative, and reading comprehension. *Cognitive Development*, *47*, 82-95. https://doi.org/10.1016/j.cogdev.2018.04.005

Sunderman, G., & Kroll, J. F. (2006). First language activation during second language lexical processing: An investigation of lexical form, meaning, and grammatical class. *Studies in second language acquisition*, *28*(3), 387-422. https://doi.org/10.1017/S0272263106060177

Swanborn, M. S. L., & de Glopper, K. (2002). Impact of reading purpose on incidental word learning from context. *Language learning*, *52*(1), 95-117. https://doi.org/10.1111/1467-9922.00178

Talamas, A., Kroll, J. F., & Dufour, R. (1999). From form to meaning: Stages in the acquisition of second-language vocabulary. *Bilingualism: language and cognition*, *2*(1), 45-58. https://doi.org/10.1017/S1366728999000140

Tamminen, J., Payne, J. D., Stickgold, R., Wamsley, E. J., & Gaskell, M. G. (2010). Sleep spindle activity is associated with the integration of new memories and existing knowledge. *Journal of Neuroscience*, *30*(43), 14356-14360. https://doi.org/10.1523/JNEUROSCI.3028-10.2010

Taylor, J. S. H., Duff, F. J., Woollams, A. M., Monaghan, P., & Ricketts, J. (2015). How word meaning influences word reading. *Current Directions in Psychological Science*, *24*(4), 322-328. https://doi.org/10.1177/0963721415574980

Team, A. (2015). Audacity (version 2.1. 1)[computer software].

Team, R. C. (2017). R: A language and environment for statistical com-puting.

Thorn, A. S., & Frankish, C. R. (2005). Long-term knowledge effects on serial recall of nonwords are not exclusively lexical. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *31*(4), 729. https://doi.org/10.1037/0278-7393.31.4.729

Tonzar, C., Lotto, L., & Job, R. (2009). L2 vocabulary acquisition in children: Effects of learning method and cognate status. *Language Learning*, *59*(3), 623-646. https://doi.org/10.1111/j.1467-9922.2009.00519.x

Torgeson, J. K., Wagner, R. K., & Rashotte, C. A. (1999). *Test Review: Test of Word Reading Efficiency (TOWRE)*. Pro-ed.

Vadasy, P. F., & Sanders, E. A. (2015). Incremental learning of difficult words in story contexts: The role of spelling and pronouncing new vocabulary. *Reading and Writing*, *28*(3), 371-394. https://doi.org/10.1007/s11145-014-9529-9

Valente, D., Ferré, P., Soares, A., Rato, A., & Comesaña, M. (2018). Does phonological overlap of cognate words modulate cognate acquisition and processing in developing and skilled readers?. *Language Acquisition*, *25*(4), 438-453. https://doi.org/10.1080/10489223.2017.1395029

Valentini, A., Ricketts, J., Pye, R. E., & Houston-Price, C. (2018). Listening while reading promotes word learning from stories. *Journal of experimental child psychology*, *167*, 10-31. https://doi.org/10.1016/j.jecp.2017.09.022

Van Assche, E., Duyck, W., & Gollan, T. H. (2013). Whole-language and item-specific control in bilingual language production. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *39*(6), 1781. https://doi.org/10.1037/a0032859

Van Gelderen, A., Schoonen, R., De Glopper, K., Hulstijn, J., Snellings, P., Simis, A., & Stevenson, M. (2003). Roles of linguistic knowledge, metacognitive knowledge and processing speed in L3, L2 and L1 reading comprehension: A structural equation modeling approach. *International Journal of bilingualism*, *7*(1), 7-25. https://doi.org/10.1177/13670069030070010201

Van Hell, J. G., & Mahn, A. C. (1997). Keyword mnemonics versus rote rehearsal: Learning concrete and abstract foreign words by experienced and inexperienced learners. *Language learning*, *47*(3), 507-546. https://doi.org/10.1111/0023-8333.00018

Van Heuven, W. J., Dijkstra, T., & Grainger, J. (1998). Orthographic neighborhood effects in bilingual word recognition. *Journal of memory and language*, *39*(3), 458-483. https://doi.org/10.1006/jmla.1998.2584

Van Wijnendaele, I., & Brysbaert, M. (2002). Visual word recognition in bilinguals: phonological priming from the second to the first language. *Journal of Experimental Psychology: Human Perception and Performance*, *28*(3), 616. https://doi.org/10.1037/0096-1523.28.3.616

Ventura, P., Morais, J., & Kolinsky, R. (2007). The development of the orthographic consistency effect in speech recognition: From sublexical to lexical involvement. *Cognition*, *105*(3), 547-576. https://doi.org/10.1016/j.cognition.2006.12.005

Vitevitch, M. S., & Luce, P. A. (2004). A web-based interface to calculate phonotactic probability for words and nonwords in English. *Behavior Research Methods, Instruments, & Computers*, *36*(3), 481-487. https://doi.org/10.3758/BF03195594

Voga, M., & Grainger, J. (2007). Cognate status and cross-script translation priming. *Memory & cognition*, *35*(5), 938-952. https://doi.org/10.3758/BF03193467

Wang, H. C., Nickels, L., Nation, K., & Castles, A. (2013). Predictors of orthographic learning of regular and irregular words. *Scientific Studies of Reading*, *17*(5), 369-384. https://doi.org/10.1080/10888438.2012.749879

Waring, R., & Takaki, M. (2003). At what rate do learners learn and retain new vocabulary from reading a graded reader?.

Warren, D. E., & Duff, M. C. (2014). Not so fast: Hippocampal amnesia slows word learning despite successful fast mapping. *Hippocampus*, *24*(8), 920-933. https://doi.org/10.1002/hipo.22279

Weatherhead, D., Arredondo, M. M., Nácar Garcia, L., & Werker, J. F. (2021). The Role of Audiovisual Speech in Fast-Mapping and Novel Word Retention in Monolingual and Bilingual 24-Month-Olds. *Brain Sciences*, *11*(1), 114. https://doi.org/10.3390/brainsci11010114

Wechsler D (2005) Échelle d'intelligence de Wechsler pour enfants: WISC-IV.ECPA, les Éditions du centre de psychologie appliquée.

Wegener, S., Wang, H. C., de Lissa, P., Robidoux, S., Nation, K., & Castles, A. (2018). Children reading spoken words: Interactions between vocabulary and orthographic expectancy. *Developmental Science*, *21*(3), e12577. https://doi.org/10.1111/desc.12577

Welby, P., Spinelli, E., & Bürki, A. (2021). Spelling provides a precise (but sometimes misplaced) phonological target. Orthography and acoustic variability in second language word learning. *arXiv preprint arXiv:2109.03490*.

Wilhelm, I., Prehn-Kristensen, A., & Born, J. (2012). Sleep-dependent memory consolidation–what can be learnt from children?. *Neuroscience & Biobehavioral Reviews*, *36*(7), 1718-1728. https://doi.org/10.1016/j.neubiorev.2012.03.002

Wilhelm, O., Hildebrandt, A. H., & Oberauer, K. (2013). What is working memory capacity, and how can we measure it?. *Frontiers in psychology*, *4*, 433. https://doi.org/10.3389/fpsyg.2013.00433

Willis, M., & Ohashi, Y. (2012). A model of L2 vocabulary learning and retention. *The Language Learning Journal*, *40*(1), 125-137. https://doi.org/10.1080/09571736.2012.658232

Ziegler, J. C., Jacobs, A. M., & Stone, G. O. (1996). Statistical analysis of the bidirectional inconsistency of spelling and sound in French. *Behavior Research Methods, Instruments, & Computers*, *28*(4), 504-515. https://doi.org/10.3758/BF03200539

Appendices

Appendix 1. *List of the selected German words and their associated (cross-)linguistic characteristics using in the Study 1 (Study 1a and Study 1b)*

Ge_word	Fr_word	Eng_word	Ph.form (XSAMPA)	Length (Ortho)	Length (Phono)	Congr	Freq_Fr	Min_big_Fr	Min_big_Ge	OLD	PLD	Concreteness (Bonin scale)	Imageability (Glasgow scale)
Birne	poire	pear	b.I.R.n.5	5	5	congr	20.35	0.0022	0.004	0.4	0	4.67	6.71
Nest	nid	nest	**n.E.s.t**	**4**	**4**	**congr**	84.12	**0.0019**	**0.0052**	**0.25**	**0.25**	**4.17**	**6.57**
Berg	montagne	mountain	b.E.R.k	4	4	congr	176.94	0.0022	0.0076	0.13	0	4.20	6.83
Kette	collier	necklace	k.E.t.5	5	4	congr	56.19	0.0001	0.004	0.17	0.25	4.64	6.54
Glocke	sonnette	bell	g.l.O.k.5	6	5	congr	9.38	0.0002	0.001	0.67	0.4	4.60	6.57
Fahrrad	vélo	bike	f.a.r.a.t	7	5	congr	76.24	0.0001	0.0013	0	0	4.90	6.79
Hose	pantalon	trousers	h.o.z.5	4	4	congr	46.28	0.0037	0.005	0	0	4.67	6.63
Lippe	lèvres	lips	**l.I.p.5**	**5**	**4**	**congr**	54.26	**0.0012**	**0.0012**	**0.4**	**0.25**	**4.80**	**6.57**
Kopf	tête	head	**k.O.p.f**	**4**	**4**	**congr**	772.91	**0**	**0.0018**	**0**	**0**	**4.50**	**6.54**
Esel	âne	donkey	i.z.5.l	4	4	congr	110.53	0.0006	0.0001	0.25	0	4.96	6.67
Schaf	mouton	sheep	**S.a.f**	**5**	**3**	**congr**	43.59	**0.0003**	**0.0013**	**0**	**0**	**4.96**	**6.57**
Pferd	cheval	horse	pf.i.R.t	5	4	congr	353.91	0	0.0008	0.17	0	4.90	6.83
Regen	pluie	rain	**R.i.g.5.n**	**5**	**5**	**incong**	172.05	**0.0021**	**0.0108**	**0**	**0**	**3.83**	**6.57**
Stern	étoile	star	S.t.E.R.n	5	5	incong	77.44	0.0016	0.0019	0.17	0.2	3.97	6.59
Blume	fleur	flower	b.l.U.m.5	5	5	incong	97.20	0.0013	0.0017	0.2	0.2	4.53	6.79
Tafel	tableau	chalkboard	**t.a.f.5.l**	**5**	**5**	**incong**	225.75	**0.0015**	**0.0017**	**0.43**	**0.4**	**4.60**	**6.57**

Ge_word	Fr_word	Eng_word	Ph.form (XSAMPA)	Length (Ortho)	Length (Phono)	Congr	Freq_Fr	Min_big_Fr	Min_big_Ge	OLD	PLD	Concreteness (Bonin scale)	Imageability (Glasgow scale)
Stuhl	chaise	chair	S.t.u.l	5	4	incong	69.35	0	0.0002	0	0.25	4.83	6.60
Geige	violon	violin	g.aI.g.5	5	4	incong	45.28	0.0018	0.0023	0	0	4.76	6.86
Hand	main	hand	**h.a.n.t**	**4**	**4**	**incong**	480.88	**0.0053**	**0.0109**	**0.25**	**0.25**	**4.73**	**6.57**
Zunge	langue	tongue	ts.U.N.5	5	4	incong	155.91	0	0.0083	0.5	0.2	3.77	6.74
Knochen	os	bones	k.n.O.x.5.n	7	6	incong	57.55	0	0.0009	0.14	0.17	4.76	6.63
Katze	chat	cat	k.a.ts.5	5	4	incong	528.58	0	0.0049	0.2	0.2	4.90	6.77
Ziege	chèvre	goat	ts.i.g.5	5	4	incong	73.83	0	0.0016	0.17	0.2	4.87	6.57
Schlange	serpent	snake	**S.l.a.N.5**	**8**	**5**	**incong**	89.42	**0.0001**	**0.008**	**0.25**	**0.33**	**4.96**	**6.57**

Note - We have used several abbreviations that will be highlighted here. Ge_word. Fr_word and Eng_word referred respectively to German. French and English words. Ph.form referred to the phonological form of German selected words in XPAMPA-format. The abbreviation Congr referred to congruency and we distinguished between congruent (congr) and incongruent (incong) words. Freq_Fr referred to the frequency of the French words extracted from MANULEX (Lété et al., 2004). Minimal bigram frequency in French (Min_big_Fr) and in German (Min_big_Ge) were estimated from Clearpond (Marian et al., 2012). Orthographic and phonological Levenshtein distance were calculated using the vwr-package (Keuleers, 2013). Measure of concreteness and of imageability were extracted from Bonin et al.' database (Bonin et al., 2018) and from Glasgow psycholinguistic norms (Scott et al., 2018) respectively. For concreteness, the measure was on a 5-point scale, but on a 7-point scale for Imageability.The eight additional words included in Study 1b are highlighted in bold font.

Appendix 2. *Study 1a: Target and distractive pictures used for the forced-choice recognition task (16 items)*

Session	Target	Pos1	Pos1_Nb	Pos2	Pos2_Nb	Pos3	Pos3_Nb	Pos4	Pos4_Nb
Immediate	Stern	Stern	447	Blume	312	Esel	624	Geige	566
	Blume	Hose	718	Blume	312	Zunge	503	Pferd	117
	Fahrrad	Pferd	117	Knochen	24	Fahrrad	23	Berg	407
	Katze	Geige	566	Birne	42	Kopf	182	Katze	606
	Pferd	Knochen	24	Zunge	503	Ziege	354	Pferd	117
	Kette	Stuhl	122	Birne	42	Kette	54	Berg	407
	Zunge	Fahrrad	23	Zunge	503	Stern	447	Knochen	24
	Birne	Birne	42	Katze	606	Pferd	117	Kette	54
	Berg	Berg	407	Stern	447	Kopf	182	Fahrrad	23
	Esel	Pferd	117	Hose	718	Ziege	354	Esel	624
	Stuhl	Berg	407	Stuhl	122	Blume	312	Kette	54
	Kopf	Kopf	182	Fahrrad	23	Kette	54	Geige	566
	Ziege	Zunge	503	Knochen	24	Ziege	354	Blume	312
	Knochen	Katze	606	Berg	407	Birne	42	Knochen	24
	Hose	Berg	407	Esel	624	Hose	718	Stern	447
	Geige	Kopf	182	Blume	312	Geige	566	Pferd	117

Session	Target	Pos1	Pos1_Nb	Pos2	Pos2_Nb	Pos3	Pos3_Nb	Pos4	Pos4_Nb
Delayed	Stern	Esel	624	Stern	447	Blume	312	Knochen	24
	Blume	Blume	312	Zunge	503	Pferd	117	Fahrrad	23
	Fahrrad	Berg	407	Geige	566	Knochen	24	Fahrrad	23
	Katze	Katze	606	Ziege	354	Kopf	182	Birne	42
	Pferd	Pferd	117	Stuhl	122	Zunge	503	Ziege	354
	Kette	Birne	42	Fahrrad	23	Stuhl	122	Kette	54
	Zunge	Zunge	503	Stern	447	Knochen	24	Geige	566
	Birne	Blume	312	Kette	54	Birne	42	Pferd	117
	Berg	Stern	447	Kopf	182	Stuhl	122	Berg	407
	Esel	Esel	624	Ziege	354	Kette	54	Hose	718
	Stuhl	Kette	54	Berg	407	Stuhl	122	Katze	606
	Kopf	Zunge	503	Geige	566	Fahrrad	23	Kopf	182
	Ziege	Blume	312	Ziege	354	Berg	407	Knochen	24
	Knochen	Esel	624	Knochen	24	Katze	606	Birne	42
	Hose	Hose	718	Ziege	354	Stern	447	Berg	407
	Geige	Stuhl	122	Geige	566	Pferd	117	Kopf	182

Note - Position of target and distractive pictures are labelled by Pos1 to Pos4, with Pos1 referring to a presentation on the upper left side of the computer screen and Pos4 to the down right side of the screen; Pos1_Nb to Pos4_Nb refer to the corresponding picture number in the MULTIPIC database (Duñabeitia et al., 2018).

Appendix 3. *Experimental German words and distractive pseudowords according to congruency and session for the go/no-go auditive recognition task in Study 1a*

Cognateness	English words	PW immediate and delayed	PW spontaneous
Congruency	German words	PW_immediate and delayed	PW_spontaneous
congruent	Berg	Birg	Bolg
	Birne	Bisme	Bilze
	Esel	Inel	Idel
	Fahrrad	Fatzkad	Fahrnad
	Glocke	Plokke	Swokke
	Hose	Lode	Soge
	Kette	Kitte	Satte
	Pferd	Pfeus	Pfelm
incongruent	Blume	Pulne	Felme
	Geige	Feise	Veide
	Katze	Lalze	Wetze
	Knochen	Schiden	Spichen
	Stern	Stelm	Stetz
	Stuhl	Pfohl	Druhl
	Ziege	Miege	Zalge
	Zunge	Junse	Wulse

Note - The term PW refers to the distractive pseudowords presented during the go/no-go auditive recognition task. Information about the session was labelled with the respective list of pseudowords: PW immediate and delayed refers to the list of pseudowords pronounced during the immediate and delayed session; PW spontaneous refers to those used in spontaneous session.

Appendix 4. *Word and orthographic distractive pseudowords for the orthographic judgment task in Study 1a*

Session	Congruency	Word	Close_ortho_distractor	Distant_ortho_distractor	Phonol_distractor	Pos_1	Pos_2	Pos_3	Pos_4
Immediate	congruent	Birne	Binre	Biclo	Bilneux	BIRNE	BILNEUX	BICLO	BINRE
		Berg	Breg	Bimp	Bergue	BREG	BIMP	BERGUE	BERG
		Kette	Ketet	Kemli	Kete	KETTE	KEMLI	KETET	KETE
		Fahrrad	Fahrard	Faschup	Farrade	FARRADE	FAHRRAD	FAHRARD	FASCHUP
		Hose	Hoes	Hiba	Hozeux	HOSE	HOES	HOZEUX	HIBA
		Kopf	Kpof	Kudt	Kofe	KOPF	KOFE	KPOF	KUDT
		Esel	Esle	Ekra	Izel	ESLE	IZEL	ESEL	EKRA
		Pferd	Pfred	Pfolt	Pferte	PFOLT	PFERD	PFERTE	PFRED
	incongruent	Stern	Stren	Stonf	Chterne	CHTERNE	STREN	STERN	STONF
		Blume	Bulme	Blano	Bloumeux	BLANO	BLUME	BLOUMEUX	BULME
		Tafel	Tafle	Tadok	Tafeul	TAFLE	TAFEUL	TADOK	TAFEL
		Stuhl	Sthul	Strepf	Chtule	CHTULE	STHUL	STREPF	STUHL
		Geige	Giege	Geuza	Gaigueux	GIEGE	GAIGUEUX	GEIGE	GEUZA
		Zunge	Zugne	Zutpi	Tsungueux	ZUTPI	ZUGNE	ZUNGE	TSUNGUEUX
		Knochen	Knochne	Knodrum	Knorren	KNORREN	KNOCHNE	KNOCHEN	KNODRUM
		Katze	Katez	Kadul	Katceux	KATEZ	KATZE	KADUL	KATCEUX
		Ziege	Zigee	Ziado	Tsigueux	ZIEGE	ZIADO	ZIGEE	TSIGUEUX

Session	Congruency	Word	Close_ortho_distractor	Distant_ortho_distractor	Phonol_distractor	Pos_1	Pos_2	Pos_3	Pos_4
Delayed	congruent	Birne	Binre	Biclo	Bilneux	BILNEUX	BICLO	BINRE	BIRNE
		Berg	Breg	Bimp	Bergue	BIMP	BERGUE	BERG	BREG
		Kette	Ketet	Kemli	Kete	KEMLI	KETET	KETE	KETTE
		Fahrrad	Fahrard	Faschup	Farrade	FAHRRAD	FAHRARD	FASCHUP	FARRADE
		Hose	Hoes	Hiba	Hozeux	HOES	HOZEUX	HIBA	HOSE
		Kopf	Kpof	Kudt	Kofe	KOFE	KPOF	KUDT	KOPF
		Esel	Esle	Ekra	Izel	IZEL	ESEL	EKRA	ESLE
		Pferd	Pfred	Pfolt	Pferte	PFERD	PFERTE	PFRED	PFOLT
		Stern	Stren	Stonf	Chterne	STREN	STERN	STONF	CHTERNE
		Blume	Bulme	Blano	Bloumeux	BLUME	BLOUMEUX	BULME	BLANO
		Tafel	Tafle	Tadok	Tafeul	TAFEUL	TADOK	TAFEL	TAFLE
		Stuhl	Sthul	Strepf	Chtule	STHUL	STREPF	STUHL	CHTULE
	incongruent	Geige	Giege	Geuza	Gaigueux	GAIGUEUX	GEIGE	GEUZA	GIEGE
		Zunge	Zugne	Zutpi	Tsungueux	ZUGNE	ZUNGE	TSUNGUEUX	ZUTPI
		Knochen	Knochne	Knodrum	Knorren	KNOCHNE	KNOCHEN	KNODRUM	KNORREN
		Katze	Katez	Kadul	Katceux	KATZE	KADUL	KATCEUX	KATEZ

Appendix 5. *Study 1b: Target and distractive pictures used for the forced-choice recognition task (24 items)*

Session	Target	Pos1	Pos1_Nb	Pos2	Pos2_Nb	Pos3	Pos3_Nb	Pos4	Pos4_Nb
Immediate	Stern	Stern	447	Blume	312	Kette	54	Fahrrad	23
	Blume	Fahrrad	23	Zunge	503	Katze	606	Blume	312
	Fahrrad	Pferd	117	Schlange	133	Regen	190	Fahrrad	23
	Katze	Nest	445	Katze	606	Hose	718	Tafel	402
	Nest	Schaf	636	Lippe	513	Nest	445	Stuhl	122
	Schlange	Schlange	133	Kette	54	Kopf	182	Berg	407
	Tafel	Zunge	503	Stern	447	Tafel	402	Schaf	636
	Schaf	Stuhl	122	Blume	312	Schaf	636	Birne	42
	Pferd	Geige	566	Pferd	117	Hand	264	Regen	190
	Kette	Kette	54	Zunge	503	Birne	42	Glocke	565
	Zunge	Zunge	503	Ziege	354	Hand	264	Berg	407
	Hand	Esel	624	Birne	42	Hand	264	Berg	407
	Birne	Glocke	565	Birne	42	Katze	606	Stuhl	122
	Glocke	Kopf	182	Glocke	565	Ziege	354	Nest	445
	Berg	Fahrrad	23	Regen	190	Knochen	24	Berg	407
	Esel	Lippe	513	Esel	624	Stern	447	Stuhl	122
	Stuhl	Kopf	182	Lippe	513	Stuhl	122	Geige	566
	Kopf	Kopf	182	Regen	190	Ziege	354	Kette	54
	Regen	Regen	190	Hand	264	Ziege	354	Knochen	24
	Ziege	Glocke	565	Geige	566	Ziege	354	Zunge	503
	Knochen	Nest	445	Schlange	133	Regen	190	Knochen	24
	Hose	Hose	718	Tafel	402	Katze	606	Esel	624
	Lippe	Geige	566	Schaf	636	Fahrrad	23	Lippe	513
	Geige	Geige	566	Blume	312	Tafel	402	Stern	447

Session	Target	Pos1	Pos1_Nb	Pos2	Pos2_Nb	Pos3	Pos3_Nb	Pos4	Pos4_Nb
Delayed	Stern	Geige	566	Stern	447	Fahrrad	23	Kette	54
	Blume	Hose	718	Blume	312	Katze	606	Fahrrad	23
	Fahrrad	Fahrrad	23	Schlange	133	Kopf	182	Pferd	117
	Katze	Katze	606	Tafel	402	Knochen	24	Hose	718
	Nest	Nest	445	Birne	42	Lippe	513	Stuhl	122
	Schlange	Kette	54	Berg	407	Schlange	133	Hand	264
	Tafel	Tafel	402	Glocke	565	Stern	447	Schaf	636
	Schaf	Birne	42	Schaf	636	Fahrrad	23	Stuhl	122
	Pferd	Blume	312	Regen	190	Hand	264	Pferd	117
	Kette	Kette	54	Glocke	565	Kette	54	Zunge	503
	Zunge	Hand	264	Stuhl	122	Ziege	354	Zunge	503
	Hand	Hand	264	Berg	407	Birne	42	Schlange	133
	Birne	Katze	606	Stuhl	122	Birne	42	Lippe	513
	Glocke	Glocke	565	Schaf	636	Nest	445	Ziege	354
	Berg	Regen	190	Fahrrad	23	Berg	407	Pferd	117
	Esel	Esel	624	Stuhl	122	Hand	264	Stern	447
	Stuhl	Kopf	182	Geige	566	Stern	447	Stuhl	122
	Kopf	Ziege	354	Kopf	182	Kette	54	Zunge	503
	Regen	Katze	606	Knochen	24	Regen	190	Hand	264
	Ziege	Zunge	503	Ziege	354	Glocke	565	Kette	54
	Knochen	Knochen	24	Regen	190	Hose	718	Schlange	133
	Hose	Tafel	402	Stuhl	122	Esel	624	Hose	718

Note - Position of target and distractive pictures are labelled by Pos1 to Pos4, with Pos1 referring to a presentation on the upper left side of the computer screen and Pos4 to the down right side of the screen; Pos1_Nb to Pos4_Nb refer to the corresponding picture number in the MULTIPIC database (Duñabeitia et al., 2018).

Appendix 6. *Experimental German words and distractive pseudowords according to congruency and session for the go/no-go auditive recognition task in Study 1b*

Congruency	German words	PW_immediate and delayed	PW_spontaneous
congruent	Berg	Birg	Bolg
	Birne	Bisme	Bilze
	Esel	Inel	Idel
	Fahrrad	Fatzkad	Fahrnad
	Glocke	Plokke	Swokke
	Hose	Lode	Soge
	Kette	Kitte	Satte
	Kopf	Korm	Kolz
	Lippe	Zeppe	Fippe
	Nest	Negt	Dest
	Pferd	Pfeus	Pfelm
	Schaf	Spraf	Schai
incongruent	Blume	Pulne	Felme
	Geige	Feise	Veide
	Hand	Hagd	Hald
	Katze	Lalze	Wetze
	Knochen	Schiden	Spichen
	Regen	Sesen	Keden
	Schlange	Schwanfe	Schnanke
	Stern	Stelm	Stetz
	Stuhl	Pfohl	Druhl
	Tafel	Tamel	Gadel
	Ziege	Miege	Zalge
	Zunge	Junse	Wulse

Note - The term PW refers to the distractive pseudowords presented during the go/no-go auditive recognition task. Information about the session was labelled with the respective list of pseudowords: PW immediate and delayed refers to the list of pseudowords pronounced during the immediate and delayed session; PW spontaneous refers to those used in spontaneous session.

Appendix 7. *Word and orthographic distractive pseudowords for the orthographic judgment task in Study 1b*

Session	Congruency	Word	Close_ortho_distractor	Distant_ortho_distractor	Phonol_distractor	Pos_1	Pos_2	Pos_3	Pos_4
Immediate	Congruent	Birne	Binre	Biclo	Bilneux	BIRNE	BILNEUX	BICLO	BINRE
		Nest	Nast	Namp	Neste	NAMP	NEST	NAST	NESTE
		Berg	Breg	Bimp	Bergue	BREG	BIMP	BERGUE	BERG
		Kette	Ketet	Kemli	Kete	KETTE	KEMLI	KETET	KETE
		Glocke	Golcke	Gluhva	Gloque	GLOCKE	GLOQUE	GLUHVA	GOLCKE
		Fahrrad	Fahrard	Faschup	Farrade	FARRADE	FAHRRAD	FAHRARD	FASCHUP
		Hose	Hoes	Hiba	Hozeux	HOSE	HOES	HOZEUX	HIBA
		Lippe	Lipep	Libta	Lipeux	LIPEUX	LIPEP	LIBTA	LIPPE
		Kopf	Kpof	Kudt	Kofe	KOPF	KOFE	KPOF	KUDT
		Esel	Esle	Ekra	Izel	ESLE	IZEL	ESEL	EKRA
		Schaf	Scahf	Scrom	Chafe	CHAFE	SCROM	SCAHF	SCHAF
		Pferd	Pfred	Pfolt	Pferte	PFOLT	PFERD	PFERTE	PFRED
	Incongruent	Regen	Regun	Redim	Reguen	REDIM	REGEN	REGUN	REGUEN
		Stern	Stren	Stonf	Chterne	CHTERNE	STREN	STERN	STONF
		Blume	Bulme	Blano	Bloumeux	BLANO	BLUME	BLOUMEUX	BULME
		Tafel	Tafle	Tadok	Tafeul	TAFLE	TAFEUL	TADOK	TAFEL
		Stuhl	Sthul	Strepf	Chtule	CHTULE	STHUL	STREPF	STUHL
		Geige	Giege	Geuza	Gaigueux	GIEGE	GAIGUEUX	GEIGE	GEUZA
		Hand	Hadn	Hapm	Hente	HADN	HAPM	HENTE	HAND
		Zunge	Zugne	Zutpi	Tsungueux	ZUTPI	ZUGNE	ZUNGE	TSUNGUEUX
		Knochen	Knochne	Knodrum	Knorren	KNORREN	KNOCHNE	KNOCHEN	KNODRUM
		Katze	Katez	Kadul	Katceux	KATEZ	KATZE	KADUL	KATCEUX
		Ziege	Zigee	Ziado	Tsigueux	ZIEGE	ZIADO	ZIGEE	TSIGUEUX
		Schlange	Schlagne	Schrudi	Chlangueux	CHLANGUEUX	SCHRUDTI	SCHLANGE	SCHLAGNE

Session	Congruency	Word	Close_ortho_distractor	Distant_ortho_distractor	Phonol_distractor	Pos_1	Pos_2	Pos_3	Pos_4
Delayed	Congruent	Birne	Binre	Biclo	Bilneux	BILNEUX	BICLO	BINRE	BIRNE
		Nest	Nast	Namp	Neste	NEST	NAST	NESTE	NAMP
		Berg	Breg	Bimp	Bergue	BIMP	BERGUE	BERG	BREG
		Kette	Ketet	Kemli	Kete	KEMLI	KETET	KETE	KETTE
		Glocke	Golcke	Gluhva	Gloque	GLOQUE	GLUHVA	GOLCKE	GLOCKE
		Fahrrad	Fahrard	Faschup	Farrade	FAHRRAD	FAHRARD	FASCHUP	FARRADE
		Hose	Hoes	Hiba	Hozeux	HOES	HOZEUX	HIBA	HOSE
		Lippe	Lipep	Libta	Lipeux	LIPEP	LIBTA	LIPPE	LIPEUX
		Kopf	Kpof	Kudt	Kofe	KOFE	KPOF	KUDT	KOPF
		Esel	Esle	Ekra	Izel	IZEL	ESEL	EKRA	ESLE
		Schaf	Scahf	Scrom	Chafe	SCROM	SCAHF	SCHAF	CHAFE
		Pferd	Pfred	Pfolt	Pferte	PFERD	PFERTE	PFRED	PFOLT
	Incongruent	Regen	Regun	Redim	Reguen	REGEN	REGUN	REGUEN	REDIM
		Stern	Stren	Stonf	Chterne	STREN	STERN	STONF	CHTERNE
		Blume	Bulme	Blano	Bloumeux	BLUME	BLOUMEUX	BULME	BLANO
		Tafel	Tafle	Tadok	Tafeul	TAFEUL	TADOK	TAFEL	TAFLE
		Stuhl	Sthul	Strepf	Chtule	STHUL	STREPF	STUHL	CHTULE
		Geige	Giege	Geuza	Gaigueux	GAIGUEUX	GEIGE	GEUZA	GIEGE
		Hand	Hadn	Hapm	Hente	HAPM	HENTE	HAND	HADN
		Zunge	Zugne	Zutpi	Tsungueux	ZUGNE	ZUNGE	TSUNGUEUX	ZUTPI
		Knochen	Knochne	Knodrum	Knorren	KNOCHNE	KNOCHEN	KNODRUM	KNORREN
		Katze	Katez	Kadul	Katceux	KATZE	KADUL	KATCEUX	KATEZ
		Ziege	Zigee	Ziado	Tsigueux	ZIADO	ZIGEE	TSIGUEUX	ZIEGE
		Schlange	Schlagne	Schrudi	Chlangueux	SCHRUDTI	SCHLANGE	SCHLAGNE	CHLANGUEUX

Note - The distractive spellings are labelled Close_ortho_distractor for the pseudoword sharing a large orthographic overlap with the target word, Distant_ortho_distractor for the ones sharing a small orthographic overlap with the target word and Phonol_distractor for the one which spelling was homophonic with the target word using the French grapheme-to-phoneme correspondences.

Appendix 8. *Overview of the response times for the three experimental tasks in Study 1b*

	Third graders				Fifth graders			
	NOLM		OLM		NOLM		OLM	
	M	SD	M	SD	M	SD	M	SD
Forced-choice recognition task (response time)								
Immediate	2690	568	2755	424	2455	443	2690	340
Delayed	2650	530	2429	444	2323	533	2274	327
Go no go auditive recognition task (response time)								
Immediate	1518	203	1573	211	1518	207	1502	285
Spontaneous	1638	241	1632	236	1551	256	1532	176
Delayed	1574	214	1569	213	1523	181	1450	244
Orthographic judgment task (response time)								
Immediate	3049	1411	3403	1131	3853	1702	2840	791
Delayed	3271	1323	3024	857	3038	1234	2512	1073

Appendix 9. *Overview of the response times for the three experimental tasks according to the degree of grapheme/phoneme incongruency in Study 1b*

	Third graders				Fifth graders			
	NOLM		OLM		NOLM		OLM	
	M	SD	M	SD	M	SD	M	SD
Forced-choice recognition task (response time)								
Immediate								
congruent	2665	559	2702	500	2462	418	2368	427
incongruent	2712	728	2810	499	2448	567	2428	354
Delayed								
congruent	2689	492	2489	577	2427	582	2351	417
incongruent	2609	725	2365	460	2211	734	2191	390
Go no go auditive recognition task (response time)								
Immediate								
congruent	1540	255	1562	254	1501	235	1468	308
incongruent	1496	241	1583	251	1536	246	1537	277
Spontaneous								
congruent	1666	318	1604	252	1516	238	1503	192
incongruent	1610	263	1660	274	1584	315	1560	207
Delayed								
congruent	1543	271	1521	254	1512	248	1435	290
incongruent	1605	253	1614	216	1533	181	1466	260
Orthographic judgment task (response time)								
Immediate								
congruent	3284	1816	3180	1877	3866	1042	2538	949
incongruent	2803	1334	3624	1788	3837	1529	3151	867
Delayed								
congruent	3199	1515	3271	1330	3037	1117	2510	1224
incongruent	3363	1537	2740	1238	3038	1004	2513	1055

Appendix 10. *Overview of the accuracy (and discriminative performance) for the three experimental tasks according to the degree of grapheme/phoneme incongruency in Study 1b.*

	Third graders				Fifth graders			
	NOLM		OLM		NOLM		OLM	
	M	SD	M	SD	M	SD	M	SD
Forced-choice recognition task (in percent)								
Immediate								
congruent	48.66	23.78	75.57	22.64	64.75	20.04	80.86	13.64
incongruent	48.12	19.09	70.98	26.52	61.98	20.00	80.56	12.24
Delayed								
congruent	57.26	20.15	76.95	19.19	66.58	14.97	84.88	16.67
incongruent	52.96	18.07	72.13	21.91	57.03	18.93	76.85	17.35
Go no go auditive recognition task (discrimination score)								
Immediate								
congruent	1.01	0.75	1.61	0.73	1.38	0.91	1.77	0.83
incongruent	0.61	0.67	1.28	0.57	1.28	0.79	1.28	0.74
Spontaneous								
congruent	0.99	0.88	1.32	1.21	1.30	0.62	1.76	0.87
incongruent	0.77	0.81	1.29	0.94	1.26	0.88	1.35	0.83
Delayed								
congruent	0.99	1.09	1.38	0.86	1.35	0.81	2.08	0.72
incongruent	0.76	0.88	1.27	0.71	1.14	1.00	1.52	0.68
Orthographic judgment task (in percent)								
Immediate								
congruent	31.45	12.07	58.90	20.47	38.54	22.66	70.68	19.53
incongruent	30.38	13.36	61.78	20.94	38.80	20.27	69.75	16.20
Delayed								
congruent	34.95	17.90	59.48	23.53	39.32	21.57	70.37	20.59
incongruent	28.76	16.34	54.31	21.56	37.50	19.82	65.74	17.65

Appendix 11. *List of the selected German words as well as their (cross-)linguistic characteristics with French used in the Study 2.*

Ge_word	En_word	Fr_word	Ph.word	Length (Ortho)	Length (Phono)	Congr	Nb_incong	Locus_incong	Freq_Fr	OLD	Min_Fr_Bigr	Min_Ge_Big	Concreteness (Bonin scale)	Imageability (Glasgow scale)
Rabe	crow	corbeau	R.a.b.5	4	4	congr			43.64	0.286	0.0016	0.0089		6.73
Birne	pear	poire	b.I.R.n.5	5	5	congr			20.35	0.4	0.0022	0.004	4.67	6.71
Schaf	sheep	mouton	s.a.f	5	3	congr			43.59	0	0.0003	0.0367	4.96	6.87
Kamm	comb	peigne	k.a.m	4	3	congr			9.93	0	0.0002	0.01	4.76	6.66
Glocke	bell	cloche	g.l.O.k.5	7	5	congr			28.22	0.667	0.0002	0.001	4.60	6.74
Treppe	stairs	escalier	t.R.E.p.5	7	5	congr			107.36	0.125	0.0003	0.0008		
Knopf	button	bouton	k.n.O.p.f	5	5	congr			32.98	0	0	0.0009	4.44	6.65
Fahrrad	bike	vélo	f.a.r.a.t	7	5	congr			76.24	0	0.0001	0.0013	4.90	6.79
Schloss	castle	château	s.l.O.s	7	4	congr			175.81	0.143	0.0001	0.0367		6.76
Kirsche	cherry	cerise	k.I.R.s.5	7	5	congr			8.93	0.29	0.0007	0.0306	4.96	6.62
Pferd	horse	cheval	pf.i.R.t	5	4	congr			353.91	0.29	0	0.0008	4.90	6.83
Tisch	table	table	t.I.s	5	3	congr			281.73	0.2	0.0036	0.0337	4.73	6.79
Geier	vulture	vautour	g.aI.56	5	3	incongr	3	<g>.<ei>.<er>	3.80	0.143	0.0018	0.0472		5.94
Zaun	fences	barrière	ts.aU.n	4	3	incongr	2	<z>.<au>	18.91	0.125	0.0001	0.002	4.43	
Ziege	goat	chèvre	ts.i.g.5	5	4	incongr	2	<z>.<g>	73.83	0.167	0	0.0016	4.87	6.57
Klingel	bell	sonnette	k.l.I.N.5.l	7	7	incongr	3	<in>.<g>.<el>	9.38	0.125	0.0001	0.0039		6.74
Daumen	thumb	pouce	d.aU.m.5.n	7	5	incongr	2	<au>.<en>	22.66	0.333	0.0013	0.0017	4.77	6.74
Metzger	butcher	boucher	m.E.ts.g.56	7	5	incongr	3	<z>.<g>.<er>	45.28	0.286	0	0.0332		6.43
Seife	soap	savon	z.aI.f.5	5	4	incongr	2	<s>.<ei>	30.20	0.2	0.0013	0.0283	4.60	
Rauch	smoke	fumée	R.aU.x	5	3	incongr	2	<au>. <ch>	48.82	0	0.0056	0.0337		6.03
Bauch	belly	ventre	b.aU.x	5	3	incongr	2	<au>.<ch>	123.78	0	0.0056	0.003	4.23	6.07
Mauer	wall	mur	m.aU.56	5	3	incongr	2	<au>.<er>	163.74	0.6	0.0021	0.0342	4.50	6.62
Zunge	tongue	langue	ts.U.N.5	5	4	incongr	3	<z>.<u>.<g>	155.91	0.5	0	0.003	3.77	6.74
Zeitung	newspaper	journal	ts.aI.t.U.N	7	5	incongr	4	<z>.<ei>.<u>.<g>	195.20	0	0.0001	0.0283		

Note - We have used several abbreviations that will be highlighted here. Ge_word. En_word and Fr_word referred respectively to German. English and French words. Ph.form referred to the phonological form of German selected words in XPAMPA-format. The abbreviation Congr referred to congruency and we distinguished between congruent (congr) and incongruent (incong) words. The number of incongruent letter/sound mapping (Nb_incongr) and their locus (Locus_incongr) have been reported for each grapheme. Freq_Fr referred to the frequency of the French words extracted from MANULEX (Lété et al., 2004). Minimal bigram frequency in French (Min_big_Fr) and in German (Min_big_Ge) were estimated from Clearpond (Marian et al., 2012). Orthographic Levenshtein distance were calculated using the vwr-package (Keuleers, 2013). Measure of concreteness and of imageability were extracted from Bonin et al.' database (Bonin et al., 2018) and from Glasgow psycholinguistic norms (Scott et al., 2018) respectively.

Appendix 12. *Study 2: Target and distractive pictures used for the forced-choice recognition task (24 items)*

Session	Congruency	Target	Pos1	Pos1_Nb	Pos2	Pos2_Nb	Pos3	Pos3_Nb	Pos4	Pos4_Nb
Immediate	Congruent	Rabe	Rabe	658	Klingel	433	Geier	53	Knopf	64
		Birne	Birne	42	Daumen	438	Zaun	530	Fahrrad	23
		Schaf	Schaf	636	Metzger	255	Ziege	354	Schloss	349
		Kamm	Klingel	433	Kamm	426	Kirsche	692	Seife	619
		Glocke	Daumen	438	Glocke	435	Pferd	117	Rauch	274
		Treppe	Metzger	255	Treppe	500	Tisch	110	Bauch	94
		Knopf	Kamm	426	Geier	53	Knopf	64	Klingel	433
		Fahrrad	Glocke	435	Zaun	530	Fahrrad	23	Daumen	438
		Schloss	Treppe	500	Ziege	354	Schloss	349	Metzger	255
		Kirsche	Geier	53	Mauer	227	Kamm	426	Kirsche	692
		Pferd	Zaun	530	Zunge	503	Glocke	435	Pferd	117
		Tisch	Ziege	354	Zeitung	61	Treppe	500	Tisch	110
	incongruent	Geier	Knopf	64	Kirsche	692	Mauer	227	Geier	53
		Zaun	Fahrrad	23	Pferd	117	Zunge	503	Zaun	530
		Ziege	Schloss	349	Tisch	110	Zeitung	61	Ziege	354
		Klingel	Seife	619	Knopf	64	Klingel	433	Rabe	658
		Daumen	Rauch	274	Fahrrad	23	Daumen	438	Birne	42
		Metzger	Bauch	94	Schloss	349	Metzger	255	Schaf	636
		Seife	Kirsche	692	Seife	619	Rabe	658	Mauer	227
		Rauch	Pferd	117	Rauch	274	Birne	42	Zunge	503
		Bauch	Tisch	110	Bauch	94	Schaf	636	Zeitung	61
		Mauer	Mauer	227	Rabe	658	Seife	619	Kamm	426
		Zunge	Zunge	503	Birne	42	Rauch	274	Glocke	435
		Zeitung	Zeitung	61	Schaf	636	Bauch	94	Treppe	500

Session	Congruency	Target	Pos1	Pos1_Nb	Pos2	Pos2_Nb	Pos3	Pos3_Nb	Pos4	Pos4_Nb
Delayed	congruent	Rabe	Knopf	64	Geier	53	Rabe	658	Daumen	438
		Birne	Fahrrad	23	Zaun	530	Birne	42	Metzger	255
		Schaf	Schloss	349	Ziege	354	Schaf	636	Klingel	433
		Kamm	Seife	619	Pferd	117	Klingel	433	Kamm	426
		Glocke	Rauch	274	Tisch	110	Daumen	438	Glocke	435
		Treppe	Bauch	94	Kirsche	692	Metzger	255	Treppe	500
		Knopf	Metzger	255	Knopf	64	Kamm	426	Geier	53
		Fahrrad	Klingel	433	Fahrrad	23	Glocke	435	Zaun	530
		Schloss	Daumen	438	Schloss	349	Treppe	500	Ziege	354
		Kirsche	Kirsche	692	Glocke	435	Geier	53	Mauer	227
		Pferd	Pferd	117	Treppe	500	Zaun	530	Zunge	503
		Tisch	Tisch	110	Kamm	426	Ziege	354	Zeitung	61
	incongruent	Geier	Geier	53	Zeitung	61	Knopf	64	Kirsche	692
		Zaun	Zaun	530	Mauer	227	Fahrrad	23	Pferd	117
		Ziege	Ziege	354	Zunge	503	Schloss	349	Tisch	110
		Klingel	Rabe	658	Klingel	433	Bauch	94	Knopf	64
		Daumen	Birne	42	Daumen	438	Seife	619	Fahrrad	23
		Metzger	Schaf	636	Metzger	255	Rauch	274	Schloss	349
		Seife	Mauer	227	Schaf	636	Kirsche	692	Seife	619
		Rauch	Zunge	503	Rabe	658	Pferd	117	Rauch	274
		Bauch	Zeitung	61	Birne	42	Tisch	110	Bauch	94
		Mauer	Treppe	500	Seife	619	Mauer	227	Rabe	658

Note - Position of target and distractive pictures are labelled by Pos1 to Pos4, with Pos1 referring to a presentation on the upper left side of the computer screen and Pos4 to the down right side of the screen; Pos1_Nb to Pos4_Nb refer to the corresponding picture number in the MULTIPIC database (Duñabeitia et al., 2018).

Appendix 13. *Experimental German words and distractive pseudowords according to congruency and session for the go/no-go auditive recognition task in Study 2*

Congruency	German words	PW_immediate and delayed		PW_spontaneous	
		Close ph. distractor	*Distant ph. distractor*	*Close ph. distractor*	*Distant ph. distractor*
Congruent	Rabe	Mabe	Reba	Rafe	Relk
	Birne	Firne	Bezil	Bilze	Brein
	Schaf	Scraf	Safch	Scaf	Scoki
	Kamm	Kagd	Kott	Kumm	Makm
	Glocke	Glotze	Glezba	Plokke	Gecolk
	Treppe	Vreppe	Terpep	Trelfe	Tliffe
	Knopf	Znopf	Knati	Kropf	Konfp
	Fahrrad	Fahrnad	Famodu	Falzkad	Frahdrar
	Schloss	Schlotz	Slossch	Kloss	Scromz
	Kirsche	Kirste	Kietel	Firsche	Kreschi
	Pferd	Pfred	Prefd	Berd	Pfolm
	Tisch	Tirsch	Sitch	Zisch	Tomtu
Incongruent	Geier	Gauer	Ganpa	Peier	Greil
	Zaun	Saun	Zuan	Raun	Zerm
	Ziege	Ziede	Zegei	Miege	Zaofy
	Klingel	Spinkel	Klizza	Trinkel	Kegliln
	Daumen	Gaumen	Druter	Daufen	Demaun
	Metzger	Motzger	Metlang	Metzler	Mterzeg
	Seife	Seile	Seuto	Teife	Sfeie
	Rauch	Raug	Rapon	Zauch	Ruack
	Bauch	Fauch	Baudi	Baugd	Bucha
	Mauer	Tauer	Madzo	Mauel	Muera
	Zunge	Punge	Zegun	Zunpe	Zidap
	Zeitung	Keitung	Zungeit	Zeinung	Zebalgo

Appendix 14. *Word and orthographic distractive pseudowords for the orthographic judgment task in Study 2*

Session	Congruency	Word	Close_ortho_distractor	Distant_ortho_distractor	Phonol_distractor	Pos_1	Pos_2	Pos_3	Pos_4
Immediate	congruent	Rabe	Rabbe	Rigu	Rabeux	RABEUX	RIGU	RABE	RABBE
		Birne	Binre	Bisma	Birneux	BIRNE	BINRE	BISMA	BIRNEUX
		Schaf	Sckaf	Sclow	Chafe	SCKAF	SCLOW	CHAFE	SCHAF
		Kamm	Kamn	Kerr	Camme	KERR	KAMM	CAMME	KAMN
		Glocke	Gloche	Glubra	Gloqueux	GLOCKE	GLOQUEUX	GLOCHE	GLUBRA
		Treppe	Trepfe	Trunny	Traipeux	TREPPE	TRUNNY	TREPFE	TRAIPEUX
		Knopf	Konpf	Knugd	Quenopfe	QUENOPFE	KNOPF	KNUGD	KONPF
		Fahrrad	Farhrad	Fahschip	Farrade	FAHRRAD	FAHSCHIP	FARRADE	FARHRAD
		Schloss	Scholss	Sckruzz	Chlauce	CHLAUCE	SCHOLSS	SCKRUZZ	SCHLOSS
		Kirsche	Pfred	Plojn	Ferde	QUIRCHEUX	KIRSCHE	KIRSCKE	KISTLY
		Pferd	Tirch	Tikpt	Tiche	FERDE	PFRED	PFERD	PLOJN
		Tisch	Geire	Geauv	Gaïlleur	TIKPT	TIRCH	TICHE	TISCH
	incongruent	Geier	Zain	Zeox	Tsaone	GEAUV	GAÏLLEUR	GEIRE	GEIER
		Zaun	Zigee	Zioba	Tsigueux	ZAIN	ZEOX	ZAUN	TSAONE
		Ziege	Klignel	Klibtup	Clingueul	ZIEGE	TSIGUEUX	ZIGEE	ZIOBA
		Klingel	Daumne	Dayfoj	Doïmeune	CLINGUEUL	KLIGNEL	KLIBTUP	KLINGEL
		Daumen	Meztger	Metbnij	Mezgueur	DOÏMEUNE	DAUMEN	DAYFOJ	DAUMNE
		Metzger	Siefe	Seopa	Saïffe	MEZTGER	METBNIJ	METZGER	MEZGUEUR
		Seife	Rauck	Rayls	Raore	SAÏFFE	SIEFE	SEIFE	SEOPA
		Rauch	Bauck	Baixn	Baore	RAYLS	RAORE	RAUCH	RAUCK
		Bauch	Maeur	Maioh	Maoeur	BAUCK	BAUCH	BAORE	BAIXN
		Mauer	Zugne	Zulfy	Tsungueux	MAEUR	MAOEUR	MAIOH	MAUER
		Zunge	Zietung	Zeipalm	Tsaïtoungue	ZUNGE	ZUGNE	TSUNGUEUX	ZULFY
		Zeitung	Rabbe	Rigu	Rabeux	ZEIPALM	ZEITUNG	TSAÏTOUNGUE	ZIETUNG

Session	Congruency	Word	Close_ortho_distractor	Distant_ortho_distractor	Phonol_distractor	Pos_1	Pos_2	Pos_3	Pos_4
Delayed	congruent	Rabe	Rabbe	Rigu	Rabeux	RABBE	RABEUX	RIGU	RABE
		Birne	Binre	Bisma	Birneux	BIRNEUX	BIRNE	BINRE	BISMA
		Schaf	Sckaf	Sclow	Chafe	SCHAF	SCKAF	SCLOW	CHAFE
		Kamm	Kamn	Kerr	Camme	KAMN	KERR	KAMM	CAMME
		Glocke	Gloche	Glubra	Gloqueux	GLUBRA	GLOCKE	GLOQUEUX	GLOCHE
		Treppe	Trepfe	Trunny	Traipeux	TRAIPEUX	TREPPE	TRUNNY	TREPFE
		Knopf	Konpf	Knugd	Quenopfe	KONPF	QUENOPFE	KNOPF	KNUGD
		Fahrrad	Farhrad	Fahschip	Farrade	FARHRAD	FAHRRAD	FAHSCHIP	FARRADE
		Schloss	Scholss	Sckruzz	Chlauce	SCHLOSS	CHLAUCE	SCHOLSS	SCKRUZZ
		Kirsche	Pfred	Plojn	Ferde	KISTLY	QUIRCHEUX	KIRSCHE	KIRSCKE
		Pferd	Tirch	Tikpt	Tiche	PLOJN	FERDE	PFRED	PFERD
		Tisch	Geire	Geauv	Gaïlleur	TISCH	TIKPT	TIRCH	TICHE
	incongruent	Geier	Zain	Zeox	Tsaone	GEIER	GEAUV	GAÏLLEUR	GEIRE
		Zaun	Zigee	Zioba	Tsigueux	TSAONE	ZAIN	ZEOX	ZAUN
		Ziege	Klignel	Klibtup	Clingueul	ZIOBA	ZIEGE	TSIGUEUX	ZIGEE
		Klingel	Daumne	Dayfoj	Doïmeune	KLINGEL	CLINGUEUL	KLIGNEL	KLIBTUP
		Daumen	Meztger	Metbnij	Mezgueur	DAUMNE	DOÏMEUNE	DAUMEN	DAYFOJ
		Metzger	Siefe	Seopa	Saïffe	MEZGUEUR	MEZTGER	METBNIJ	METZGER
		Seife	Rauck	Rayls	Raore	SEOPA	SAÏFFE	SIEFE	SEIFE
		Rauch	Bauck	Baixn	Baore	RAUCK	RAYLS	RAORE	RAUCH
		Bauch	Maeur	Maioh	Maoeur	BAIXN	BAUCK	BAUCH	BAORE
		Mauer	Zugne	Zulfy	Tsungueux	MAUER	MAEUR	MAOEUR	MAIOH
		Zunge	Zietung	Zeipalm	Tsaïtoungue	ZULFY	ZUNGE	ZUGNE	TSUNGUEUX
		Zeitung	Rabbe	Rigu	Rabeux	ZIETUNG	ZEIPALM	ZEITUNG	TSAÏTOUNGUE

Note - The distractive spellings are labelled Close_ortho_distractor for the pseudoword sharing a large orthographic overlap with the target word, Distant_ortho_distractor for the ones sharing a small orthographic overlap with the target word and Phonol_distractor for the one which spelling was homophonic with the target word using the French grapheme-to-phoneme correspondences.

Appendix 15. *Word and orthographic distractive pseudowords for the spelling generalization task according to session (training vs. immediate and delayed session) and degree of letter/sound incongruency in Study 2*

Session	Congruency	Word	Close_ortho_distractor	Distant_ortho_distractor	Phonol_distractor	Pos_1	Pos_2	Pos_3	Pos_4
Training	Congruent	Kehr	Kehn	Kefz	Kere	KEHN	KEZF	KEHR	KERE
		Lahre	Lahne	Laklo	Larre	LAKLO	LAHNE	LARRE	LAHRE
		Draf	Drapf	Dral	Draphe	DRAPHE	DRAPF	DRAL	DRAF
		Frikt	Pfrikt	Pzikt	Phrikt	FRIKT	PFRIKT	PHRIKT	PZIKT
		Pfelm	Fpelm	Prem	Fehlm	FEHLM	PFELM	PREM	FPELM
		Lopf	Lofp	Lozt	Lofe	LOZT	LOFE	LOPF	LOFP
		Krosch	Kroch	Krocse	Kroche	KROCSE	KROCHE	KROSCH	KROCH
		Flosch	Floch	Flocle	Floche	FLOCHE	FLOCLE	FLOCH	FLOSCH
		Marbe	Marb	Marku	Marbeux	MARBE	MARB	MARBEUX	MARKU
		Cride	Crid	Criw	Crideux	CRIW	CRIDE	CRIDEUX	CRID
		Schless	Schlest	Schlezz	Schlece	SCHLECE	SCHLEZZ	SCHLESS	SCHLEST
		Kriss	Krist	Krizz	Krice	KRIST	KRICE	KRIZZ	KRISS
	Incongruent	Prache	Prasche	Pracre	Prahre	PRACHE	PRASCHE	PRARHE	PRACRE
		Toche	Tosche	Tocle	Torhe	TOCLE	TOCHE	TOSCHE	TORHE
		Drau	Dreu	Droy	Draho	DRAU	DRAHO	DROY	DREU
		Schaude	Scheude	Schoude	Schaode	SCHAODE	SCHAUDE	SCHOUDE	SCHEUDE
		Zern	Sern	Ztren	Tsern	SERN	ZTREN	ZERN	TSERN
		Scharze	Scharse	Schardg	Scharse	SCHARSE	SCHARTSE	SCHARDG	SCHARZE
		Meife	Maufe	Moafe	Mayfe	MAYFE	MOAFE	MEIFE	MAUFE
		Pfeid	Pfeud	Pfouz	Pfayd	PFAYD	PFOUZ	PFEUD	PFEID
		Ploge	Ploke	Plowe	Plogue	PLOGE	PLOWE	PLOKE	PLOGUE
		Fonge	Fonke	Fonzze	Fongue	FONZZE	FONGE	FONKE	FONGUE
		Ratner	Ratnen	Ratnir	Ratneur	RATNEN	RATNEUR	RATNER	RATNIR
		Moscher	Moschel	Mosckras	Moscheur	MOSCKRAS	MOSCHEL	MOSCHEUR	MOSCHER

Session	Congruency	Word	Close_ortho_distractor	Distant_ortho_distractor	Phonol_distractor	Pos_1	Pos_2	Pos_3	Pos_4
Immediate and Delayed	Congruent	Dahr	Dahn	Datf	Darre	DAHN	DAHR	DARRE	DATF
		Schohre	Schone	Schofma	Schorre	SCHOHRE	SCHOHNE	SCHORRE	SCHOFMA
		Kref	Krepf	Kreq	Krephe	KREPF	KREPHE	KREQ	KREF
		Molf	Molpf	Moldp	Molphe	MOLPF	MOLF	MOLDP	MOLPHE
		Schnipf	Schnifp	Schnigd	Schnihff	SCHNIPF	SCHNIHFF	SCHNIGD	SCHNIFP
		Pfimt	Fpimt	Pkimt	Fhimt	FHIMT	PFIMT	FPIMT	PKIMT
		Pasch	Pach	Pacle	Pache	PACLE	PASCH	PACH	PACHE
		Milasch	Milach	Milacse	Milache	MILASCH	MILACSE	MILACH	MILACHE
		Dirke	Dirk	Dirly	Dirkeux	DIRLY	DIRKE	DIRKEUX	DIRK
		Ralpe	Ralp	Ralx	Ralpeux	RALP	RALPEUX	RALPE	RALX
		Tross	Trost	Trozz	Troce	TROCE	TROZZ	TROST	TROSS
		Flass	Flast	Flazp	Flace	FLASS	FLAST	FLAZP	FLACE
	Incongruent	Blache	Blasche	Blacse	Blarhe	BLACSE	BLASCHE	BLARHE	BLACHE
		Schroch	Schrosch	Schrocre	Schrorhe	SCHROCRE	SCHRORHE	SCHROCH	SCHROSCH
		Naude	Neude	Noyde	Nahode	NAHODE	NOYDE	NEUDE	NAUDE
		Faum	Feum	Fewm	Fahom	FEUM	FEWM	FAUM	FAHOM
		Zolm	Solm	Ztolm	Tsolm	ZTOLM	ZOLM	TSOLM	SOLM
		Bolz	Bolss	Bolc	Blotse	BOLZ	BOLTSE	BOLSS	BOLC
		Beische	Beusche	Beesche	Baïsche	BEISCHE	BEUSCHE	BAÏSCHE	BEESCHE
		Neim	Naum	Noox	Naym	NEIM	NOOX	NAYM	NAUM
		Triege	Trieke	Triewe	Trigue	TRIEKE	TRIGUE	TRIEWE	TRIEGE
		Gilbe	Kilbe	Bfilbe	Guilbe	BFILBE	KILBE	GUILBE	GILBE
		Kalder	Kaldel	Kaldop	Kaldeur	KALDEUR	KALDER	KALDEL	KALDOP
		Pimmer	Pimmen	Pimmad	Pimmeur	PIMMER	PIMMEN	PIMMAD	PIMMEUR

Note - The distractive spellings are labelled Close_ortho_distractor for the pseudoword sharing a large orthographic overlap with the target word, Distant_ortho_distractor for the ones sharing a smaller orthographic overlap with the target word and Phonol_distractor for the one which spelling was homophonic with the target word using the French grapheme-to-phoneme correspondences.

Appendix 16. *List of the selected English words as well as there (cross-) linguistic caracteristics with (L1) French and (L2) English used in Study 3.*

Ge_word	GPhoWord	Cogn	Length (ortho)	Length (phono)	Freq_Ge	En_word	Eng_ ph.form	Eng_ length (ortho)	Eng_length (Phono)	Freq_Eng	OLD	PLD	Min_big_Fr	Min_big_En	Min_big_Ge	Bonin	Glasgow scale
Adler	a.d.l.56	cogn	5	4	6.42	Eagle	i.g.l	5	3	11,49	2	5	0.0002	0.0008	0.0001	4.83	6.84
Apfel	a.p.f.5.l	cogn	5	5	9.41	apple	1.p.l	5	3	23,67	2	5	0.0054	0.0037	0.0005	4.96	6.91
Bogen	b.o.g.5.n	cogn	5	5	7.13	bow	b.oU	3	2	20,27	2	6	0	0.005	0.0012	4.41	6.03
Feder	f.i.d.56	cogn	5	4	11.58	feather	f.E.D.56	7	4	6,63	3	2	0.0004	0.0044	0.0013	4.2	
fliege	f.l.i.g.5	cogn	6	5	24.6	fly	f.l.aI	3	3	85,60	5	4	0.0001	0.0005	0.0002	4.83	5.74
Frosch	f.R.O.S	cogn	6	4	8.9	frog	f.r0.A.g	4	4	11,82	2	4	0.0013	0.0013	0.001	4.73	6.89
Kinn	k.I.n	cogn	4	3	5.24	chin	tS.I.n	4	3	12,69	2	2	0.0027	0.0091	0.0019		6.62
Nadel	n.a.d.5.l	cogn	5	5	9.72	needle	n.i.d.l	6	4	11,92	3	3	0	0.0037	0.0008	4.67	6.43
Schal	S.a.l	cogn	5	3	3.78	scarf	s.k.Ar.f	5	4	4,69	3	6	0	0.0004	0.0002		6.69
Schiff	S.I.f	cogn	6	3	169.1	ship	S.I.p	4	3	98,88	3	1	0.0004	0.0035	0.0008		6.53
Schuh	S.u	cogn	5	2	13.27	shoe	S.u	4	2	30,39	2	0	0	0.0006	0	4.9	7.94
Spinne	S.p.I.n.5	cogn	6	5	8.11	spider	s.p.aI.d.56	6	5	10,98	3	4	0.0013	0.0024	0.0014	4.84	6.79
Boot	b.o.t	cogn	4	3	64.92	boat	b.oU.t	4	3	95,78	2	1	0.0002	0.0043	0.0005		6.83
Flagge	f.l.a.g.5	cogn	6	5	14.69	flag	f.l.1.g	4	4	17,49	2	3	0.0035	0.0033	0.0021	4.8	
Helm	h.E.l.m	cogn	4	4	9.61	helmet	h.E.l.m.I0.t	6	6	9,47	3	5	0.001	0.0012	0.0014	4.67	
Hut	h.u.t	cogn	3	3	43.78	hat	h.1.t	3	3	64,18	2	1	0.0053	0.0114	0.0079	4.7	6.79
Kamel	k.a.m.5.l	cogn	5	5	2.99	camel	k.1.m.l	5	4	5,20	1	3	0.0055	0.0065	0.0026	4.8	6.63
Knie	k.n.i	cogn	4	3	35.71	knee	n.i	4	2	14,69	2	2	0	0.002	0.0005		
Knoten	k.n.o.t.5.n	cogn	6	6	8.72	knot	n.A.t	4	3	3,69	2	7	0	0.002	0.0009		6.28
Schild	S.I.l.t	cogn	6	4	20.16	shield	S.i.l.d	6	4	8,20	3	2	0	0.0013	0.0018		6.29
Schwan	S.v.a.n	cogn	6	4	1.42	Swan	s.w.A.n	4	4	6,82	2	3	0	0.0019	0.0002	4.8	6.83
Socke	z.O.k.5	cogn	5	4	2.8	sock	s.A.k	4	3	8,98	1	4	0.0007	0.005	0.0039	4.76	6.68
Fahrrad	f.a.r.a.t	noncogn	7	5	12.52	bike	b.aI.k	4	3	25,88	7	6	0	0.0013	0.0012	4.9	6.79
Glocke	g.l.O.k.5	noncogn	6	5	12.95	bell	b.E.l	4	3	39,33	6	7	0.0024	0.0107	0.0119		6.38
Hexe	h.E.k.s.5	noncogn	4	5	27.52	witch	w.I.tS	5	3	27,65	5	7	0	0.0037	0.0003		6.06
Ente	E.n.t.5	noncogn	4	4	9.76	duck	d.V.k	4	3	24,76	4	5	0.0007	0.0033	0.0029	4.93	6.6

Ge_word	GePhoWord	Cogn	Length (ortho)	Length (phono)	Freq_Ge	En_word	Eng_ ph.form	Eng_ length (ortho)	Eng_length (Phono)	Freq_Eng	OLD	PLD	Min_big_Fr	Min_big_En	Min_big_Ge	Bonin	Glasgow scale
Zahn	ts.a.n	noncogn	4	3	9.57	tooth	t.u.T	5	3	13,57	5	3	0.0004	0.0067	0.0013	4.92	6.57
Wolke	v.O.l.k.5	noncogn	5	5	6.54	cloud	k.l.aU.d	5	4	11,75	5	6	0.0008	0.0009	0.0001	3.13	6.53
Gabel	g.a.b.5.l	noncogn	5	5	4.25	fork	f.or.k	4	3	8,82	5	7	0.0002	0.0038	0.0035	4.73	6.67
Rabe	R.a.b.5	noncogn	4	4	0.94	crow	k.r0.oU	4	3	4,45	4	6	0	0.0052	0.0004		6.73
Pferd	pf.i.R.t	noncogn	5	4	45.91	horse	h.or.s	5	3	92,88	5	6	0.0037	0.0057	0.006	4.9	6.83
Birne	b.I.R.n.5	noncogn	5	5	9.25	pear	p.Er	4	2	1,33	5	8	0.001	0.0103	0.0036	4.67	6.71
Messer	m.E.s.56	noncogn	6	4	48.19	knife	n.aI.f	5	3	46,80	5	6	0	0.0017	0.001	4.93	6.67
Schwein	S.v.aI.n	noncogn	7	4	55.99	pig	p.I.g	3	3	39,14	6	5	0.0055	0.0062	0.0024	4.7	6.7
Drachen	d.R.a.x.5.n	noncogn	7	6	18.86	kite	k.aI.t	4	3	2,29	6	8	0.0007	0.0037	0.003	4.81	6.6
Kerze	k.E.R.ts.5	noncogn	5	5	6.22	candle	k.1.n.d.l	6	5	8,20	5	5	0	0.004	0.0008	4.57	6.77
Flasche	f.l.a.S.5	noncogn	7	5	35.24	bottle	b.A.t.l	6	4	50,75	6	6	0.0001	0.0039	0.0021	4.88	6.56
Affe	a.f.5	noncogn	4	3	15.83	monkey	m.V.n.k.i	6	5	33,51	5	7	0.0001	0.0036	0.0013	4.97	6.79
Zauberer	ts.aU.b.5.r.56	noncogn	8	6	16.5	wizard	w.I.z.56.d	6	5	10,63	7	9	0	0.0007	0.0005		6.27
Regen	R.i.g.5.n	noncogn	5	5	36.69	rain	r0.eI.n	4	3	48,90	4	6	0.0096	0.008	0.002	3.83	6.53
Pfirsich	pf.I.R.z.I.C	noncogn	8	6	1.18	peach	p.i.tS	5	3	6,35	6	9	0.001	0.0078	0.0022	4.4	6.79
Hose	h.o.z.5	noncogn	4	4	37.5	trousers	t.r0.aU.s.56.z	8	6	5,16	5	10	0.0062	0.0044	0.0001	4.67	6.63
Knochen	k.n.O.x.5.n	noncogn	7	6	31.1	bone	b.oU.n	4	3	26,59	5	8	0.0032	0.0078	0.0033	4.76	6.26
Kette	k.E.t.5	noncogn	5	4	18.15	necklace	n.E.k.l.5.s	8	6	9,75	6	6	0.0001	0.0014	0.0003	4.64	6.54

Note - We have used several abbreviations that will be highlighted here. Ge_word. En_word referred respectively to German. English words. Ph.form referred to the phonological form of German selected words in XPAMPA-format. The abbreviation Cogn referred to cognateness and we distinguished between cognate (cogn) and noncognate (noncogn) words. Freq_Ger referred to the frequency of the German words extracted from childLex-database (Schroeder et al., 2015). Freq_Engl referred to the frequency of the English words extracted from SUBTLEX-US database (Brysbaert & New, 2009). Minimal bigram frequency in French (Min_big_Fr), in English (Min_big_En) and in German (Min_big_Ge) were estimated from Clearpond (Marian et al., 2012). Orthographic and phonological Levenshtein distance were calculated using the vwr-package (Keuleers, 2013). Measure of concreteness and of imageability were extracted from Bonin et al.' database (Bonin et al., 2018) and from Glasgow psycholinguistic norms (Scott et al., 2018) respectively.

Appendix 17. *Target and distractive pictures used for the forced-choice recognition task in Study 3*

Word List	Session	Cognateness	Target	Pos1	Pos1_Nb	Pos2	Pos2_Nb	Pos3	Pos3_Nb	Pos4	Pos4_Nb
List 1	Immediate	Non cognate	duck	apple	552	pig	446	sock	416	duck	400
			witch	candle	68	scarf	628	witch	184	helmet	327
			tooth	knee	222	tooth	569	wizard	736	frog	612
			fork	fork	673	peach	697	needle	235	hat	690
			horse	horse	117	flag	295	ship	583	bone	24
			pig	wizard	736	pig	446	knee	222	flag	295
			candle	shoe	541	apple	552	candle	68	necklace	54
			wizard	witch	184	sock	416	needle	235	wizard	736
			peach	frog	612	horse	117	scarf	628	peach	697
			bone	helmet	327	duck	400	bone	24	hat	690
			necklace	tooth	569	necklace	54	flag	295	shoe	541
		Cognate	apple	wizard	736	apple	552	necklace	54	scarf	628
			scarf	scarf	628	knee	222	horse	117	fork	673
			frog	hat	690	bone	24	frog	612	witch	184
			needle	necklace	54	wizard	736	needle	235	helmet	327
			ship	sock	416	witch	184	tooth	569	ship	583
			shoe	duck	400	shoe	541	helmet	327	horse	117
			flag	flag	295	fork	673	duck	400	shoe	541
			hat	hat	690	candle	68	peach	697	tooth	569
			knee	bone	24	hat	690	knee	222	pig	446
			helmet	peach	697	helmet	327	pig	446	apple	552
			sock	ship	583	peach	697	fork	673	sock	416
	Delayed	Non cognate	duck	sock	416	duck	400	horse	117	apple	552
			witch	witch	184	helmet	327	scarf	628	tooth	569

Word List	Session	Cognateness	Target	Pos1	Pos1_Nb	Pos2	Pos2_Nb	Pos3	Pos3_Nb	Pos4	Pos4_Nb
			tooth	necklace	54	frog	612	tooth	569	knee	222
			fork	hat	690	fork	673	bone	24	needle	235
			horse	wizard	736	ship	583	flag	295	horse	117
			pig	pig	446	flag	295	candle	68	knee	222
			candle	necklace	54	candle	68	shoe	541	helmet	327
			wizard	sock	416	hat	690	wizard	736	witch	184
			peach	peach	697	bone	24	helmet	327	scarf	628
			bone	bone	24	witch	184	hat	690	duck	400
			necklace	knee	222	shoe	541	necklace	54	tooth	569
		Cognate	apple	scarf	628	necklace	54	peach	697	apple	552
			scarf	horse	117	scarf	628	fork	673	pig	446
			frog	frog	612	ship	583	witch	184	bone	24
			needle	needle	235	helmet	327	wizard	736	sock	416
			ship	witch	184	ship	583	frog	612	tooth	569
			shoe	flag	295	horse	117	shoe	541	duck	400
			flag	duck	400	apple	552	fork	673	flag	295
			hat	shoe	541	tooth	569	hat	690	candle	68
			knee	pig	446	knee	222	bone	24	frog	612
			helmet	helmet	327	apple	552	peach	697	shoe	541
			sock	candle	68	fork	673	sock	416	ship	583
List 2	Immediate	Non cognate	bell	swan	528	bell	565	knife	359	eagle	183
			cloud	boat	482	cloud	599	fly	462	kite	720
			crow	rain	190	eagle	183	crow	658	shield	501
			pear	bow	680	knot	267	feather	97	pear	42
			knife	knife	359	feather	97	bike	23	fly	462
			kite	kite	720	boat	482	crow	658	spider	38
			bottle	feather	97	trousers	718	camel	77	bottle	343

Word List	Session	Cognateness	Target	Pos1	Pos1_Nb	Pos2	Pos2_Nb	Pos3	Pos3_Nb	Pos4	Pos4_Nb
			monkey	chin	6	crow	658	spider	38	monkey	708
			rain	shield	501	rain	190	swan	528	knife	359
			trousers	monkey	708	fly	462	trousers	718	knot	267
			bike	bike	23	bottle	343	knot	267	bell	565
		Cognate	eagle	cloud	599	camel	77	Eagle	183	bike	23
			bow	pear	42	monkey	708	bow	680	swan	528
			fly	fly	462	kite	720	bottle	343	bell	565
			chin	trousers	718	chin	6	boat	482	rain	190
			spider	shield	501	spider	38	pear	42	trousers	718
			boat	spider	38	bike	23	bell	565	boat	482
			camel	eagle	183	pear	42	cloud	599	camel	77
			knot	knot	267	bow	680	monkey	708	chin	6
			swan	crow	658	swan	528	chin	6	cloud	599
			feather	camel	77	bike	23	kite	720	feather	97
			shield	bottle	343	knife	359	shield	501	bow	680
	Delayed	Non cognate	bell	swan	528	bell	565	knife	359	eagle	183
			cloud	boat	482	cloud	599	fly	462	kite	720
			crow	rain	190	eagle	183	crow	658	shield	501
			pear	bow	680	knot	267	feather	97	pear	42
			knife	knife	359	feather	97	bike	23	fly	462
			kite	kite	720	boat	482	crow	658	spider	38
			bottle	feather	97	trousers	718	camel	77	bottle	343
			monkey	chin	6	crow	658	spider	38	monkey	708
			rain	shield	501	rain	190	swan	528	knife	359
			trousers	monkey	708	fly	462	trousers	718	knot	267
			bike	bike	23	bottle	343	knot	267	bell	565
		Cognate	eagle	cloud	599	camel	77	Eagle	183	bike	23

Word List	Session	Cognateness	Target	Pos1	Pos1_Nb	Pos2	Pos2_Nb	Pos3	Pos3_Nb	Pos4	Pos4_Nb
			bow	pear	42	monkey	708	bow	680	swan	528
			fly	fly	462	kite	720	bottle	343	bell	565
			chin	trousers	718	chin	6	boat	482	rain	190
			spider	shield	501	spider	38	pear	42	trousers	718
			boat	spider	38	bike	23	bell	565	boat	482
			camel	eagle	183	pear	42	cloud	599	camel	77
			knot	knot	267	bow	680	monkey	708	chin	6
			swan	crow	658	swan	528	chin	6	cloud	599
			feather	camel	77	bike	23	kite	720	feather	97
			shield	bottle	343	knife	359	shield	501	bow	680

Note - Position of target and distractive pictures are labelled by Pos1 to Pos4, with Pos1 referring to a presentation on the upper left side of the computer screen and Pos4 to the down right side of the screen; Pos1_Nb to Pos4_Nb refer to the corresponding picture number in the MULTIPIC database (Duñabeitia et al., 2018).

Appendix 18. *Experimental English words and distractive pseudowords according to list, cognateness and session for the go/no-go auditive recognition task*

List number	Cognateness	English words	PW_immediate and delayed	PW_spontaneous
List 1	Non cognate	duck	durk	dulk
		witch	wetch	wutch
		tooth	wooth	toath
		fork	furk	fonk
		horse	hirse	horze
		pig	piz	vig
		candle	bantle	cantle
		wizard	wixard	wozard
		peach	peath	jeach
		bone	bonk	bine
		necklace	nucklade	tecklace
	Cognate	apple	upple	aptle
		scarf	scalf	scurf
		frog	frob	frig
		needle	teedle	neeble
		ship	shup	shib
		shoe	stoe	shob
		flag	clag	flab
		hat	het	haf
		knee	bnee	klee
		helmet	hulmet	hegmet
		sock	sonk	sork

List number	Cognateness	English words	PW immediate and delayed	PW spontaneous
List 2	Non cognate	bell	berl	belz
		cloud	sloud	croud
		crow	crob	vrow
		pear	pead	zear
		knife	knibe	knafe
		kite	kice	kute
		bottle	bopple	gottle
		monkey	ponkey	monbey
		rain	rawn	roin
		trousers	troovers	crousers
		bike	bive	bipe
	Cognate	eagle	eatle	eadle
		bow	bew	dow
		fly	scy	fle
		chin	slin	chig
		spider	sliper	criper
		boat	joat	boad
		camel	bamel	cadel
		knot	knop	knet
		swan	swun	swen
		feather	peather	foather
		shield	shiend	shierd

Note— The term PW refers to the distractive pseudowords presented during the go/no-go auditive recognition task. Information about the session was labelled with the respective list of pseudowords: PW immediate and delayed refers to the list of pseudowords pronounced during the immediate and delayed session; PW spontaneous refers to those used in spontaneous session.

Appendix 19. *Word and orthographic distractive pseudowords for the orthographic judgment task*

List number	Session	Cognateness	Word	Close_ortho_distractor	Distant_ortho_distractor	Phonol_distractor	Pos_1	Pos_2	Pos_3	Pos_4
List 1	Immediate	Non cognate	duck	dulk	duzy	deuque	DUCK	DULK	DUZY	DEUQUE
			witch	wicth	wibra	huiche	WICTH	WIBRA	HUICHE	WITCH
			tooth	toath	tospi	touce	TOSPI	TOUCE	TOOTH	TOATH
			fork	frok	fidu	forque	FORQUE	FORK	FIDU	FROK
			horse	hosre	hozta	horce	HORSE	HOSRE	HOZTA	HORCE
			pig	pid	pez	pigue	PID	PEZ	PIG	PIGUE
			candle	candel	canfou	candole	CANFOU	CANDLE	CANDEL	CANDOLE
			wizard	wizrad	witeno	huiseurd	WIZRAD	WITENO	HUISEURD	WIZARD
			peach	peath	peado	pitche	PEATH	PEACH	PEADO	PITCHE
			bone	boen	borv	baune	BONE	BOEN	BORV	BAUNE
			necklace	nekclace	nemborli	neclaice	NEMBORLI	NECLAICE	NECKLACE	NEKCLACE
		Cognate	apple	aptle	apudi	apole	APOLE	APPLE	APTLE	APUDI
			scarf	scraf	scowi	scalfe	SCRAF	SCOWI	SCALFE	SCARF
			frog	forg	flab	frogue	FORG	FLAB	FROGUE	FROG
			needle	neelde	neetog	nideule	NEETOG	NEEDLE	NIDEULE	NEELDE
			ship	sihp	sbud	chipe	SHIP	SBUD	CHIPE	SIHP
			shoe	sheo	shum	chous	SHOE	SHEO	SHUM	CHOUS
			flag	falg	frup	flague	FLAGUE	FRUP	FALG	FLAG
			hat	hap	hob	hatte	HOB	HATTE	HAT	HAP
			knee	kene	klat	nis	KENE	KLAT	KNEE	NIS
			helmet	hemlet	hebrop	elmaite	HEMLET	HEBROP	HELMET	ELMAITE
			sock	sork	sobu	soque	SORK	SOBU	SOQUE	SOCK
	Delayed	Non cognate	duck	dulk	duzy	deuque	DEUQUE	DUZY	DULK	DUCK
			witch	wicth	wibra	huiche	WITCH	HUICHE	WIBRA	WICTH
			tooth	toath	tospi	touce	TOATH	TOOTH	TOUCE	TOSPI
			fork	frok	fidu	forque	FROK	FIDU	FORK	FORQUE

List number	Session	Cognateness	Word	Close_ortho_distractor	Distant_ortho_distractor	Phonol_distractor	Pos_1	Pos_2	Pos_3	Pos_4
			horse	hosre	hozta	horce	HORCE	HOZTA	HOSRE	HORSE
			pig	pid	pez	pigue	PIGUE	PIG	PEZ	PID
			candle	candel	canfou	candole	CANDOLE	CANDEL	CANDLE	CANFOU
			wizard	wizrad	witeno	huiseurd	WIZARD	HUISEURD	WITENO	WIZRAD
			peach	peath	peado	pitche	PITCHE	PEATH	PEACH	PEADO
			bone	boen	borv	baune	BAUNE	BORV	BOEN	BONE
			necklace	nekclace	nemborli	neclaice	NEKCLACE	NECKLACE	NECLAICE	NEMBORLI
		Cognate	apple	aptle	apudi	apole	APUDI	APTLE	APPLE	APOLE
			scarf	scraf	scowi	scalfe	SCARF	SCALFE	SCOWI	SCRAF
			frog	forg	flab	frogue	FROG	FROGUE	FLAB	FORG
			needle	neelde	neetog	nideule	NEELDE	NIDEULE	NEEDLE	NEETOG
			ship	sihp	sbud	chipe	SIHP	CHIPE	SBUD	SHIP
			shoe	sheo	shum	chous	CHOUS	SHUM	SHEO	SHOE
			flag	falg	frup	flague	FLAG	FALG	FRUP	FLAGUE
			hat	hap	hob	hatte	HAP	HAT	HATTE	HOB
			knee	kene	klat	nis	NIS	KNEE	KLAT	KENE
			helmet	hemlet	hebrop	elmaite	ELMAITE	HELMET	HEBROP	HEMLET
			sock	sork	sobu	soque	SOCK	SOQUE	SOBU	SORK
List 2	Immediate	Non cognate	bell	blel	bagt	baile	BELL	BLEL	BAGT	BAILE
			cloud	claud	clebo	claode	CLOUD	CLAUD	CLEBO	CLAODE
			crow	corw	chiw	cros	CROW	CORW	CHIW	CROS
			pear	paer	pogd	pers	PEAR	PAER	POGD	PERS
			knife	knief	knipo	naïfe	KNIFE	KNIEF	KNIPO	NAÏFE
			kite	kiet	kiba	caïte	KIET	KIBA	CAÏTE	KITE
			bottle	bottel	botgan	boteul	BOTTEL	BOTGAN	BOTEUL	BOTTLE
			monkey	mokney	modavi	monequi	MOKNEY	MODAVI	MONEQUI	MONKEY
			rain	rawn	ravo	raigne	RAWN	RAVO	RAIGNE	RAIN
			trousers	trousres	troufari	traseurs	TROUSRES	TROUFARI	TRASEURS	TROUSERS
			bike	bice	bift	baïque	BIFT	BAÏQUE	BIKE	BICE

List number	Session	Cognateness	Word	Close_ortho_distractor	Distant_ortho_distractor	Phonol_distractor	Pos_1	Pos_2	Pos_3	Pos_4
		Cognate	eagle	ealge	eabom	iguole	EABOM	IGUOLE	EAGLE	EALGE
			bow	baw	bix	bau	BIX	BAU	BOW	BAW
			fly	fle	fab	flaille	FAB	FLAILLE	FLY	FLE
			chin	cihn	cogu	tchin	COGU	TCHIN	CHIN	CIHN
			spider	spidre	spifon	spideur	SPIDEUR	SPIDER	SPIDRE	SPIFON
			boat	baot	buwn	baute	BAUTE	BOAT	BAOT	BUWN
			camel	camle	cabug	camole	CAMOLE	CAMEL	CAMLE	CABUG
			knot	kont	kibo	naute	NAUTE	KNOT	KONT	KIBO
			swan	sawn	sbep	soine	SOINE	SWAN	SAWN	SBEP
			feather	feahter	fejadig	faiseur	FEAHTER	FEJADIG	FAISEUR	FEATHER
			shield	sheild	shodip	childe	SHODIP	CHILDE	SHEILD	SHIELD
	Delayed	Non cognate	bell	blel	bagt	baile	BAGT	BAILE	BELL	BLEL
			cloud	claud	clebo	claode	CLEBO	CLAODE	CLOUD	CLAUD
			crow	corw	chiw	cros	CHIW	CROS	CROW	CORW
			pear	paer	pogd	pers	POGD	PERS	PEAR	PAER
			knife	knief	knipo	naïfe	KNIPO	NAÏFE	KNIFE	KNIEF
			kite	kiet	kiba	caïte	CAÏTE	KITE	KIET	KIBA
			bottle	bottel	botgan	boteul	BOTEUL	BOTTLE	BOTTEL	BOTGAN
			monkey	mokney	modavi	monequi	MONEQUI	MONKEY	MOKNEY	MODAVI
			rain	rawn	ravo	raigne	RAIGNE	RAIN	RAWN	RAVO
			trousers	trousres	troufari	traseurs	TRASEURS	TROUSERS	TROUSRES	TROUFARI
			bike	bice	bift	baïque	BIKE	BICE	BIFT	BAÏQUE
		Cognate	eagle	ealge	eabom	iguole	EAGLE	EALGE	EABOM	IGUOLE
			bow	baw	bix	bau	BOW	BAW	BIX	BAU
			fly	fle	fab	flaille	FLY	FLE	FAB	FLAILLE
			chin	cihn	cogu	tchin	CHIN	CIHN	COGU	TCHIN
			spider	spidre	spifon	spideur	SPIDRE	SPIFON	SPIDEUR	SPIDER
			boat	baot	buwn	baute	BAOT	BUWN	BAUTE	BOAT
			camel	camle	cabug	camole	CAMLE	CABUG	CAMOLE	CAMEL

List number	Session	Cognateness	Word	Close_ortho_distractor	Distant_ortho_distractor	Phonol_distractor	Pos_1	Pos_2	Pos_3	Pos_4
			knot	kont	kibo	naute	KONT	KIBO	NAUTE	KNOT
			swan	sawn	sbep	soine	SAWN	SBEP	SOINE	SWAN
			feather	feahter	fejadig	faiseur	FAISEUR	FEATHER	FEAHTER	FEJADIG
			shield	sheild	shodip	childe	SHEILD	SHIELD	SHODIP	CHILDE

Note—The distractive spellings are labelled Close_ortho_distractor for the pseudoword sharing a large orthographic overlap with the target word, Distant_ortho_distractor for the ones sharing a small orthographic overlap with the target word and Phonol_distractor for the one which spelling was homophonic with the target word using the French grapheme-to-phoneme correspondences.