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Predictors of Decoding Acquisition in Newcomer Non-Francophone Children: A Focus on Visual-Verbal Paired Associate Learning

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English summary

The strategic aim of this research was to lay the foundations for the creation of tools for the early detection of reading difficulties in newcomer non-francophone children (EANA) of primary school age. To this end, we recruited 179 EANA children and 259 French children. The two groups were matched on the duration of attendance at primary school. They completed a series of cognitive and linguistic tests, and parents answered questionnaires on languages spoken and previous schooling. We observed that EANA children's decoding scores were lower than those of French children and showed considerable heterogeneity. Children who had started to learn to read in another language, especially if it was a Latin orthography, obtained higher scores than others. Younger children had lower scores than older children, probably due to greater experience of reading in their first language. Whether the children had attended school before arriving in France and the language family of the languages spoken (other than French) had no effect on word reading skills. Then, we observed that the main cognitive-linguistic predictors (phonological awareness, rapid automatized naming, phonological short-term memory and vocabulary) explained much of the variance in decoding skills among EANA children. In line with previous literature on oral language assessment of second language learners, we stressed the importance of managing the typological distance between first languages and French, as well as the degree of exposure to French. With this in mind, we examined the predictive power of a visual-verbal paired associate learning task (PAL), arguing that it should not be biased by the amount of exposure to French, and that it is possible to create items that are independent of the typological properties of French. Visual-verbal PAL scores were strongly correlated with decoding skills and showed a unique contribution comparable to other cognitive and linguistic predictors in EANA children. In French children, they showed a moderate simple correlation with decoding skills and a low unique contribution. We further investigated the mechanisms that explain the relationship between visual-verbal PAL and decoding skills by conducting a systematic review. Previous literature has shown that the verbal learning mechanisms of visual-verbal PAL are central to its relationship with decoding skills, at least in alphabetic orthographies, and that cross-modal association learning may also be involved, although the results are inconsistent. We tested these components in the French subsample of our first study and showed that verbal learning best explained the relationship between visual-verbal PAL and decoding skills. According to the literature, this relationship may be stronger with the reading of complex words (words with contextual graphemes and irregular words) than with the reading of simple words. We therefore conducted a second study of 186 first-grade children as part of a second data collection but were unable to confirm this hypothesis. This suggests either that there is no causal relationship between visual-verbal PAL and decoding skills, or that verbal learning is important for word and nonword decoding in general, regardless of grapheme complexity or word regularity. Future longitudinal studies controlling for all cognitive-linguistic predictors of decoding skills are needed to determine whether visual-verbal PAL has a causal contribution to decoding skills in French and may represent a sensitive tool for detecting children at risk of reading failure (particularly among EANA children) in combination with other measures.

Keywords: second language assessment, reading acquisition, reading predictors, newcomer children, visual-verbal paired associate learning.

Résumé français

L'objectif de cette recherche était de jeter les bases de la création d'outils de détection précoce des difficultés de lecture chez les enfants allophones nouvellement arrivés (EANA) en âge de fréquenter l'école primaire. Nous avons recruté 179 enfants EANA et 259 enfants français, appariés sur la durée de fréquentation de l'école primaire qui ont passé une série de tests cognitivo-linguistiques. Les scores de décodage des scores des enfants EANA étaient inférieurs à ceux des enfants français et présentaient une grande hétérogénéité. Ceux qui avaient commencé à apprendre à lire dans une autre langue, surtout s'il s'agissait d'une orthographe latine, obtenaient des scores plus élevés que les autres. Les plus jeunes avaient des scores plus faibles que les enfants plus âgés. Le fait que les enfants aient été scolarisés avant leur arrivée en France et la famille linguistique des langues parlées (autres que le français) ne présentaient pas d’effet sur les compétences en décodage. Ensuite, nous avons observé que les principaux prédicteurs cognitivo-linguistiques de la lecture (conscience phonologique, dénomination rapide automatisée, mémoire phonologique à court terme et vocabulaire) expliquaient une grande partie de la variance des scores de décodage chez les enfants EANA. Conformément à la littérature antérieure sur l'évaluation du langage oral des apprenants de langues secondes, nous avons souligné l'importance de gérer la distance typologique entre les langues premières et le français, ainsi que le degré d'exposition au français. Dans ce sens, nous avons examiné le pouvoir prédictif d'un test d’apprentissage de paires associées visuelle-verbale (PAL) qui ne devrait pas être biaisé par la quantité d'exposition au français et pour lequel il était possible de créer des items indépendants des propriétés typologiques du français. Les scores de PAL visuelle-verbale étaient fortement corrélés aux compétences de décodage et présentaient une contribution unique comparable aux autres prédicteurs cognitivo-linguistiques chez les enfants EANA. Chez les enfants français, ils présentaient une corrélation simple modérée avec les compétences de décodage et une faible contribution unique au-delà des autres prédicteurs. Nous avons examiné les mécanismes qui expliquent la relation entre la PAL visuelle-verbale et les compétences de décodage en effectuant une revue systématique de la littérature. La littérature antérieure a montré que les mécanismes d'apprentissage verbal de la PAL visuelle-verbale étaient au cœur de sa relation avec les compétences de décodage, du moins dans les orthographes alphabétiques, et que l'apprentissage d'association cross-modale pouvait également être impliqué, bien que les résultats soient inconsistants. Nous avons testé ces composantes dans le sous-échantillon contrôle français de notre première étude et avons montré que l'apprentissage verbal expliquait mieux la relation entre la PAL visuelle-verbale et les compétences de décodage. Selon la littérature, cette relation pourrait être plus forte avec la lecture de mots complexes (mots avec des graphèmes contextuels ou bien des mots irréguliers) qu'avec la lecture de mots simples. Nous avons donc mené une deuxième étude auprès de 186 enfants de première année, mais nous n'avons pas pu confirmer cette hypothèse. Cela suggère, soit qu'il n'y a pas de relation causale entre la PAL visuelle-verbale et les compétences de décodage, soit que l'apprentissage verbal est important pour le décodage en général, quelle que soit la complexité des graphèmes ou la régularité des mots. De futures études longitudinales contrôlant tous les prédicteurs cognitivo-linguistiques sont nécessaires pour dénouer ces résultats inconsistants et déterminer si la PAL visuelle-verbale peut représenter un outil sensible pour détecter les enfants à risque d'échec en lecture, en particulier chez les enfants EANA.

Mots-clés: évaluation langagière en langue seconde, acquisition de la lecture, prédicteurs de la lecture, enfants allophones nouvellement arrivés, apprentissage de paires associées visuo-verbales.

Résumé substantiel en français

En 2021, près de 10.3% de la population française était considérée comme “immigrée” et près d’un cinquième des permis de séjour étaient délivrés pour des motifs économiques ou humanitaires (INSEE, 2023). On peut s’attendre à ce que ces flux migratoires s’intensifient en raison de la crise climatique et environnementale. De nombreuses régions souffrent déjà de profondes ruptures dans leurs systèmes physiques (par ex. inondations, sécheresses), biologiques (par ex. chute de la biodiversité) et humanitaires (par ex. insécurité alimentaire; Pachauri & Meyer, 2014).

Accueillir les personnes migrantes représente un vrai défi. Comparativement au reste de la population française, les personnes migrantes ont plus de risques de se trouver au chômage, d’être recrutées dans des emplois peu qualifiés et de percevoir de faibles salaires (INSEE, 2023). Les compétences langagières, tout particulièrement à l’écrit, sont un facteur critique de l’intégration sociale, académique et professionnelle. Cette thèse se concentre donc sur les mécanismes impliqués dans l’acquisition de la lecture en français chez des enfants allophones nouvellement arrivés d’âge primaire (EANA). En 2021-2022, près de 35374 enfants allophones nouvellement arrivés (EANA) étaient scolarisés à l’école primaire en France (Brun, 2023).

Selon l’Organisation de coopération et de développement économiques (OCDE), les enfants migrants ont plus de chance d’avoir des difficultés de lecture que le reste de la population à l’âge de 15 ans. En France, l’écart entre enfants issus de l’immigration ou non est plus fort que dans le reste de l’OCDE (OECD, 2019). Ces difficultés sont en partie liées à un manque de maîtrise de la langue orale (OECD, 2015). Par ailleurs, comme tout enfant natif, les enfants EANA peuvent présenter des troubles des apprentissages. Néanmoins, le repérage de ces troubles est inopérant puisque l’on ne sait pas encore bien différencier les difficultés liées à un manque d’exposition à la langue des difficultés liées à un véritable trouble. Cela peut conduire à un retard dans la prise en charge et donc une perte de chance pour les enfants concernés (Jørgensen et al., 2020). Bien que la littérature autour de l’évaluation langagière en langue seconde se soit fortement développée lors des dernières décennies et que des outils apparaissent pour le langage oral (Armon-Lotem et al., 2015; dos Santos

& Ferré, 2018; Moro, 2017; Tuller, 2015), il n’existe à ce jour aucun test standardisé, du moins en français, pour dépister précocement les enfants EANA à risque de présenter des difficultés en lecture. Pourtant, il est crucial de les identifier le plus vite possible, compte tenu des facteurs de vulnérabilité économiques, sociaux ou psychologiques auxquels ils sont déjà confrontés. Cela permettrait une prise en charge adaptée et intensive dès leur arrivée, par exemple par des orthophonistes.

L'objectif principal de ces travaux de recherche était de fournir des données préliminaires pour le développement futur d’outils standardisés destinés à dépister précocement les enfants EANA à risque de présenter des difficultés en lecture. Nos analyses ont porté sur un jeu de prédicteurs cognitivo-linguistiques connus pour leur pouvoir prédictif dans les compétences en lecture: la conscience phonologique, la dénomination rapide automatisée et la mémoire phonologique à court terme (Kirby et al., 2008; Wagner & Torgesen, 1987) et le niveau de vocabulaire (Duff & Hulme, 2012; Mitchell & Brady, 2013; Ouellette, 2006; Ricketts et al., 2007). En nous concentrant sur les enfants francophones et EANA à l'école primaire, nous avons comparé la contribution de ces prédicteurs aux compétences de décodage, qui servent de piliers aux futures compétences de compréhension de la lecture chez les enfants monolingues (Gough & Tunmer, 1986; Hoover & Gough, 1990; Ouellette & Beers, 2010; Tunmer & Chapman, 2012b) et chez les enfants bilingues (Verhoeven & van Leeuwe, 2012). Nous nous sommes demandé si le poids de ces prédicteurs pouvait être réduit pour les enfants EANA dont les capacités de lecture sont influencées par beaucoup d'autres facteurs. Certains d'entre eux seront abordés dans cette recherche, comme la scolarité des enfants avant leur arrivée en France, l'âge auquel ils sont arrivés, et la similarité linguistique entre les autres langues qu'ils maîtrisent et le français.

En outre, les enfants EANA peuvent produire diverses substitutions phonémiques lors de tâches nécessitant une production phonologique, en fonction de la distance typologique entre le français et leurs autres langues parlées. Les examinateurs pourraient interpréter ces substitutions comme des erreurs liées aux processus ciblés par la tâche. Par conséquent, la capacité réelle des compétences ciblées, telles que le décodage et la conscience phonologique, peut être sous-estimée. Cette thèse a permis d'étudier la pertinence de certaines adaptations des évaluations cognitivo-linguistiques pour les enfants EANA de sorte à minimiser ces erreurs de cotations.

Enfin, nous avons examiné la contribution d'une tâche d'apprentissage de paires associées visuelles-verbales (PAL) à la prédiction des compétences de lecture de mots et de pseudo-mots chez les enfants EANA et francophones natifs, en contrôlant les autres prédicteurs cognitivo-linguistiques. Plusieurs études tendent à montrer que cette tâche présente une contribution unique aux scores de lecture de mots et de pseudo-mots (Litt et al., 2013; Poulsen & Elbro, 2018; Warmington & Hulme, 2012; Windfuhr & Snowling, 2001). Elle présente par ailleurs des caractéristiques intéressantes pour minimiser les biais liés à l'évaluation en langue seconde. Tout d'abord, elle ne repose pas sur des connaissances linguistiques, puisqu'elle consiste à apprendre des non-mots. En outre, précisément parce qu'elle est basée sur l'apprentissage de non-mots, il est facile de construire des items ayant des propriétés phonologiques universelles.

Toutefois, les preuves d'une contribution véritablement unique restent fragiles (e.g. Lervåg et al., 2009) et les mécanismes qui expliquent cette relation ont fait l'objet de débats (Hulme et al., 2007; Litt et al., 2013). Pour ces raisons, et compte tenu des difficultés à recruter des enfants EANA, nous avons décidé d'ouvrir un second axe de recherche visant à confirmer l'existence d'une contribution unique des scores d'apprentissage de la PAL visuelle-verbale dans la lecture en français, et à mieux comprendre les mécanismes impliqués dans cette relation.

En résumé, cette thèse s'articule autour de deux axes de recherche relativement distincts, mais dont l'objectif commun est d'identifier les mesures cognitivo-linguistiques les plus pertinentes à prendre chez les enfants EANA afin de détecter le plus précocement possible les difficultés de lecture. L'un porte sur la prédiction des capacités de lecture et l'adaptation des outils d'évaluation aux enfants EANA. L'autre propose une discussion approfondie sur la relation entre les scores aux tâches de PAL visuelles-verbales et la lecture.

I. Prédire le développement de la lecture chez les enfants EANA

Dans ce premier axe de recherche, nous avons tout d'abord cherché à adapter la cotation des tests de lecture et des différents prédicteurs cognitivo-linguistiques pour les enfants EANA. Puis, nous avons comparé leurs performances en décodage avec celle d'enfants francophones appariés sur le temps de scolarisation en primaire. Nous avons ensuite testé l'effet d'un ensemble de facteurs contextuels qui pourraient avoir un impact sur le développement de la lecture chez les enfants EANA. Nous avons également testé le pouvoir prédictif de différents facteurs cognitivo-linguistiques: la conscience phonologique, la dénomination rapide automatisée, la mémoire phonologique à court terme, le vocabulaire et l'apprentissage de paires associées visuelles-verbales. Enfin, nous nous sommes demandé comment créer des normes adaptées aux enfants EANA pour tester ces facteurs cognitivo-linguistiques. Les analyses présentées dans cette section portent toutes sur un même échantillon d'élèves francophones recrutés dans le cadre du projet TANMALL (reference: 2021-466-S90).

I.1. Rationnel pour l'utilisation d'une cotation flexible des productions verbales des enfants EANA

L'une des difficultés lorsque l'on examine les productions verbales des enfants dans leur langue seconde est de bien distinguer les erreurs liées à la distance phonologique entre la langue seconde et la langue maternelle ainsi les erreurs liées aux processus ciblés par la tâche. Pourtant, il est possible que les enfants aient simplement remplacé les sons cibles par des équivalents proches dans leur langue maternelle ou des équivalents entre le son de la langue maternelle et le français. À cela s'ajoute le fait que l'examinateur peut percevoir un son légèrement différent de celui produit par l'enfant, d'autant plus si ce son n'existe pas en français. Soulignons que cela est d'autant plus vrai pour les voyelles. En effet, la fidélité interjuge lors de la transcription de voyelles est moins grande que la transcription de consonnes (Stoel-Gammon, 2001). Deux problèmes se posent donc : (1) celui de distinguer les erreurs liées véritablement à la nature de la tâche et celles liées aux différences de répertoire phonémiques entre les langues parlées par l'enfant; (2) la subjectivité dans la transcription, tout particulièrement des voyelles. Compter toute substitution de sons comme erronée risquerait de fausser la mesure du test pour les enfants produisant beaucoup de substitutions sur des sons proches. Pour éviter cela, nous avons testé un mode de cotation alternatif, flexible, autorisant les substitutions de voyelles proches sur le triangle acoustique du français (ex. compter comme valide la substitution de /y/ par /u/).

La limite d'une telle solution est qu'elle ignore le problème plutôt que de le traiter de manière fine et individualisée. Il est possible que des réponses véritablement incorrectes soient considérées comme correctes. La sensibilité du test pourrait en être diminuée. Le but des analyses de cette partie était de vérifier que la sensibilité des différents tests utilisés dans cette thèse n'était pas altérée par l'utilisation de la cotation souple en évaluant le risque d'effet plafond. Nous avons également comparé la proportion d'erreurs corrigées par la cotation souple chez les enfants EANA et francophones afin de vérifier que la cotation souple cible bien des erreurs spécifiques aux enfants allophones.

I.1.1. Méthode

Nous avons sélectionné un sous-échantillon 157 enfants EANA scolarisés en école primaire, tous niveaux confondus et 243 enfants francophones recrutés en classe de CP et CE1, appariés aux enfants allophones sur le temps de scolarisation en école primaire en France. Nous avons analysé les productions verbales à des tests de lecture de mots et de pseudo-mots, de conscience phonologique, de répétition de non-mots ainsi que d'apprentissage de paires associées visuelles-verbales.

I.1.2. Résultats et Discussion

Une fois la cotation souple appliquée, les tests ne présentaient aucun effet plafond chez les enfants EANA et francophones au critère de 1 écart-type au-dessus de la moyenne. De plus, un plus grand nombre de substitutions étaient considérées comme correctes chez les enfants allophones que chez les enfants tout-venant, indiquant que les erreurs corrigées étaient spécifiques à la population allophone. Il semblait donc opportun d'utiliser cette cotation souple dans la suite de nos recherches.

I.2. Comparaison des performances en lecture de mots et de pseudo-mots entre les enfants EANA et les enfants francophones

Le but de ce chapitre était de comparer les performances de décodage des enfants EANA et francophones. Les études antérieures suggèrent que les enfants testés dans leur langue seconde s'en sortent aussi bien que des enfants natifs en décodage (Geva et al., 2019; Melby-Lervåg & Lervåg, 2014), toutefois ces études portent en majorité sur des enfants exposés précocement à la langue seconde (dès l'école maternelle). De plus, l'on sait que le vocabulaire présente un appui considérable pour les capacités de lecture de mots, et ce à travers différents mécanismes (Ricketts et al., 2007; Tunmer & Chapman, 2012b, 2012a; Wegener et al., 2018). Dès lors, l'on peut s'interroger sur la possibilité de généraliser les résultats de la littérature obtenus sur des populations exposées à la langue seconde depuis plusieurs années à des enfants nouvellement arrivés dans le pays et donc ayant bénéficié de moins d'exposition à la langue seconde.

Le but de ce chapitre était de comparer les performances en lecture de mots et de pseudo-mots des enfants EANA à des enfants francophones soit monolingues soit exposés à une autre langue que le français à la maison (présentés comme "francophones bilingues" par la suite par simplicité). Nous émettions l'hypothèse que les enfants allophones présenteraient des scores inférieurs à ceux des deux autres groupes en lecture de mots du fait d'un manque de vocabulaire, mais pas en lecture de pseudo-mots qui ne dépendent pas directement, du niveau de vocabulaire. Nous émettions également l'hypothèse, conformément à la littérature antérieure, que les enfants francophones bilingues obtiendraient des scores similaires aux enfants francophones monolingues.

I.2.1. Méthode

Nous avons comparé les performances en lecture de mots et de pseudo-mots d'un sous-échantillon d'enfants recrutés dans le cadre du projet TANMALL: 154 enfants EANA, 166 enfants francophones monolingues et 71 enfants francophones bilingues. Les groupes étaient appariés sur le temps de scolarisation en école primaire en France et les habiletés non-verbales. Ils ont réalisé des tests de lecture de mots et de pseudo-mots.

I.2.2. Résultats et Discussion

Les enfants EANA ont obtenu des scores de lecture de mots et de pseudo-mots inférieurs aux enfants francophones monolingues et bilingues. Les enfants francophones bilingues ont obtenu des scores similaires aux enfants monolingues. Nos hypothèses étaient donc partiellement validées. Il est étonnant d'observer une différence en lecture de pseudo-mots entre les enfants francophones et EANA. Il est possible que le vocabulaire soit un soutien indirect à la lecture de pseudo-mots. En aidant à ajuster les décodages erronés de mots, il pourrait soutenir le renforcement des connaissances des règles graphèmes-phonèmes, utiles à la réalisation d'une tâche de lecture de pseudo-mots. Il est possible également que la lecture de pseudo-mots soit soutenue par les connaissances phonotactiques liées au niveau de vocabulaire (Edwards et al., 2004; Estes et al., 2016; Munson et al., 2005). En effet les pseudo-mots étaient appariés aux mots sur la base de la fréquence des bigrammes, ce qui pourrait avoir conduit à un bon apparemment également au niveau phonotactique. Notons que les scores des enfants allophones sont très hétérogènes. Il est donc crucial d'examiner les raisons d'une telle hétérogénéité.

I.3. Prédire les performances en lecture des enfants EANA par des facteurs contextuels et cognitivo-linguistiques

Nous avons vu que les enfants EANA obtenaient des scores de lecture de mots et de pseudo-mots inférieurs aux enfants francophones natifs et qu'ils présentaient une plus grande hétérogénéité. Cette hétérogénéité peut être liée à plusieurs facteurs que nous avons évalués dans cette recherche. (1) Le fait que l'enfant ait été scolarisé avant d'arriver en France. 20% des enfants EANA n'ont jamais été scolarisés avant d'arriver en France (Brun, 2023). Cela pourrait jouer sur leur capacité à s'adapter à l'environnement scolaire. (2) Cela implique également que certains ont déjà commencé à apprendre à lire dans une autre langue et pas d'autres. Les enfants ayant commencé à lire pourraient être avantagés (Melby-Lervåg & Lervåg, 2011). (3) Cela pourrait être d'autant plus vrai que le système d'écriture dans lequel ils ont commencé à apprendre à lire est proche du système latin. (4) Les enfants arrivés avant ou au cours du CP pourraient aussi être avantagés du fait qu'ils bénéficient d'une instruction explicite à la lecture en même temps que les élèves francophones natifs. Les enfants EANA plus âgés pourraient être désavantagés du fait qu'ils ont le défi d'apprendre à parler, lire et rattraper leur retard scolaire en UPE2A à la fois. (5) Les enfants dont la langue maternelle est indo-européenne comme le français pourraient présenter plus de facilités à apprendre le français que les autres en supposant que ce critère permet également de rendre compte de la distance typologique entre les langues.

Dans cette partie nous nous intéressons également aux facteurs cognitivo-linguistiques qui pourraient prédire la réussite en lecture chez les enfants EANA. Nous nous sommes intéressés à la conscience phonologique, la dénomination rapide automatisée, la mémoire phonologique à court terme, le vocabulaire dont le pouvoir prédicteur est consensuel pour les enfants monolingues (e.g. Lervåg et al., 2009; Melby-Lervåg, 2012; Ouellette & Beers, 2010; Parrila et al., 2004; Piquard-Kipffer & Sprenger-Charolles, 2013; Poulsen & Elbro, 2018; Ricketts et al., 2007) et bilingues (e.g. Chiappe et al., 2002; Comeau et al., 1999; Geva & Farnia, 2012; Gottardo et al., 2008; Jongejan et al., 2007; Y. Liu et al., 2017; MacKay et al., 2023; Muter & Diethelm, 2001). Nous nous demandons si ces mesures sont aussi prédictrices de la réussite en lecture chez les enfants EANA que chez les enfants francophones compte tenu du grand nombre de facteurs contextuels pouvant aussi influencer la réussite en lecture. Nous avons également mis à l'épreuve un prédicteur additionnel, les capacités d'apprentissage visuelles-verbales qui a montré un bon pouvoir prédicteur dans diverses orthographes (e.g. Georgiou et al., 2017; Poulsen & Elbro, 2018; Warmington & Hulme, 2012). Cette mesure est tout particulièrement intéressante pour les enfants EANA puisqu'elle ne repose pas sur les connaissances langagières puisqu'elle consiste en l'apprentissage de non-mots associés à des images. Il est de plus possible de créer des non-mots aux propriétés universelles sur le plan syllabique et phonémique ce qui limite plus encore les erreurs liées au seul statut linguistique (EANA ou pas).

I.3.1. Méthode

Nous avons sélectionné un sous-échantillon du projet TANMALL de 129 enfants EANA et 237 enfants francophones natifs, appariés sur le temps de scolarisation en école primaire en France et les habiletés non-verbales. Ils ont réalisé des tests de lecture de mots et de pseudo-mots, d'habiletés non-verbales, de conscience phonologique, de dénomination rapide automatisée, de répétition de non-mots, de vocabulaire et d'apprentissage de paires associées visuelles-verbales. Les informations sur les facteurs contextuels ont été obtenues au moyen de questionnaires remplis par les familles avec l'aide des enseignants.

I.3.2. Résultats et Discussions

I.3.2.1 Facteurs contextuels

Des analyses de régression multiples ont été réalisées chez les enfants EANA pour observer l'impact des différents facteurs conceptuels sur un score composite de décodage agrégeant les scores de lecture de mots et de pseudo-mots. Premièrement, ces analyses ont révélé que les enfants arrivés après le CP en France s'en sortent mieux en lecture que les enfants les plus jeunes alors que nous prédisions l'inverse. Cela pourrait s'expliquer par le fait que les enfants plus âgés ont simplement plus d'expérience de la lecture dans leur langue maternelle que les enfants les plus jeunes. Ils pourraient également être plus engagés dans les apprentissages scolaires, car ils y mettraient plus de sens. Enfin, des analyses complémentaires ont suggéré que le niveau de développement cognitif, approximé par une mesure des habiletés non-verbales, pourrait expliquer partiellement cet avantage des enfants les plus âgés.

Deuxièmement, nous avons observé que le fait d'avoir été scolarisé avant d'arriver en France n'était pas un contributeur de la réussite en lecture au-delà du fait d'avoir commencé à apprendre à lire avant d'arriver en France. L'inverse cependant était vrai, indiquant qu'il existe un transfert positif des compétences acquises en langue maternelle sur les compétences en langue additionnelle (Melby-Lervåg & Lervåg, 2011).

Troisièmement, les performances en lecture des enfants EANA ne semblent pas influencées par le fait qu'ils aient déjà été exposés à une orthographe alphabétique ou non. Cela s'explique probablement par le fait que seulement 3 enfants ont été exposés à un système logographique dans notre échantillon. Les autres avaient été exposés à des systèmes que l'on pourrait qualifier de "semi-alphabétique" où les consonnes apparaissent et où les voyelles sont plus ou moins représentées. Ces systèmes impliquent de développer de bonnes compétences de conscience phonologique (e.g. Abou-Elsaad et al., 2016) qui peut profiter à l'apprentissage du français écrit.

Quatrièmement, les enfants ayant été exposés à un système d'écriture latin obtiennent de meilleurs scores que les autres, possiblement parce qu'il n'est pas nécessaire d'apprendre à reconnaître de nouveaux caractères. Un tel effet pourrait néanmoins être modéré par la congruence entre les règles de conversion graphème-phonèmes de la langue maternelle et celles du français.

Pour finir, la famille de langues ne présentait aucune contribution. Il est tout à fait possible qu'un tel critère soit inopérant pour rendre compte de la distance typologique entre les langues compte tenu de l'hétérogénéité des langues au sein des langues indo-européennes.

En complément de ces analyses, nous avons comparé les enfants présentant les facteurs les plus favorables à l'apprentissage de la lecture en français, c'est-à-dire les enfants arrivés après le CP qui avaient déjà commencé à apprendre à lire dans un système latin avant d'arriver en France, aux enfants francophones natifs. Nous détections toujours une différence entre les groupes indiquant que d'autres facteurs pouvaient expliquer ces différences tels que l'exposition à des événements traumatiques (Fazel et al., 2005), le degré de violence perçu à l'école, l'engagement relationnel et dans les apprentissages à l'école (Suárez-Orozco et al., 2009), les ressources familiales telles que le niveau d'éduction des parents, le nombre d'adultes à la maison, les ruptures de scolarité (Suárez-Orozco et al., 2010).

I.3.2.2 Facteurs cognitivo-linguistiques

Des analyses de régression multiples ont permis d'examiner le pouvoir prédictif de la conscience phonologique, de la dénomination rapide automatisée, de la répétition de non-mots, du niveau de vocabulaire et de l'apprentissage de paires associées visuelles-verbales dans les capacités de lecture de mots et de pseudo-mots.

L'ensemble des ces facteurs expliquent une plus grande part de variance en lecture de mots et de pseudo-mots chez les enfants EANA que chez les enfants tout-venant. Ce résultat est important dans la mesure où il suggère qu'il est pertinent d'utiliser des tests cognitivo-linguistiques pour dépister des difficultés de lecture précocement chez les enfants EANA en dépit du fait que de nombreux facteurs contextuels jouent aussi sur la réussite en lecture.

La conscience phonologique et la dénomination rapide automatisée sont d'excellents prédicteurs conformément à la littérature antérieure. La répétition de non-mots est corrélée à la réussite en lecture dans les deux groupes, mais ne résiste pas au contrôle des autres facteurs chez les allophones ce qui peut s'expliquer par l'implication de la boucle phonologique dans la tâche de conscience phonologique (Melby-Lervåg, 2012; Melby-Lervåg & Lervåg, 2012). Soulignons que le niveau de vocabulaire joue sur le niveau de lecture de mot et de pseudo-mots tandis qu'il ne contribue pas significativement à la lecture chez les enfants francophones natifs. Il est possible que les mots lus soient suffisamment fréquents à l'oral pour que la tâche de lecture de mots ne permette pas de capturer la variance expliquée par le niveau de vocabulaire chez les francophones natifs. En revanche, les enfants EANA présentant un faible niveau de vocabulaire comparativement aux enfants francophones natifs, les performances à la tâche de lecture de mots pourraient être sensible aux variations de niveau de vocabulaire. Enfin, les capacités d'apprentissage visuelles-verbales ont montré une contribution significative chez les enfants francophones natifs et EANA en lecture de mots et que chez les enfants EANA en lecture de pseudo-mots. Un tel résultat suggère qu'il est intéressant d'approfondir notre compréhension de ce prédicteur avant peut-être d'utiliser dans une démarche de dépistages précoce des difficultés en lecture conjointement aux autres mesures.

I.4. Des analyses corrélationnelles aux testings individuels par la comparaison avec un groupe de contrôle

Le fait que les facteurs cognitivo-linguistiques soient bien corrélés à la réussite en lecture chez les enfants EANA ne signifie pas qu'il est possible de dépister les difficultés en lecture avec les tests standardisés existants. En effet, l'ensemble des tests sont normés sur des populations francophones natives. Il est donc peu probable que les normes soient opérantes pour les enfants EANA compte tenu du peu d'exposition au français et de la distance typologique entre les langues. Pour limiter de tels biais, nous avons adopté différentes solutions telles qu'appliquer une cotation flexible des productions verbales ou encore l'examen d'un prédicteur potentiellement peu biaisé: les capacités d'apprentissage de paires associées visuelles-verbales. Nous nous demandons si, grâce à ces adaptations, des normes communes aux enfants francophones et EANA peuvent être utilisées. Cela représenterait un intérêt pratique considérable puisqu'il serait possible de créer les normes sur une population francophone, plus accessible que la population EANA. Pour tester cela, nous avons comparé les performances à l'ensemble des prédicteurs entre les groupes en contrôlant les habiletés non-verbales notamment. Comme les enfants EANA présentent de moins bonnes performances en lecture et qu'il est connu que la relation entre la lecture et les prédicteurs cognitivo-linguistiques est réciproque, tout particulièrement pour la conscience phonologique, nous avons opéré cette comparaison en contrôlant le niveau en lecture également. Nous émettions l'hypothèse que les enfants allophones présenteraient de moins bonnes performances pour les tests s'appuyant sur des connaissances langagières à savoir: le niveau de vocabulaire et la dénomination rapide automatisée. Le niveau de conscience phonologique et d'apprentissage de paires associées visuelles-verbales devrait également être moins bon chez les enfants EANA en l'absence de contrôle du niveau de lecture. On ne s'attendait pas à observer de différence entre les groupes sur les habiletés non-verbales et la répétition de non-mots.

I.4.1. Méthode

Les analyses réalisées dans cette section portent sur le même échantillon et les mêmes mesures que la section précédente.

I.4.2. Résultats et Discussion

En l'absence de contrôle de la lecture, conformément aux hypothèses, les enfants EANA présentaient des scores inférieurs aux enfants tout-venant sur la conscience phonologique, la dénomination rapide automatisée, le niveau de vocabulaire et l'apprentissage de paires associées visuelles-verbales. En revanche, ils présentaient des résultats similaires aux habiletés non-verbales et en répétition de non-mots. Ces résultats suggèrent que des normes communes peuvent être utilisées pour ces deux mesures. Notons qu'elles expliquaient 33% de la variance en lecture.

Ensuite, conformément aux hypothèses, l'effet du groupe sur la conscience phonologique et l'apprentissage de paires associées visuelles-verbales n'a pas résisté au contrôle du niveau en lecture. Étonnamment, l'effet du groupe a également disparu pour la dénomination rapide automatisée suggérant que les enfants EANA ne sont pas pénalisés par le fait qu'il s'agisse de dénommer des mots français. Cela est potentiellement dû au fait qu'il s'agissait de dénommer des lettres et des chiffres qui sont largement entraînés à l'école.

Cela signifie que pour la conscience phonologique, la dénomination rapide automatisée et l'apprentissage de paires associées visuelles-verbales, il est possible d'utiliser des normes communes pour les EANA et les enfants francophones à condition que les enfants aient le même degré d'instruction à la lecture en français ou, de manière moins certaine, dans une autre orthographe latine ou alphabétique. Dans le cas où les enfants EANA seraient arrivés plus tardivement sur le territoire et n'auraient pas le même niveau d'instruction à la lecture que des enfants francophones dans une orthographe alphabétique il ne semble pas pertinent de créer des normes communes. Il semble donc important de comparer ces enfants à des populations EANA de référence plus fidèles à leur profil tout en limitant le nombre de groupes contrôles à constituer pour faciliter le recrutement de participants.

II. Second Axis: Examining the Role of Visual-Verbal Paired Associate Learning in Word reading Skills in Primary Schooled

Nous avons examiné la contribution d'un jeu de prédicteurs cognitivo-linguistiques sur la réussite en lecture chez les enfants EANA et constaté qu'ils étaient tous associés aux capacités de lecture de mots et de pseudo-mots (bien que les habiletés non-verbales et de répétition de non-mots ne résistaient pas au contrôle des autres variables). Nous avons notamment observé que les scores d'apprentissage de paires associées visuelles-verbales (PAL visuelle-verbale) contribuaient aux scores de décodage chez les enfants francophones et EANA conformément à la littérature antérieure. Un tel résultat est important puisqu'il s'agit d'un prédicteur peu biaisé par la quantité d'exposition à la langue, ce qui représente un avantage considérable pour créer des tests de dépistage des difficultés en lecture chez les enfants EANA. Toutefois les mécanismes par lesquels cette contribution s'opère restent mal compris. L'objectif de cette section est donc d'améliorer notre compréhension des relations entre les capacités de PAL visuelle-verbale et de décodage.

II.1. Examen critique du rôle de l'apprentissage multimodal par association de paires dans l'acquisition de la lecture de textes alphabétiques

Les tâches de PAL visuelles-verbales consistent à apprendre des paires de non-mots et d'images. Une tâche classique consistera par exemple à apprendre le nom de trois dessins d'animaux imaginaires. L'expérimentateur présente les paires à l'enfant une première fois. Puis, il présente dans un ordre aléatoire les trois images et demande à l'enfant de les dénommer. Un feedback est donné après chaque essai. Puis l'examinateur mélange les images et les présente une nouvelle fois à l'enfant pour qu'il les dénomme, toujours avec un feedback correctif. Le test continue jusqu'à ce que l'enfant dénomme 3 fois de suite chaque image correctement ou bien au bout de 14 essais par image (cet exemple est celui de la tâche utilisée par Mayringer & Wimmer, 2000). Le score peut être soit le nombre d'essais requis pour apprendre toutes les images ou bien le nombre de dénominations correctes sur l'ensemble des essais.

Une telle tâche implique des mécanismes variés qui peuvent tous expliquer, de manière non exclusive, la relation avec la lecture. La tâche de PAL visuelle-verbale et la lecture impliquent par nature un apprentissage associatif. Les capacités d'apprentissage associatif générales pourraient donc expliquer le lien avec la réussite en lecture. Certains auteurs défendent cependant l'idée qu'une telle relation n'existe que dans le cas où il s'agit d'apprendre l'association entre une information verbale et une information visuelle (Hulme et al., 2007). D'autres suggèrent que le composant verbal explique la relation avec la lecture par l'intermédiaire des capacités d'apprentissage verbal (Litt et al., 2013; Poulsen & Elbro, 2018) ou bien de production verbale (Litt et al., 2019). Le but de ce chapitre était de conduire une revue systématique de littérature pour faire l'état des preuves expérimentales pour chacune de ces hypothèses.

II.1.1. Méthode

Nous avons examiné la littérature publiée jusqu'à décembre 2023. Nous avons repéré 1939 références dans les bases de données Scopus, Web of Science et PsychINFO et inclus 34 articles.

II.1.2. Résultats et Discussion

Il apparaissait clairement que la relation entre la PAL visuelle-verbale et la réussite en lecture n'est pas liée aux capacités d'apprentissage associatif "générales" puisque toutes les tâches ne montrent pas le même niveau de relation avec la réussite en lecture. Par exemple, les capacités d'apprentissage associatif visuelles-visuelles sont peu ou pas corrélées aux performances en lecture (Hulme et al., 2007; Litt et al., 2013; C. Liu et al., 2020; Wang et al., 2017; Wass et al., 2019). L'hypothèse d'un rôle de la cross-modalité est soutenue par l'étude de Hulme et al. (2007) dans laquelle l'apprentissage de paires associées visuelle-verbale contribue à la lecture au-delà de mesures de PAL verbale-verbale et visuelle-visuelle. Toutefois ce résultat est inconsistant avec le reste de la littérature (e.g. Clayton et al., 2018; Litt et al., 2013; Litt & Nation, 2014). L'apprentissage verbal explique en partie la relation entre la PAL visuelle-verbale et la lecture, du moins dans les systèmes alphabétiques opaques (Elbro & Jensen, 2005; Litt et al., 2019; Litt &

Nation, 2014; Vellutino et al., 1995), mais ne semble pas jouer dans des orthographes plus transparentes (Mayringer & Wimmer, 2000; Messbauer & de Jong, 2003). Cette observation est conforme à la proposition théorique de Elbro & de Jong (2017) selon laquelle l'apprentissage verbal est censé soutenir la lecture de mots irréguliers, qui sont plus nombreux dans les orthographes opaques que dans les orthographes transparentes (Schmalz et al., 2015). Enfin, le rôle de l'output verbal pourrait être principalement lié à sa meilleure sensibilité pour rendre compte de l'apprentissage verbal que les tâches de reconnaissances. La seule étude entendant distinguer l'effet des processus de production verbale de ceux liés à la sensibilité de la tâche présente des résultats contradictoires et portait sur très peu de participants (Litt et al., 2019). De plus, notons que les raisons théoriques d'un rôle direct de la production verbale dans le lien entre la PAL visuelle-verbale et la lecture sont fragiles.

II.2. Examining Cross-modal and Verbal Learning in Word and Nonword Reading Skills in French Children

Nous avons vu que la contribution des capacités de PAL visuelles-verbales semble essentiellement liée à l'apprentissage verbal bien. L'importance de l'apprentissage cross-modal associatif n'est pas encore bien élucidée. L'objectif de ce chapitre était d'analyser des données complémentaires de la population contrôle du projet TANMALL. Ces données nous ont permis de tester la contribution de l'apprentissage cross-modal associatif et l'apprentissage verbal.

II.2.1. Méthode

Nous avons analysé les données de 227 enfants francophones du projet TANMALL qui ont réalisé des tests de lecture de mots et de pseudo-mots, d'habiletés non-verbales, de conscience phonologique, de dénomination rapide automatisée, de répétition de non-mots, de vocabulaire et de PAL visuelle-verbale. Deux mesures complémentaires étaient ajoutées au paradigme classique de PAL visuelle-verbale : une mesure de reconnaissance auditive pour tester l'apprentissage verbal au cours de la tâche et une mesure de désignation d'image pour tester plus directement l'apprentissage cross-modal associatif.

II.2.2. Résultats et Discussion

Nous avons observé que les scores de PAL visuelle-verbale contribuaient significativement aux scores de lecture de mots, mais pas de lecture de pseudo-mots, une fois les autres prédicteurs contrôlés. Cela indique que le rôle de la PAL visuelle-verbale dans la lecture se situe plutôt au niveau lexical que sous-lexical. La reconnaissance auditive présentait également une contribution unique dans la réussite en lecture de mots, mais pas en lecture de pseudo-mots. Ce résultat indique que l'apprentissage verbal est une partie de l'explication du rôle de la PAL visuelle-verbale dans la lecture de mots. Pour finir, le score de désignation ne contribuait ni en lecture de mots, ni en lecture de pseudo-mots échouant donc à démontrer que l'apprentissage cross-modal associatif présente un rôle substantiel dans la relation entre la PAL visuelle-verbale et la lecture de mots.

II.3. Examining Cross-modal and Verbal Learning in Simple and Complex Word Reading Skills in French Children

Dans ce chapitre, nous souhaitions comprendre plus en détail pourquoi l'apprentissage verbal présente une contribution unique dans la lecture de mots. Elbro & de Jong (2017) suggèrent que les enfants apprennent la prononciation orthographique des mots inconsistants et que cela les aide ultérieurement à récupérer la bonne prononciation du mot. Par exemple, ils apprendraient la prononciation orthographique "feumeu" de "femme" de sorte que la fois suivante où ils liraient "feumeu", ils en déduiraient qu'il s'agit du mot "femme". Ce processus d'apprentissage verbal est donc supposé venir en soutien plutôt à la lecture de mots inconsistants que de mots consistants. C'est ce que nous souhaitions tester dans ce dernier chapitre.

II.3.1. Méthode

Nous avons recruté 186 enfants de niveau CP qui ont réalisé des tâches de lecture de mots, d'habiletés non-verbales, de conscience phonologique, de dénomination rapide automatisée, de répétition de non-mots et de PAL visuelle-verbale et verbale-verbale.

La tâche de lecture de mot consistait à lire quatre listes de mots de complexité croissante. Les deux premières listes comportaient des mots parfaitement consistants. Les deux dernières listes comportaient des mots inconsistants soit comportant des graphies contextuelles, soit complètement irréguliers. Nous avons calculé pour chaque liste des scores d'exactitude et de scores de fluence (nombre de mots correctement lus en une minute).

Nous avons testé l'apprentissage verbal dans la PAL visuelle-verbale et la PAL verbale-verbale en utilisant une tâche de reconnaissance auditive comme dans le chapitre précédent. Nous avons également utilisé une mesure de dénomination sur indiçage phonologique en plus de la mesure de dénomination spontanée. L'effet de la cross-modalité a été testé de nouveau en comparant la contribution des scores de PAL visuelle-verbale à ceux de la PAL verbale-verbale qui est unimodale. Ce choix est motivé par l'examen de la littérature antérieure et le fait que la tâche de désignation qui remplissait ce rôle ne présentait aucune contribution dans l'étude précédente.

II.3.2. Résultats et Discussion

Toutes les analyses de contribution unique sont réalisées en contrôlant l'indicateur de position sociale des écoles, l'âge en mois des participants, les habiletés non-verbales, la conscience phonologique, la dénomination rapide automatisée, la répétition de non-mots et le niveau de vocabulaire.

Les scores de dénomination et de reconnaissance de la PAL visuelle-verbale contribuent significativement aux scores d'exactitude et de fluence en lecture de mots et de pseudo-mots. Nous reproduisons donc globalement les résultats du chapitre précédent en démontrant que l'apprentissage verbal joue un rôle prépondérant dans la relation entre la PAL visuelle-verbale et le décodage. Étonnamment, seul le score de dénomination de la PAL verbale-verbale contribue à la réussite en lecture de mots et ce, seulement pour les mesures de fluence. Ce résultat est inconsistant avec la littérature qui a souvent démontré que la PAL verbale-verbale contribuait aussi bien ou mieux à la lecture de mot que le la PAL visuelle-verbale (Clayton et al., 2018; Litt et al., 2013; Wang et al., 2017; Wass et al., 2019). Nos données semblent indiquer que la cross-modalité dans la tâche de PAL visuelle-verbale pourrait améliorer sa contribution dans la réussite en lecture de mots bien qu'il puisse aussi s'agir d'un artefact statistique lié à la sensibilité de nos différentes mesures ou bien à la puissance statistique de notre étude.

Par ailleurs, nous nous attendions à ce que l'apprentissage verbal présente une contribution unique sur la lecture de mots inconsistants une fois les scores de lecture de mot consistant contrôlés. Aucune analyse n'aboutit à une telle conclusion suggérant deux interprétations : (1) soit le rôle de l'apprentissage verbal est mineur ou absent en français. Cela semble plausible puisque le français présente une orthographe peu opaque dans le sens de la lecture. Les enfants seraient donc moins amenés à développer de telles stratégies pour lire les mots inconsistants. (2) Soit l'apprentissage verbal est aussi important pour la lecture de mots très réguliers que de mots inconsistants. Des études complémentaires doivent être menées pour tester plus directement le rôle de l'apprentissage verbal dans la lecture de mots inconsistants.

III. Conclusion

Cette recherche visait à jeter les bases de la création d'outils conçus pour identifier les enfants EANA à risque de présenter des difficultés en lecture. Nous avons souligné l'importance d'un certain nombre de facteurs contextuels et cognitivo-linguistiques des compétences de décodage, en nous concentrant plus particulièrement sur l'apprentissage de paires associées visuelles-verbales. Les prédicteurs cognitivo-linguistiques ont permis de prédire une grande partie de la variance des compétences de décodage chez les enfants EANA, ce qui confirme leur pertinence pour créer des outils permettant d'identifier précocement les enfants présentant un risque d'échec en lecture. Nous avons également insisté sur l'importance de prendre en compte la distance typologique entre les langues maternelles et le français et les biais potentiels dus aux connaissances linguistiques. Nous avons examiné le rôle prédictif d'une tâche de paires associées visuelles-verbales chez les enfants français et EANA, précisément parce qu'elle ne repose pas sur des connaissances linguistiques et parce qu'il est possible de créer des items ayant des propriétés universelles adaptés aux enfants EANA. Bien qu'elle ait présenté une bonne contribution unique aux compétences de décodage chez les enfants EANA, les mécanismes expliquant cette relation ne sont pas bien élucidés. De plus, il n'est pas encore certain qu'il contribue de manière causale aux compétences de décodage. Nous avons proposé des pistes de travail pour l'avenir, à la fois pour créer des outils standardisés permettant d'identifier les enfants EANA ayant des difficultés de lecture et pour mieux comprendre les mécanismes impliqués dans la PAL visuelle-verbale.

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Introduction

In 2021, almost 10.3% of the French population were immigrants and almost one fifth of residence permits were issued for economic or humanitarian reasons (INSEE, 2023). These migratory flows are set to increase as a result of the climate and environmental crisis. Many regions are already suffering disruption to their physical systems (e.g. floods, droughts), biological systems (e.g. loss of marine and terrestrial biodiversity) and humanitarian systems (e.g. food insecurity; Pachauri & Meyer, 2014).

Welcoming people with a migrant background is a challenge. Compared to the rest of the French population, people with a migrant background have a higher unemployment rate, lower wage levels and are often employed in lower-skilled jobs (INSEE, 2023). Language proficiency, especially written language, is a critical factor for success in integration, socialization, academic and professional life. This thesis investigates the mechanisms involved in the development of reading in newcomer non-francophone children focusing on primary school children.

In 2021–2022, there were almost 35,374 'newcomer non-francophone children' (French equivalent: 'enfant allophone nouvellement arrivé', EANA) in primary school (Brun, 2023). According to the Organisation for Economic Co-operation and Development (OECD), immigrant children are more likely to have reading difficulties at the age of 15 than the general population. This is particularly the case in France, where the gap between immigrant children and non-immigrant children is greater than in the rest of the OECD (OECD, 2019). These difficulties are partly related to a lack of proficiency in the additional language (OECD, 2015). Moreover, like native French-speaking children, EANA children are likely to have learning disorders. Nevertheless, they suffer from delayed orientation due to the difficulty of dissociating linguistic difficulties caused by lack of exposure to the language from actual disorders (C. R. Jørgensen et al., 2020). Although the literature and some tools have been developed over the last decades for the second oral language assessment (Armon-Lotem et al., 2015; dos Santos & Ferré, 2018; Moro, 2017; Tuller, 2015) there is currently no suitable standardized tool to identify written language disorders or at least risk factors in newcomer non-francophone children. Nevertheless, it is important to identify them as early as possible, as they are already vulnerable due to economic, social and psychological factors, because they arrive late, after formal and explicit reading instruction. Detecting early children at risk would enable for intensive and early intervention, for example, by speech and language therapists.

The primary aim of this thesis was to provide preliminary work for the future development of screening tools. Our analysis focused on a set of cognitive-linguistic predictors, in particular phonological skills, which show a strong correlation with reading achievement (Kirby et al., 2008; Wagner & Torgesen, 1987) and the level of vocabulary (F. Duff & Hulme, 2012; Mitchell & Brady, 2013; Ouellette, 2006; Ricketts et al., 2007). Focusing on French and EANA children at primary school level, we compared the contribution of these predictors to the decoding skills, which serve as the pillars of future reading comprehension skills in monolingual children (Gough & Tunmer, 1986; Hoover & Gough, 1990; Ouellette & Beers, 2010; Tunmer & Chapman, 2012b) as well as in bilingual children (Verhoeven & van Leeuwe, 2012). We wondered whether the weight of these predictors might be reduced for EANA children whose reading ability is influenced by many other factors. Some of these will be addressed in this research, such as the child's schooling before arriving in France, the age at which he or she arrived, and the linguistic similarity of the other languages he or she speaks with French.

Moreover, EANA children may produce various phonemic substitutions on tasks requiring phonological output, depending on the typological distance between French and their other spoken languages. This could be misleading for examiners who could interpret these substitutions as errors. As a result, the actual ability of the targeted skills, such as decoding and phonological awareness, may be underestimated. This thesis provided an opportunity to investigate the relevance of some adaptations of cognitive-linguistic assessments to EANA children.

Finally, we examined the contribution of a visual-verbal paired associate learning (PAL) task to the prediction of word and pseudoword reading skills in EANA and French children, among the other cognitive-linguistic predictors. Several studies tend to show that it makes a unique contribution (Litt et al., 2013; Poulsen & Elbro, 2018; Warmington & Hulme, 2012; Windfuhr & Snowling, 2001) and it has some interesting features for EANA children. First, it does not rely on language knowledge, as it consists of learning nonwords. Furthermore, precisely because it is based on nonword learning, it is easy to construct items with universal phonological properties. However, the evidence for a truly unique contribution remains fragile (e.g. Lervåg et al., 2009) and the mechanisms that account for this relationship have been the subject of debate (Hulme et al., 2007; Litt et al., 2013). For these reasons, and given the difficulties in recruiting EANA children, we decided to open a second line of research which aimed at confirming the existence of a unique contribution of learning scores for visual-verbal PAL in French reading, and at better understanding the mechanisms involved.

In short, this thesis is structured around two relatively distinct lines of research, but with the common aim of identifying the most relevant cognitive-linguistic measures to be taken with EANA children in order to detect reading difficulties at the earliest stage. One focuses on the prediction of reading ability and the adaptation of assessment tools for EANA children. The other proposes an in-depth discussion of the relationship between scores on visual-verbal PAL tasks and reading, which is a promising measure for the EANA children but which is still poorly understood.

Part 1. Theoretical Background

IV. First axis: predicting reading development in newcomer non-francophone children (EANA).

Reading processes can be divided into two components: decoding and comprehension (Gough & Tunmer, 1986). As this research focused on children learning to read, we focused on decoding skills which are a key to the development of future reading comprehension skills. Throughout this manuscript, we will use the term **'decoding skills'** to refer to **'the ability to find the correct phonological form of a written word out of context'**. In this section, we presented some theoretical models that describe the development of decoding skills in alphabetic scripts, from letter learning to expert processing of written words. The main cognitive and linguistic predictors of decoding skills were then presented. Finally, we looked at the extent to which decoding development and its predictors differ, or not, in children learning an additional language.

IV.1. The Development of Decoding Skill in a Monolingual Context

The aim of this section was to present the main steps in learning to read in alphabetic orthographies in a monolingual context. We then described the main predictors of future reading achievement.

IV.1.1. From Letter Recognition to Sight Word Vocabulary

Expert readers can recognize written words quickly, automatically, and irrepressibly (Ferrand, 2007). A fun manifestation of this speed, automaticity and irrepressibility is the Stroop effect (Stroop, 1935). In this paradigm, participants had to name the colors of written words. They were slower when they had to name written color names that were inconsistent with the font color. The time needed to complete the task was thus influenced by the meaning of the words although it was not necessary to read to complete the task. One possible explanation is that readers' brains encode a 'sight vocabulary' that contains the orthographic representations of words. This sight vocabulary is closely linked to phonological and semantic representations (Perfetti & Lesley Hart, 2002). One misconception is that sight word vocabulary is a repertoire of visual forms. It might be better defined as abstract orthographic patterns of written words or sublexical segments (hereafter orthographic representations), regardless of fonts or case (Dehaene et al., 2001, 2005). To understand how such representations may be constructed, we look below at some developmental and expert accounts of word reading skills.

According to Ehri's (2005) framework, the development of sight word vocabulary requires the child to map orthographic to phonological units in memory. To do this, they go through different overlapping learning phases corresponding to different levels of alphabetic knowledge: 'pre-alphabetic', 'partial alphabetic', 'full alphabetic' and 'consolidated alphabetic'. The pre-alphabetic phase corresponds to the ability to recognize words on the basis of non-alphabetic cues (e.g. recognizing a brand logo). The partial alphabetic phase characterizes children who learn grapheme-phoneme correspondences but only partially use them to map orthographic to phonological information. In other words, they guess words by concentrating on a few letters. The full alphabetic phase corresponds to children who know enough grapheme-phoneme correspondences to map entire word spellings onto their pronunciations. The children find the exact phonological form of words by blending the phonemes obtained by recoding the letters. Finally, the consolidated alphabetic phase corresponds to the retention of the orthographic form in memory (after the first decoding of a given word). This phase allows the rapid and automatic recognition of known written words and facilitates the recognition of new words on the basis of known orthographic patterns (syllables, morphemes, etc.). These phases are assumed to overlap during the development of reading[1].

The two final phases correspond roughly to both procedures used by expert readers to read words according to the Dual Route Cascade (DRC) model of Coltheart et al. (2001). This model suggests

1 This theoretical account is a kind of updated version of Frith's (1986) ' stage ' model.

that readers read words using either an indirect phonological sequential recoding procedure or a direct lexical procedure (recognizing the whole orthographic representation and automatically addressing it to the corresponding phonological and semantic representations). The recoding procedure is useful when the reader encounters nonwords or new words. However, it is more time-consuming and laborious than the lexical procedure. Note that although this model is a good proxy for the present section, other model were proposed in the literature such as Triangle Models (e.g. Plaut et al., 1996; for a critical synthesis of the contribution of the DRC model and connectionnists approach, see Seidenberg et al., 2022).

The development of both procedures depends on school teaching and on the child's experience. Teaching children to read consists, first of all, of developing the recoding procedure. School helps them to 'crack the code' by learning the rules of grapheme-phoneme conversions so that they can decode new words themselves. However, the school does not have the power to teach the thousands of written words that a child will learn in the course of his or her schooling (for an estimate of the size of the reading vocabulary in primary school, see White et al., 1990). Sight vocabulary growth is more a fact of reading experience as theorized by Share (1995). The more children read, the more they are exposed to new spelling patterns that enrich their sight word vocabulary. Decoding new words is a fundamental and effective step in increasing sight word vocabulary (e.g. Ricketts et al., 2011). We will see in a further section that oral vocabulary could also be a support to the development of sight word vocabulary (Tunmer & Chapman, 2012b).

Interestingly, several effects can help to determine which procedure is used to read words (either phonological recoding or the lexical procedure): lexicality, regularity and length. (1) Basically, the "lexicality effect" is the fact that real words are better read than pseudowords. It is expected to increase across grades. (2) The "regularity effect" is the fact that orthographically consistent words (i.e. with regular grapheme-phoneme correspondences) are better read than inconsistent words (i.e.

with inconsistent or irregular grapheme-phoneme correspondences). It is expected to decrease over the school years. (3) The 'length effect' is the fact that long words are easier to read than short words. This effect is expected to hold for pseudowords, whereas it is expected to diminish over the school years for real words. These patterns are well known (e.g. Sprenger-Charolles et al., 2005; Zoccolotti et al., 2009) and provide indirect evidence for the development of a sight word vocabulary over time and reading experience.

Let’s Recap

- Learning to read is based on the maturation of alphabetic knowledge.
- Word reading skills develop thanks to:
  - explicit teaching of the rules for converting graphemes into phonemes
  - a self-learning process facilitated by oral language knowledge
- As a proxy, reading words could be achieved:
  1. recoding each grapheme sequentially into the corresponding phoneme, then combining all the phonemes to form syllables and/or words.
  2. Recognizing the orthographic pattern of written words and retrieving the associated phonological and semantic representations from memory.

IV.1.2. Factors Involved in Decoding Acquisition in Native Speakers

According to the Component Model of Reading (Aaron et al., 2008; M. Li et al., 2020), learning to read is underpinned by cognitive (e.g. phonological skills), psychological (e.g. motivation) and ecological (e.g. family environment) components. In this research we have focused on cognitive and linguistic predictors, although in the case of additional language learners we also examine some ecological predictors. The aim of this section was to present the strongest cognitive-linguistic predictors of reading in a monolingual context.

IV.1.2.1 *Letter Knowledge*

Intuitively, the basis of alphabetic knowledge (in the sense of Ehri, 2005) is letter knowledge. Letter knowledge is either operationalized as ‘letter name knowledge’ (Leppänen et al., 2008; Manu et al., 2021; Piquard-Kipffer & Sprenger-Charolles, 2013; Poulsen & Elbro, 2018), ‘letter sound knowledge’ (Clayton et al., 2020) or both (Lervåg et al., 2009; Peng et al., 2019; Schatschneider et al., 2004). Interestingly, when assessed before or at the very beginning of formal reading instruction, both kinds of letter knowledge predict future reading achievement in primary school years (Clayton et al., 2020; Leppänen et al., 2008; Lervåg et al., 2009; Peng et al., 2019; Piquard-Kipffer & Sprenger-Charolles, 2013; Poulsen & Elbro, 2018; Schatschneider et al., 2004) or beyond (Manu et al., 2021; but see: Poulsen & Elbro, 2018). Similarly, both letter naming and sound learning improve written word recognition, although letter sounds knowledge is slightly more effective (Levin et al., 2006). Letter sounds knowledge is needed to recode written words into their phonological form. The effect of letter name knowledge is less clear (for a review, see Noel Foulin, 2005). Letter name knowledge effect on reading might be mediated by home literacy experiences which are known to be predictive of future reading achievement (Sénéchal & LeFevre, 2014). Letter name knowledge may also promote the learning of letter sounds, as names usually give indications of the sound of the letters (for example, the sound /l/ is included in the name of the letter ‘l’).

IV.1.2.2 *Phonological Awareness*

Basically, phonological awareness is the ability to manipulate phonological units of words. It is the most important predictor of decoding skills, at least in alphabetic orthographies. It has been argued that phonological awareness is related to reading development because it reflects the quality of phonemic representations that help learn the rules for converting graphemes into phonemes (Melby-Lervåg, 2012). A large body of evidence has shown that phonological awareness is a strong correlate of reading development in unselected samples of children in concurrent (e.g. Melby-

Lervåg, 2012; Swanson et al., 2003) and longitudinal designs (but see Peng et al., 2019). Moreover, poor readers fail in such tasks (Melby-Lervåg et al., 2012) and phonological awareness training has a positive impact on reading development (Bus & van IJzendoorn, 1999). The phonemic awareness (manipulation of phonemes) is better related to reading skills than other phonological awareness tasks that involve more salient phonological units such as rime (Melby-Lervåg, 2012). Furthermore, phonemic awareness predicts decoding skills with better accuracy in the beginning of reading experience than later. For example, Poulsen and Elbro (2018) found a strong correlation between phonological awareness measured before the beginning of reading development and reading at grade 1. However the relationship with reading at grade 5 was weak (see also Lervåg et al., 2009; Parrila et al., 2004). Interestingly, some authors have shown that the relationship between phonological awareness and reading is bidirectional (Clayton et al., 2020). Indeed, the experience with alphabetic orthographies could strengthen phonological awareness (Cheung et al., 2001; Cheung & Chen, 2004; Morais et al., 1979). Similarly, the correlation between phonological awareness and reading appeared to be greater when assessed after the onset of reading development than before (Bar-Kochva & Nevo, 2019), meaning that an exposure to letters could improve phonological awareness.

IV.1.2.3 Rapid Automatized Naming

Rapid automatized naming is another strong correlate of decoding skills. It refers to the ability to name a list of repeated, familiar, automatized stimuli accurately and quickly. The items are often presented in an array and can be either alphanumeric characters (letters or digits) or non-alphanumeric images (e.g. colors, pictures of objects). The literature has shown that rapid automatized naming is concurrently (Araújo et al., 2015; Swanson et al., 2003) and longitudinally correlated with reading development, more specifically with reading fluency (Bar-Kochva & Nevo, 2019; Lervåg et al., 2009; Manu et al., 2021; Poulsen et al., 2015; Powell & Atkinson, 2021).

According to Kirby et al. (2010), different hypotheses could explain the link between rapid automatized naming and reading. Each focuses on a different step involved in the task. First, the participant must identify the visual information which could be related to orthographic processing, i.e. the ability to recognize rapidly either single letters or letter patterns. Second, once the visual information has been identified, the participants must retrieve the phonological associate and produce it orally leading some authors to consider that phonological access is important in rapid automatized naming. Third, articulatory processing may play a role as well as general processing speed, although this has been debated (Araújo et al., 2011). Some authors suggested that rapid automatized naming taps into the efficacy of the link between visual and verbal information (Poulsen et al., 2015). Finally, serial aspects of the task might play an important role (Logan et al., 2011).

IV.1.2.4 Phonological Short-term Memory

The third well-documented cognitive predictor is phonological short-term memory. We could distinguish between phonological short-term memory (merely, the temporary storage of phonological information, also referred to as the 'phonological loop') and working memory (the manipulation of stored information; Baddeley & Hitch, 1974). As, these two terms are sometimes used interchangeably in the literature, we will use the term 'phonological short-term memory' throughout this document. A large body of evidence has shown that phonological short-term memory is less efficient in poor readers than good readers (Swanson et al., 2009). However, phonological short-term memory it was shown to be highly related to phonological awareness which moderates a large part, if not all, of its shared variance with reading (Melby-Lervåg, 2012; Melby-Lervåg et al., 2012). According to Peng et al. (2018), phonological short-term memory could play a role in phonological recoding. In fact, phonological recoding involves sequentially recoding graphemes into phonemes, holding them in memory, and then combining them into syllables or words.

IV.1.2.5 Vocabulary

Although to a lesser extent, breadth vocabulary has also been found to be a significant contributor to word reading skills over phonological processing (F. Duff & Hulme, 2012; Kim, 2015; Mimeau et al., 2018; Mitchell & Brady, 2013; Ouellette & Beers, 2010; Ricketts et al., 2007). Several theoretical frameworks account for this relationship. Some authors argue that word reading may be facilitated by semantic representations (McKay et al., 2008), especially irregular word reading (Ricketts et al., 2007). Semantic representations would act as mediators between opaque orthographic form and phonological representations when grapheme-to-phoneme conversion rules are inefficient. This view is commonly defended within the framework of the connectionist theory of written word recognition known as the triangle model of reading (first described by Seidenberg & McClelland, 1989). Other results have shown that knowing the phonological form of a written word facilitates its reading (McKague et al., 2001; Nation & Cocksey, 2009). This facilitation could be mediated by the ’’Set for Variability’’(A. Edwards et al., 2020; Elbro et al., 2012; Steacy et al., 2019; Tunmer & Chapman, 2012a). The ’’Set for Variability’’ is the ability to retrieve the correct phonological representation of a word from an approximate representation, e.g. retrieving 'manuscript' from /manyskipt/.

IV.1.3. Some Differences Across Orthographies

Critically, research on reading predictors has mainly been conducted in English, although it could be considered as an outlier among alphabetic orthographies given its inconsistency (Share, 2008). Due to the complexity of the English orthography, English-speaking children in first grade achieve lower reading scores than their peers who learn to read in more transparent orthographies

(Caravolas et al., 2013; Seymour et al., 2003). This complexity is also reflected in the impact of phonological processing on reading achievement. While cross-linguistic research suggests that phonological processing is important in all alphabetic orthographies, it accounts for more variance in opaque orthographies than in transparent ones. This is particularly true for phonological awareness (Caravolas et al., 2013; Landerl et al., 2013, 2019; Moll et al., 2014; Vaessen & Blomert, 2010; Ziegler et al., 2010). Because transparent orthographies have highly consistent grapheme-phoneme correspondences, phonemes are more salient (via graphemes) than in opaque orthographies. As a result, according to Ziegler et al. (2010), children quickly acquire a good level of phonological awareness, which may explain why phonological awareness is ultimately less correlated with reading development in transparent orthographies than in opaque orthographies. Furthermore, the contribution of rapid automatized naming and phonological short-term memory to reading has been found in different orthographies, but the effect of transparency on this relationship is not so clear in the literature (Landerl et al., 2013; Moll et al., 2014; Vaessen & Blomert, 2010; Ziegler et al., 2010). Finally, in Ziegler et al. (2010), vocabulary was more strongly correlated with reading in Finnish (a transparent orthography) than in more opaque orthographies, although it was found to be a unique contributor to word reading accuracy in French, the most opaque orthography in the comparison. The authors suggest that reading skills promote the development of vocabulary in Finnish (and not vice versa).

Let's Recap

- In alphabetic orthographies, word reading skills are strongly correlated with letter knowledge and phonological skills, namely:
  - Phonological awareness
  - Rapid automatized naming
  - Phonological short-term memory
- Vocabulary supports reading development through a variety of mechanisms and has been shown to correlate with decoding skills when other predictors are controlled for, although the relationship is less strong or consistent than for phonological predictors.

IV.2. Developing Decoding Skills in a Multilingual Context

We have seen the main stages in the development of decoding in monolingual children and the main predictive factors. The main aim of this section is to see how well these findings apply to the situation of children learning to read in an additional language (i.e. in another language than the mother tongue). We will first describe in detail our population of interest. We will then look at the results of previous literature comparing the decoding performance of children learning an additional language with that of monolingual children. We will examine the contextual factors and cognitive-linguistic factors that may account for decoding performance of EANA children. Particular attention will be paid to the biases that may alter the predictive power of cognitive-linguistic factors and the solutions that we have proposed to address them. Among these solutions, we will explain the value of using a visual-verbal paired associate learning paradigm as an additional cognitive-linguistic predictor.

IV.2.1. The Population of Interest

In this study, we were interested in primary school age newcomer children who are learning to read in an additional language without having mastered the spoken language. Many studies have been carried out on learning to read in a multilingual context. However, at our knowledge, none have specifically targeted our population of interest. The terminology used varies considerably from one study to another: bilingual, multilingual, second language learners, additional language learners, minority language, immigrants, newcomers, etc. This multiplicity of terms does not necessarily characterize different populations, but often overlaps and at the same time covers very different situations. In fact, we looked at the populations sampled in the studies included in a meta-analysis of Melby-Lervåg & Lervåg, (2014) which focused on additional language reading acquisition. Often, the children spoke a minority language at home, i.e. a language other than the official language(s) of the country, and were exposed to the additional language in preschool or kindergarten. Sometimes, the samples included children who arrived after kindergarten in the country (as the children targeted in our study), but never focused specifically on them. Some studies focused on specific associations between maternal and additional language, but many have included additional language learners from diverse linguistic backgrounds. Finally, a few studies have focused on children enrolled in language immersion programs.

In France, primary school age newcomer children are supported by units called 'Unité pour enfants allophones nouvellement arrivés' translated here as 'Units for Newcomer Non-francophone Children' (referred by its French acronym UPE2A for the sake of simplicity). In principle, the duration of support in these units is limited to one year (Blanquer, 2012), but in practice it can last 2 years or more.

To some extent, the UPE2A are open to a much broader population than 'newcomers'. First, many children have a migrant background but may have lived in France for several months before starting primary school (Armagnague & Rigoni, 2018). They may also be non-French-speaking children born in France who have never attended school, such as Roma children. It seems more accurate to speak of children 'newly schooled in France'. In addition, the term 'allophone', translated here as 'non-francophone' for greater clarity, refers to people whose mother tongue is not the language of the community (Académie Française, 2022). This term covers a much wider range of situations than those encountered in practice, since a person with balanced bilingualism and considerable expertise in the additional language can be considered an 'allophone'. The term 'additional language learner' better reflects the lack of proficiency in the additional language, suggesting that it is still being learned. In short, it would be more precise to define the target population for this study as follows: **French as additional language learners newly schooled in France**. However, for the sake of simplicity (both for the author and for the reader), the French acronym '**EANA**' (for 'Enfant Allophone Nouvellement Arrivé') we will be used in the following.

Although this research focused on a very specific situation of additional language learning (EANA children), there is still a great deal of heterogeneity in the target population (C. Jørgensen et al., 2021). Firstly, as mentioned above, the majority of children have a migrant background, but some do not. Secondly, the profile of migration may vary. In 2021, about 36% of valid residence permits were for family reasons, 14% for humanitarian reasons and 8% for economic reasons (INSEE, 2023). Thirdly, 20% of children had never attended school before arriving in France 2021–2022 (Brun, 2023). Fourthly, children arriving late and encountering the most difficulties can be educated with younger children within a maximum difference of age with other children of the classes of two years. In 2021–2022, 26% of pupils were one year older than the children in their mainstream class and 3% were two years older (Brun, 2023). Fifthly, the EVASCOL study, which included 353 children, estimated that they came from 55 different countries and spoke a wide variety of languages (51 languages were represented; Armagnague & Rigoni, 2018).

Let’s Recap

- The present study focused on primary schooled age ‘French as an additional language learners newly schooled in France’. The French acronym ‘EANA’ will be used in the following for the sake of simplicity.
- French learning is supported by specialized teachers in school Units for Newcomer Non-francophone Children called UPE2A.
- EANA children have very few French knowledge when they start to learn to read French.

IV.2.2. Comparison of Decoding Performance Between Monolingual Children and Children Learning to Read in a Multilingual Context

To the best of our knowledge, only the EVASCOL study has been conducted specifically on the reading development of EANA children (Armagnague & Rigoni, 2018). A sample of 353 primary and secondary school children was studied. About a third of them had been attending UPE2A for more than a year while others had arrived during the school year. Of these, 199 were followed longitudinally for 6 months (no information was provided for the duration of school attendance since their arrival in this subsample). Oral and written comprehension tests showed that most of the children performed at levels A1 and A2 according to the Common European Framework of References for Languages (CEFR) which ranges from A1 to C2. Over the six months of longitudinal follow-up, the greatest progress was made by the children who moved from level A1 to A2. In fact, the children had very little exposure to the French language, which easily explains these results. What is less clear is the impact of poor language skills on decoding skills. The authors provided only a few portraits of children who were supposed to be representative of the EANA, whether or not they had learned to read before arriving in France. They scored much lower than native French children on text reading fluency. The differences between native and EANA children were certainly partly explained by the fact that text reading is supported by language comprehension (e.g. Jenkins et al., 2003; Kim, 2015; Stanovich et al., 1984). The authors also suggested that the children needed more explicit teaching of the grapheme-phoneme conversion rules of French spelling. Indeed, the children in the study were in grades 3 to 7, where reading was no longer taught.

If we take a step back from the international literature, there is some data on learning to read in a second language, although it doesn’t focus specifically on EANA children. Melby-Lervåg & Lervåg

(2014) conducted a meta-analysis of 82 studies, with 160 effect sizes corresponding to 15,137 additional language participants compared to 111,418 monolingual first language learners under the age of 18. Most of the studies included in this meta-analysis were conducted with primary school-age children. Participants were considered bilingual if they were exposed to each language for at least 4 hours a day. This covered a variety of bilingual profiles, including children who used one or both languages at home and one or both languages at school. However, the profile of bilingualism did not affect the results of the meta-analysis, which showed that compared with monolingual children, bilingual children had lower scores in reading comprehension and equivalent scores in phonological awareness and decoding.

Analysis of other different moderators shows that socio-economic level and the country in which the studies were conducted had a significant influence on the differences between the groups in terms of decoding. Studies conducted in Canada showed an overall advantage for bilingual children, whereas studies conducted in Europe and the USA showed a disadvantage for bilingual children. The difference between bilingual and monolingual children was greater in the USA. The authors suggest that this may be due to the level of education of the populations tested. Canada may have attracted more skilled immigrants than other countries. We examined the effect size of studies involving children in first and second grade (or aged 8 years and 6 months) and found that, on average, learners of other languages did not differ from the monolingual in their decoding skills.

It should be noted that most of the bilingual children in this meta-analysis had been exposed to the additional language before entering the grade 1. They therefore had time to acquire basic oral language skills before learning to read. They also benefited from explicit reading instruction at the same rate as the other children. Therefore, the results of this meta-analysis cannot be generalized to the EANA children. Indeed, educators have observed that EANAs have difficulty with decoding skills (Armagnague & Rigoni, 2018). Since Armagnague and Rigoni (2018) did not directly compare French and EANA children and only provided data for a few children (in terms of reading performance), it would be interesting to complement their work by comparing the decoding performance of a large sample of EANA children with that of French reading learners. It would also be interesting to determine how language status (EANA or French) influences word and nonword reading performance. Word reading is facilitated by knowledge of the spoken word, whereas nonword reading only involves grapheme-phoneme conversion. Therefore, EANA children might score lower than French children in word reading only, but achieve similar results in nonword reading.

Let's Recap

- EANA are underrepresented in the international literature.
- Existing research on additional language learners cannot be generalized to EANA children due to large differences in bilingual experiences.
- Professionals in the field and the EVASCOL study suggest that EANA children have difficulties with decoding skills, although this contradicts previous research on additional language learners.

IV.2.3. Contextual Factors

This research has allowed us to test 'contextual' factors that may have a potential impact on the reading achievement of EANA children. They may explain discrepancies between the literature on second language learners and observations of EANA children in relation to decoding skills (see previous section). We do not pretend to be exhaustive, as the main aim of this paper was to focus on cognitive and linguistic predictors. These few contextual factors were chosen because they were easy to report in our study.

Firstly, almost 20% of EANA children had never attended school before arriving in France

(Brun, 2023). Children who have been to school, even if only in preschool or kindergarten, may find it easier to adapt to the demands, rigor and daily rhythm of school, and be more available for learning. Moreover, this factor is highly confounded with the fact that children arrived in France having already learned to read in another language or not. Having learned to read in another language could facilitate learning to read in French. This phenomenon is known as ‘cross-linguistic transfer’.

Different complementary theoretical frameworks can explain cross-linguistic transfer as reviewed by S. C. Chung et al. (2019). The Contrastive Typological Framework (Lado, 1957) or the Transfer Facilitation Model (Koda & Zehler, 2008) suggest that common typological features between languages are easier to learn for additional language learners (e.g. similar morphemes, Schwartz et al., 2016) than different features (e.g. gender, Montrul & Potowski, 2007). The Linguistic Interdependence Hypothesis (Cummins, 1979) and the Common Underlying Cognitive Processes (Geva & Ryan, 1993) suggest that the relationship between the two languages could be mediated by “confounding factors” such as general intelligence or metalinguistic skills. Finally, the Interactive Transfer Framework (S. C. Chung et al., 2018) identifies some factors that moderate cross-language transfer, such as the distance between languages or the proficiency in each language.

In a meta-analysis, Melby-Lervåg & Lervåg (2011) showed that cross-linguistic transfers occur in reading skills. Phonological awareness in the first language is correlated with phonological awareness and decoding skills in the second language. Decoding skills in the first language are also correlated with decoding skills in the second language. However, these relationships are moderated by writing systems. Having started learning to read in one alphabetic system is more beneficial for learning to read in another alphabetic system than having started learning to read in another writing system (e.g. logographic). In fact, understanding the alphabetic principle can be applied directly to learning to read in a second alphabetic orthography, or indirectly by strengthening phonemic awareness. Indeed, several studies have shown that learning to read in an alphabetic system strengthens phonemic awareness (Cheung et al., 2001; Cheung & Chen, 2004; McBride-Chang et al., 2004; Morais et al., 1979). It is therefore expected that children who have been schooled and/or have started to learn to read in another language before arriving in France will progress more rapidly in their decoding skills than others. It is also expected that children who have been exposed to alphabetic orthographies will have an advantage over others in learning to read in French. In particular, exposure to a Latin system may be an additional advantage, since children have not had to learn new letters, and some grapheme-phoneme correspondences may be similar.

Arriving early (during or before first grade) or late (after first grade) in primary school may also have an impact on reading skills, regardless of whether children learned to read before arriving in France. EANA children who arrived in or before the first grade may have an advantage over older children because they can benefit from an explicit reading instruction at the same time as their French peers. In addition, older children (who have never learned to read) can be expected to have more difficulties because they have had to learn to read with less explicit instruction and at the same time has to catch up with other subjects (e.g. arithmetic). In addition, the age at which a second language is acquired may have an impact on language skills (partly because of critical periods of neurological maturation Birdsong, 2018). For example, it is easier to acquire phonological contrasts of a given language in the first year of life (Gervain & Mehler, 2010). Consequently, additional language learners may have difficulties in discriminating some phonological contrasts (Bylund et al., 2021; Ingvalson et al., 2014). The literature has also shown that the age of acquisition of the additional language influences the morphosyntactic skills of additional language learners (Bylund et al., 2021; Qureshi, 2016).

Finally, features of the mother tongue could facilitate or hinder second language development as explained above (Koda & Zehler, 2008; Lado, 1957). One might expect that children whose first language is typologically distant from French would have more difficulty learning French than children whose language has similar features. For example, some contrasts are difficult for non-native speakers to produce, such as the difference between /l/ and /ɹ/ in Japanese-English bilinguals (Ingvalson et al., 2014). Although it was not beyond the scope of this research to compare a specific language with French, we rather determine whether the linguistic family (i.e. Indo-European or not) of the first language can influence the reading achievement of EANA children. Similar criteria have been used in previous studies (Bialystok et al., 2010; Melby-Lervåg & Lervåg, 2014).

There are many other factors that may have a significant impact on reading scores, but which for practical reasons have not been investigated in this research. For example, the reason for migration may play an important role (economic migration, asylum, war refugees, etc.). Indeed, refugee children may have more difficulties in learning due to the trauma caused by war or other disasters (Fazel et al., 2005; Gagné et al., 2021). Reception conditions in France can also influence levels of insecurity, particularly in relation to housing. During the first months or years in France, many families move in order to find stable housing or work. This can lead to disruptions in schooling.

Let's Recap

- Some 'contextual' factors may explain why EANA children, at least some of them, develop decoding skills more slowly than French children:
    - some have never attended school and/or learned to read in another language before arriving in France
    - some have been exposed to languages whose characteristics are very different from French (non-Indo-European languages and/or non-alphabetic writing systems).
    - some arrived late at primary school and have not been able to benefit from an explicit teaching of reading at the same pace as French children.

IV.2.4. Cognitive and Linguistic Factors Involved in Decoding Acquisition in Additional Language Learners

Beyond contextual factors, decoding skills in EANA could also be predicted by the same cognitive and reading predictors as in French children. In this section, we have briefly reviewed the evidence on the relationship between the main cognitive and linguistic predictors (letter knowledge, phonological awareness, rapid automatized naming, phonological short-term memory and vocabulary) and word reading skills when both are assessed in the second language (intra-linguistic predictors) or when the predictors are assessed in the first language (cross-linguistic predictors).

IV.2.4.1 Intra-Linguistic Predictors

In general, the predictors of reading for additional language learners, when assessed in the additional language, are the same as for monolingual children (for narrative reviews see August & Shanahan, 2006; Geva et al., 2019).

Letter knowledge has been shown to be a concurrent correlate of word and nonword reading in kindergarten and grade 1 children from diverse linguistic backgrounds and with English as an additional language (Chiappe, Siegel, & Gottardo, 2002; Chiappe, Siegel, & Wade-Woolley, 2002; Quiroga et al., 2002), even when controlling for phonological awareness (Quiroga et al., 2002). It also has a longitudinal contribution when assessed in kindergarten on further word reading outcomes (Muter & Diethelm, 2001; Yuan et al., 2022), even when controlling for phonological awareness (Lesaux & Siegel, 2003; but see Bellocchi et al., 2017; MacKay et al., 2023).

Not surprisingly, phonological awareness has also been shown to be a concurrent correlate of reading achievement in additional language learners with children from different linguistic backgrounds and at different grade levels (Chiappe, Siegel, & Gottardo, 2002; Chiappe, Siegel, & Wade-Woolley, 2002; K. K. H. Chung & Ho, 2010; Geva & Farnia, 2012; Gottardo, 2002; Gottardo et al., 2001; Jongejan et al., 2007; Nakamoto et al., 2007; Quiroga et al., 2002; Yeong et al., 2014;

Yeung et al., 2013) even when controlling for letter knowledge (Quiroga et al., 2002), rapid automatized naming (Nakamoto et al., 2007) or vocabulary (Gottardo, 2002; Yeong et al., 2014). It is also a longitudinal correlate of word reading (Chow et al., 2005; Comeau et al., 1999; Gottardo et al., 2008; Lesaux & Siegel, 2003; Muter & Diethelm, 2001), even after accounting for letter knowledge, phonological short-term memory, rapid automatized naming and vocabulary (Comeau et al., 1999; Geva et al., 2000; Muter & Diethelm, 2001).

Research has shown that rapid automatized naming is a strong concurrent correlate of word reading skills in the additional language (Chiappe, Siegel, & Gottardo, 2002; Chiappe, Siegel, & Wade-Woolley, 2002; K. K. H. Chung & Ho, 2010; Geva & Farnia, 2012; Gholamain & Geva, 1999; Gottardo, 2002; but see Gottardo et al., 2001; Jongejan et al., 2007) even after accounting for phonological awareness (K. K. H. Chung & Ho, 2010) or phonological short-term memory (Gholamain & Geva, 1999). From a longitudinal perspective, rapid automatized naming has been found to correlate with future reading achievement (Bellocchi et al., 2017; Comeau et al., 1999; Geva et al., 2000; Jongejan et al., 2007; Lesaux & Siegel, 2003; MacKay et al., 2023) even after accounting for phonological awareness, phonological short-term memory and vocabulary (Bellocchi et al., 2017; Geva et al., 2000; Jongejan et al., 2007; Lesaux & Siegel, 2003; MacKay et al., 2023).

Despite some inconsistencies, phonological short-term memory has been shown to be a concurrent correlate of word reading skills (Abu-Rabia & Siegel, 2002; Chiappe, Siegel, & Gottardo, 2002; Chiappe, Siegel, & Wade-Woolley, 2002; Geva & Farnia, 2012; but see Da Fontoura & Siegel, 1995; D'Angiulli et al., 2001; Gottardo, 2002; Jongejan et al., 2007). It has also been shown to correlate with future word reading skills (Comeau et al., 1999; Geva et al., 2000; Gottardo et al., 2008; Jongejan et al., 2007; Lesaux & Siegel, 2003). Evidence for a unique contribution is not clear-cut and suggests that, as in monolinguals, phonological short-term memory shares a large amount of variance with other reading predictors. For example, Geva et al., (2000) found that it does not contribute to word reading skills controlling for vocabulary level. Note that many studies have used phonological short-term memory tasks involving language knowledge, such as completing the missing word in several sentences and then recalling all the words (Da Fontoura & Siegel, 1995; Geva & Ryan, 1993) or sentence repetition (Lesaux & Siegel, 2003; Lindsey et al., 2003; Nakamoto et al., 2007). It seems more relevant to use nonword repetition tasks that reduce the constraint of linguistic knowledge on the outcome (Gottardo, 2002; Gottardo et al., 2001, 2008) otherwise the results could be confounded with oral proficiency in the second language (Geva et al., 2019).

Finally, the literature has provided some evidence that vocabulary level and word reading skills are correlated in additional language learners (Arab-Moghaddam & Senechal, 2001; Geva & Farnia, 2012; Gottardo, 2002; Zhao et al., 2017; Kremin et al., 2019; Yeong et al., 2014; Cheung et al., 2010; Y. Liu et al., 2017; but see Geva et al., 2000) even when controlling for phonological awareness (Gottardo, 2002; Liu et al., 2017; Zhao et al., 2017), rapid automatized naming and phonological short-term memory (Jean & Geva, 2009).

Overall, the predictors of word reading skills are very similar to additional language learners and monolingual children.

IV.2.4.2 Cross-Linguistic Predictors

It is interesting to determine whether reading predictors, when assessed in the first language, could predict word reading skills in the additional language. From a practical point of view, this would mean that assessing EANA children in their first language (provided translators and tools are available) could provide reliable information for identifying children at risk of reading failure in the additional language. Below we discuss the relevance of assessing each reading predictor in the first language for predicting reading development in the additional language in the same order as in the previous paragraphs (letter knowledge, phonological awareness, rapid automatized naming, phonological short-term memory, vocabulary).

Letter knowledge in the first language has been shown to be correlated with word reading skills in the second language (Lindsey et al., 2003; Quiroga et al., 2002). As letter knowledge is the first step in phonological recoding skills (see previous sections on monolingual children), it might be better correlated with word reading in the second language if letter-sound correspondences and alphabetic systems were similar in both languages.

Phonological awareness in the first language has been shown to be a good correlate of reading achievement in the additional language (Cheung et al., 2010; Durgunoğlu et al., 1993; Erdos et al., 2011; Gottardo, 2002; Gottardo et al., 2001; Kremin et al., 2019; Lindsey et al., 2003; Zhao et al., 2017; MacKay et al., 2023; Jared et al., 2011; for a meta-analysis see Melby-Lervåg & Lervåg, 2011) even after controlling for letter knowledge, rapid automatized naming, phonological short-term memory and vocabulary (Comeau et al., 1999; Lindsey et al., 2003). Phonological awareness tasks can be achieved provided that children have understood that words are made up of sublexical units that can be manipulated. As all languages share the same principle (sublexical units grouped into lexical units), these metalinguistic skills can easily be applied to the additional language.

Rapid automatized naming in the first language has also been shown to correlate with word reading skills in the additional language (Gholamain & Geva, 1999; Gottardo, 2002; Jared et al., 2011; Kremin et al., 2019; MacKay et al., 2023), even after controlling for letter knowledge, phonological awareness, vocabulary and phonological short-term memory (Lindsey et al., 2003). Note that most of these studies use objects (Gottardo, 2002; Lindsey et al., 2003) or digit naming (Kremin et al., 2019), so correlations could not be explained by similarities in letter names across languages. Thus, rapid automatized naming appears to capture mechanisms that are independent of the language spoken, so that it is possible to predict word reading regardless of the language in which rapid automatized naming is assessed.

Some evidence of cross-linguistic prediction has been found for various measures of phonological short-term memory. For example, Lindsey et al. (2003) found that the scores on a Spanish sentence repetition task were concurrently correlated with English word reading scores in kindergarten and grade 1. Erdos et al. (2011) found that the scores obtained on an English nonword repetition task were correlated with French word and nonword reading skills in grade 1. Jared et al. (2011) found that scores on an English backward digit span task completed in kindergarten predict French word reading scores at grade 3. Abu-Rabia & Siegel (2002) asked children in grade 4 to 8 to complete sentences in Arabic with words and to remember these words. The scores were correlated with word reading in English. Note that, once again, the results are inconsistent in the literature (e.g. Da Fontoura & Siegel, 1995; Gottardo et al., 2001) suggesting, as in monolinguals, that phonological short-term memory is a weak predictor of word reading skills.

Finally, several studies suggest that the level of vocabulary in the first language contributes less to the ability to read words in the additional language than the level of vocabulary in the additional language (Arab-Moghaddam & Senechal, 2001; Erdos et al., 2011; Gottardo, 2002; Lindsey et al., 2003; Zhao et al., 2017). This is consistent with the Set for Variability account, according to which vocabulary allows the correct phonological form of a word to be recovered from an erroneous recoding procedure (Tunmer & Chapman, 2012a). This correct phonological form is thus language dependent and cannot rely on the first language vocabulary knowledge.

Overall, all predictors of reading in the first language can predict word reading scores in the second language, with the exception of vocabulary level. Assessing predictors of first language reading may be of interest when the first language is common to the community and, if possible, shared by the testers. However, this does not seem appropriate for EANA children who speak a large variety of languages (Armagnague & Rigoni, 2018). Practically speaking, it is impossible for an examiner to conduct testing in so many languages.

Let's Recap

- Cognitive and linguistic predictors are very similar in additional language learners, when they are assessed in the additional language, and in monolingual children.
- Phonological awareness, rapid automatized naming and phonological short-term memory (to a lesser extent) in the first language predict word reading skills in the additional language.
- Letter knowledge in the first language predict word reading skills in the second language, at least if the alphabet is the same in both languages.
- Vocabulary predictive power is language dependent: word reading skills in the additional language are predicted by vocabulary in the additional language but not by vocabulary in the first language.

IV.2.5. From Correlational Analyses to Individual Testings

An important strategic aim of this research was to determine how EANA children at risk of reading difficulties can be identified as early as possible. We have seen that cognitive-linguistic factors are the same in additional language learners as in monolingual children. However, the fact that these factors are correlated with word reading does not mean that additional language learners can be tested using standardized tests with monolingual norms. In fact, standardized tests are used to compare the performance of children with a control group. Such a comparison is possible provided that the control group is representative of the population to which the children belong (Hogan et al., 2017). For this reason, language tests present norms according to children's age or the grade level (e.g. Maeder et al., 2018). At least two pitfalls can distort these comparisons for EANA children: the amount of exposure to the second language and the phonological distance between the languages.

IV.2.5.1 Effect of the Amount of Exposure to the Additional Language

The amount of exposure to the second language has been found to have an impact on language assessment, particularly on tasks with high language demands. For example, children with a high amount of exposure to the second language have been found to perform better on vocabulary and sentence repetition tasks than children with a low amount of exposure to the second language (Thordardottir, 2011, 2017; Thordardottir & Brandeker, 2013). However, children with a high amount of exposure to the second language have been found to perform a nonword repetition task as well as children with a low amount of exposure to the second language (Thordardottir & Brandeker, 2013). Indeed, nonword repetition does not rely on linguistic knowledge to the same extent as vocabulary or sentence repetition tasks.

The amount of exposure to the additional language may affect at least three of the predictors identified in the previous sections: letter knowledge, vocabulary, rapid automatized naming and phonological short-term memory. The use of letter knowledge, French vocabulary or rapid automatized naming tests on arrival in France does not seem to be relevant for predicting future reading achievement in EANA children, as they systematically need at least a minimal exposure to French. To be more nuanced, since rapid automatized naming holds for a few automatized items (e.g. common words, digits, letters, etc.), EANA children can catch up with their native peers after some exposure to the second language (Geva et al., 2019). Note that these findings are rather surprising, as it has been shown that additional language learners have a 'receptive-expressive gap' for lexical items, meaning that it is easier to understand words than to retrieve and pronounce them (Gibson et al., 2012, 2018; Keller et al., 2015; Yan & Nicoladis, 2009). Nevertheless, it may be possible to use the norms of the monolingual tests of rapid automatized naming with EANA children after several months or years in France (Geva et al., 2000), whereas it could not be used when the child has just arrived. Finally, some tasks of the phonological short-term memory test may be biased by linguistic demands (e.g. tasks with sentences or digit span). It would be more relevant to use tasks that limit language demands, such as nonword repetition tasks (Gottardo et al., 2008).

IV.2.5.2 Effect of the Typological Distance Between Languages

Additional language learners may have difficulty in producing some phonological contrasts in the additional language that are not present in the first language (Ingvalson et al., 2014). Then, EANA children may make phonemic substitutions in all tasks requiring a verbal output, i.e. in all reading measures, as well as in letter knowledge, phonological awareness, rapid automatized naming or phonological short-term memory.

Rapid automatized naming is perhaps the task in which phonemic substitutions are least troublesome. Scores often correspond to the time taken to name all the items, regardless of accuracy, because, the task by definition involves naming familiar, automatized items (e.g. Georgiou et al., 2013; Manu et al., 2021; Parrila et al., 2004; Powell & Atkinson, 2021). In addition, a brief pre-test check can help to determine whether the child is pronouncing the items correctly or making some phonological substitutions that may not be scored as errors.

It is more difficult to assess phonemic substitutions in reading tasks, letter knowledge, phonological awareness or phonological short-term memory. How can we distinguish between errors due to phonological distance between languages and errors due to difficulties in the skills targeted by the task? One way is to identify the possible sound confusions for each language pair. For example, Gottardo et al. (2008) adapted their scoring procedure for their nonword repetition tasks by allowing for some common substitutions made by Spanish-speaking children into English. Comparisons between 85 languages and French are available thanks to the 'Langue et Grammaires du Monde dans l'Espace Francophone' project (*LGMEF*, 2019). This project initially focused on the languages spoken by migrants who had recently arrived in the Paris region of France. Many researchers created files describing the cultural context of use, and the phonological and grammatical aspects of the languages in contrast to French.

However, EANA children speak many different languages, which makes it difficult to adapt the scoring procedures individually (51 were identified by Armagnague & Rigoni, 2018). In the present research, we used a flexible scoring procedure for vowel substitutions that can be systematically applied to all children, rather than an individual scoring procedure for each child.

In conclusion, standardized tests of letter knowledge and vocabulary cannot be used with EANA children. Rapid automatized naming may be relevant, but only after several months or years. Standardized tests of phonological awareness and phonological short-term memory appear to be suitable for EANA children, provided that the items are nonwords and that phonemic substitutions, plausibly due to the phonological distance between the languages are not penalized.

IV.2.5.3 Visual-Verbal Paired Associate Learning: a Promising Unbiased Predictor of Additional Language Decoding Skills

As we have seen, only phonological awareness and phonological short-term memory tasks can be used with EANA children who have recently arrived in France, with a few adaptations. It therefore seems interesting to look for an additional measure that could improve the predictive model of decoding ability in EANA and that is not influenced by the level of exposure to the second language or by the phonological distance between the languages. In fact, a less studied predictor of reading may have these interesting properties: visual-verbal paired associate learning.

Visual-verbal paired associate learning consists of learning pairs of pictures and nonwords. Consequently, it does not rely on language knowledge but rather on the language learning potential. Note that such an approach has already been used in the field of oral language assessment under the name of ‘dynamic assessment’ as an alternative to classic assessment to identify bilingual children with language impairment (Camilleri & Botting, 2013; Hasson et al., 2013; Kapantzoglou et al., 2012; Matrat et al., 2022; Orellana et al., 2019; Peña, 2000; Petersen et al., 2020). Furthermore, precisely because it is based on nonword learning, it is easy to construct items with universal phonological properties in order to limit the influence of the phonological distance between the first and the additional language.

Visual-verbal paired associate learning has been found to be a correlate of decoding skills in monolingual children. Indeed, it has been demonstrated that poor readers or children with dyslexia perform lower on this task than control children (e.g. Albano et al., 2016; Giebink & Goodsell, 1968), even after controlling for IQ (e.g. Lyle & Goyen, 1974; Vellutino et al., 1983) and phonological processing (e.g. Messbauer & De Jong, 2006; Poulsen et al., 2017). Other research has shown that visual-verbal PAL uniquely contributes to decoding skills after controlling for phonological awareness, rapid automatized naming and phonological memory, taken individually or simultaneously in different orthographies (i.e. in opaque orthographies such as English, e.g. Warmington & Hulme, 2012; in transparent orthographies like Chitonga, e.g. Mourgues et al., 2016; in logographic scripts like Chinese, e.g. G. Georgiou et al., 2017).

An interesting additional feature of such a procedure is that monolingual children and additional language learners may, on average, obtain similar scores in word learning tasks (Matrat et al., 2022). It would therefore be possible to establish common norms for additional language learners and monolingual children.

Let's Recap

- The norms for reading and the assessments of its predictors are biased by the amount of exposure to French and by the typological distance between the first language and the French language.
- Because they depend on exposure to French, norms for letter knowledge and vocabulary cannot be used for EANA children.
- Rapid automatized naming norms can be appropriate after several months or years in France.
- Phonological awareness and phonological short-term memory norms can be used provided that the items are nonwords and that some substitutions due to phonological distance between languages are not penalized.
- The use of tasks with limited linguistic demands and universal phonological features would improve the accuracy of the assessment of the target skills.
- Visual-verbal paired associate learning tasks are a good candidate for improving the reading prediction model and for the early identification of EANA children who are at risk of developing reading difficulties.

IV.3. Research Objectives of the First Axis

The first aim of this thesis was to identify certain contextual, cognitive and linguistic predictors of decoding ability in EANA children and, at the same time, to examine some adaptations of testing instruments to limit biases related to the amount of exposure to French and the phonological distance between first languages and French. To this end, we pursued four sub-objectives.

Firstly, we tested the relevance of a flexible alternative scoring procedure for tests with a verbal output. Specifically, we determined whether the sensitivity of the measures was still acceptable when flexible scoring was applied.

Secondly, it has been shown that the development of decoding skills in additional language learners is similar to that of monolingual children. However, no previous study has investigated whether this is also true for EANA children who are learning to read hardly with virtually no knowledge of oral French. We therefore compared the decoding skills of EANA children and French children, matched for the duration of attendance at primary school. We expected that EANA children would score lower on both word and nonword decoding skills. In addition, we hypothesized that the differences would be greater for word reading skills than for nonword reading skills, as word reading may be influenced by vocabulary knowledge.

Thirdly, we looked at some contextual factors that might explain the differences between EANA and French children in decoding skills. We focused on whether the children had learned to read or had attended school before arriving in France; whether the fact that the writing system of one of the spoken languages was alphabetic or Latin might advantage them in learning to read in French. We had also determine if having been exposed to an alphabetic or a Latin system might be an advantage. We have examined the grade of arrival in primary school. Finally, we wondered whether the family of the first languages have an effect, assuming that non-Indo-European languages are more typologically different from Indo-European languages than Indo-European languages from each other.

Fourth, we tested a range of cognitive and linguistic measures to see whether their weight was similar between EANA and French children. Indeed, one might expect cognitive and linguistic predictors to explain a smaller proportion of the variance, given the number of contextual factors likely to influence the reading development of EANA children. In addition, we tested the contribution of visual-verbal paired associate learning scores over other predictors to determine whether they could improve the predictive model of decoding ability in EANA children.

V. Second Axis: Examining the Role of Visual-Verbal Paired Associate Learning in Decoding Skills in Primary School Children

Although visual-verbal paired associate learning (PAL) seems to be a good candidate to complement the predictors of decoding in EANA children, little is known about the reasons for its correlation with reading. Therefore, it is important to investigate it in more detail. This would help researchers to interpret their results when using this paradigm and to confirm or not its relevance as an additional screening tool for identifying children at risk of reading failure. In this section, we first have provided definition of visual-verbal paired associate learning and how it has been operationalized in the literature. Secondly, we have examined with which decoding outcome it correlates. Third, we have presented various possible explanations for the relationship between visual-verbal PAL and reading. Fourth, we have investigated its potential role in French decoding skills. Finally, we have presented the aims of our research.

V.1. Definition of Visual-Verbal Paired Associate Learning

Visual-verbal PAL is a specific type of PAL. C. Liu et al. (2020, p. 2) defined PAL as 'the ability to establish, maintain and retrieve new and arbitrary connections between a stimulus and a response in long-term memory'. Two dimensions characterize PAL:

(1) **the modality of the mapping**: it may be unimodal (e.g. associating a visual information with another visual information) or cross-modal (e.g. associating a visual information with verbal information). For example, associating two words like a first name and a last name is a unimodal PAL (verbal-verbal PAL), while associating a face with a name is a cross-modal PAL (visual-verbal PAL);

(2) **the direction of the mapping**: it depends on the modality (e.g. visual, verbal, tactual, etc.) of the **stimuli** and the **responses**. The '**response**' is the information 'retrieved' from memory when the

‘**stimulus**’ is presented. In reading, stimuli are letters and responses are sounds that are retrieved from memory and pronounced by the readers. The direction of the mapping is therefore from visual information (i.e. letters) to verbal information (i.e. phonemes). The direction of the mapping usually determines the name of the PAL, formalized as ‘stimuli-response PAL’. In ‘visual-verbal’ PAL, the ‘visual’ information is the stimulus and the ‘verbal’ information is the response.

According to Ehm et al. (2019), ‘in the context of reading, cross-modal PAL, defined as any association that requires a connection between a visual stimulus and a verbal stimulus, is in the focus of interest’ (p. 87). In line with Ehm et al. (2019), in this axis, we have investigated both visual-verbal and verbal-visual PAL under the term cross-modal PAL. Indeed, the literature has mainly investigated the role of visual-verbal PAL as it reflects the mapping direction in reading (i.e. associating a visual stimulus such as a letter to a verbal response such as a sound). However, a relationship between verbal-visual PAL and reading might be expected as verbal-visual PAL also involves associations between visual and verbal information.

V.2. Operationalization of Cross-Modal PAL Skills

In general, multimodal PAL tasks are divided into an exposure phase in which participants learn different pairs of visual and verbal information, followed by test blocks in which they are exposed to each stimulus (e.g. pictures) and have to retrieve the response (e.g. a word). Test blocks are repeated until participants have learned the pairs to the expected level of success or until the maximum number of a given number of test phases has been completed. Participants improve from one test block to the next because learning is reinforced either by corrective feedback between tests or by the presentation of each pair between test blocks.

As an illustration, Mayringer & Wimmer (2000) used a visual-verbal PAL in which children learned three pictures of fantasy animals (i.e. the stimuli) associated with three pseudonames (i.e. the responses). In the exposure phase, the experimenter presented each stimulus-response pair. This exposure phase was followed by several test blocks. In each test block, the child saw the three pictures in a random order and named them. Irrespective of the accuracy of the responses, the experimenter gave the correct answer after each naming trial. Several test blocks were presented until the child named all the pictures correctly in three consecutive blocks or until 14 blocks were reached.

Despite similarities between cross-modal PAL tasks in the literature, they may differ in several aspects : (1) types of items used (stimuli or responses), (2) number of pairs to be learned, (3) number of test blocks, (4) scoring method and (5) general procedure.

Firstly, the visual items used varied widely between studies. Indeed, some authors have used nonsense black and white shapes (e.g. Bartholomeus & Doehring, 1972), symbols from extinct written languages (e.g. Litt et al., 2013), Chinese characters (e.g. Suk-Han Ho et al., 2006), pictures of fantasy animals (e.g. Nielsen & Juul, 2016), cuddly toys (de Jong et al., 2000), pictures of real animals (e.g. Messbauer & De Jong, 2006) or of children's faces (e.g. Lervåg et al., 2009). The use of nonsense shapes, symbols or characters seems relevant in the context of reading studies as they appear to be as arbitrary as letters. Nevertheless, using more concrete stimuli as funny pictures increase the child attention to the items as the cross-modal PAL tasks require a large amount of cognitive resources and can be very time-consuming. Similarly, verbal items can vary from nonsense words (e.g. Thomson & Goswami, 2010) to real words (e.g. Vellutino et al., 1995). These differences are sometimes motivated by the aims of the studies. For example, Vellutino et al., (1995) investigated the role of semantic properties in the mapping between visual and verbal information. Thus, it was relevant to compare visual-verbal paired associate learning with real words since they are already associated with semantic referents. Other studies, such as Thomson & Goswami (2010), aimed to assess verbal learning. Therefore, it was relevant to use nonwords that the participants had never heard or learned.

Secondly, the number of pairs to be learned varies between studies from two (e.g. Mauer & Kamhi, 1996) to 12 (e.g. Manis et al., 1987). This seems to depend mainly on the age of the participants. In most of the cases, they learned between three and seven pairs. Critically, PAL tasks are characterized by their difficulty and their duration (see the method section in Wimmer et al., 1998), which is why authors often chose to teach their participants only a few pairs. However, the small number of items may distort the estimation of the reliability of PAL measures (Nielsen & Juul, 2016).

Thirdly, the number of test blocks also varies. For example, only four test blocks are used in G. Georgiou et al. (2017) while 20 are used in Windfuhr & Snowling (2001). Testing and reinforcing learning multiple times has at least three advantages: (1) examining the dynamics of the learning across test blocks, (2) avoiding floor effects as only one presentation of the items is often insufficient to learn the pairs, and (3) obtaining accurate measures of the learning of each item since they are taken several times.

Fourthly, there are two types of scoring procedures: item scoring or test block scoring. In the former, all trials are scored across test blocks. For example, in Warmington and Hulme (2012), eight pairs were taught and 10 repetitive naming tasks/reinforcement was completed. The score was calculated by summing the success of all trials across the test blocks. The maximum score was therefore 80. On the other hand, Wimmer et al. (1998) chose to score the number of test blocks needed to reach the criterion (two consecutive successes for each pair across test blocks). The test/reinforcement are repeated 20 times. Hence the possible scores were thus between one and 20.

Finally, the general procedure sometimes differ from the usual one. For example, Poulsen and Elbro (2018) tested three fantasy animal/nonword pairs. They progressively introduced the pairs over the course of the trials, rather than introducing all the pairs from the start. They started by teaching two pairs, and once they were named correctly three times, they added the third pair.

Let's Recap

- Cross-modal PAL consists of learning pairs of visual and verbal information.
- Cross-modal PAL tasks are usually divided into learning and testing phases.
- The test phases are repeated either until a pass criterion is reached, or until a given number of repetitions of the test phases is reached.
- Children receive corrective feedback during the test phases or complete new learning phases between each test phase.
- Scores can be based on the number of correct answers across all the test phases or on the number of phases required to learn all the pairs.

V.3. To Which Word Identification Component is Cross-Modal PAL Related?

Some authors postulated that cross-modal PAL skills are related to both sublexical (e.g. associating letters with phonemes) and lexical reading skills (e.g. associating lexical orthographic patterns with auditory words) involved in isolated word reading ability (Ehm et al., 2019; Hulme et al., 2007; Warmington & Hulme, 2012; Windfuhr & Snowling, 2001). In the following, we investigated the contribution of visual-verbal PAL to both levels.

We might assume that learning cross-modal associated pairs mimics learning letters. Indeed, Ehm et al. (2019) found that cross-modal PAL contributes to letter knowledge controlling for phonological awareness, rapid automatized naming and phonological short-term memory. It is also a consistent unique contributor to nonword reading accuracy scores controlling for phonological awareness, rapid automatized naming, phonological short-term memory and nonverbal abilities (Mourgues et al., 2016; Warmington & Hulme, 2012; Windfuhr & Snowling, 2001).

At the lexical level, cross-modal PAL is consistently correlated with word reading development. Many studies have suggested that cross-modal PAL contributes uniquely to word reading accuracy controlling for the classical predictors of decoding skills such as phonological awareness, rapid automatized naming, phonological short-term memory (Chow, 2014; Hulme et al., 2007; Litt et al., 2013; Mourgues et al., 2016; Poulsen & Elbro, 2018; Warmington & Hulme, 2012; Windfuhr & Snowling, 2001). Interestingly, two studies showed that cross-modal PAL scores contributed to word reading scores when controlling for nonword reading scores (H.-C. Wang et al., 2017; Windfuhr & Snowling, 2001). These findings suggest that different processes are responsible for the link between cross-modal PAL and sublexical or lexical abilities.

Finally, cross-modal PAL is consistently correlated with measures of accuracy rather than measures of reading fluency or speed (for nonword reading, see Litt et al., 2013; for word reading, see Poulsen & Elbro, 2018). Indeed, fluency or speed reflects the automatization of reading, which could be better captured by rapid automatized naming (Poulsen & Elbro, 2018).

Let's Recap

- Cross-modal PAL scores are correlated with both nonword and word reading.
- The contribution of cross-modal PAL is higher for word reading than for nonword reading.
- The contribution of cross-modal PAL is higher for reading accuracy than for reading fluency or speed.

V.4. Why is Cross-Modal PAL Achievement Correlated with Reading Performance?

Although the relationship between cross-modal PAL and decoding skills is well documented, the mechanisms underlying this relationship are not fully understood. In the following sections, we describe the putative mechanisms responsible for this relationship. First, we focused on the mechanisms involved in cross-modal PAL tasks. We have examined the relationship between cross-modal PAL and other predictors of reading, as these may be confounding factors.

V.4.1. Putative Mechanisms Underlying the Relationship Between Cross-modal PAL and Reading Skills

Cross-modal PAL is a complex task involving multiple processes (see Figure 1). It is therefore crucial to understand which process explains its relationship to reading in order to interpret it accurately. It can be explained by three specific processes (see Figure 2):

(1) The Associative Learning Process. Cross-modal PAL tasks may involve general associative learning skills that involve learning connections between different types of information. Since reading is an associative task (e.g. associating letters with sounds), an associative learning process may explain the relationship between PAL performance and reading outcomes. Although this explanation has not been explicitly stated as a central hypothesis or directly tested, it is sometimes contrasted with the hypothesis of the role of cross-modality (see the next section; Hulme et al., 2007; Warmington & Hulme, 2012).

(2) The Cross-Modal Learning Process. Some authors have suggested that the relationship between success in cross-modal PAL and reading is not due to general associative learning, but rather to a specific cross-modal associative learning process (Hulme et al., 2007; Warmington & Hulme, 2012). This cross-modal process reflects the fact that cross-modal PAL involves linking information from different modalities (e.g. visual stimuli with verbal responses), which parallels the association required in reading (i.e., associating visual information such as letters with verbal information such as sounds).

(3) The Verbal Processes. Some studies have emphasized the importance of the verbal processes of cross-modal PAL in explaining the relationship with reading. Litt et al. (2013) termed this hypothesis the 'verbal account'. Two dimensions of the verbal processes may explain the relationship with reading: verbal learning (e.g. Poulsen & Elbro, 2018; Wimmer et al., 1998) and verbal output (e.g. Litt et al., 2019).

(a) Verbal Learning Process. Verbal learning may be involved in reading words, especially irregular words, by learning the ’’spelling pronunciation’’ derived from grapheme-phoneme correspondence rules (Elbro & de Jong, 2017). Readers would integrate the "spelling pronunciation" as an alternative to the correct phonological form stored in the mental lexicon (e.g. /ά:nswə/ as an alternative to 'answer'). Consequently, they could rely on this "spelling pronunciation" to retrieve the correct phonological form when they could not find it via orthographic representations. According to this view the contribution of verbal learning should only be useful for word reading and not for nonword reading. This is consistent with the fact that visual-verbal PAL is more strongly correlated with word reading than with nonword reading (Hulme et al., 2007; Warmington & Hulme, 2012; Windfuhr & Snowling, 2001).

(b) Verbal Output Process. This account is more applicable to visual-verbal PAL tasks, where the verbal information is the response and therefore must be spoken. Litt and colleagues (e.g. Litt et al., 2019) suggested that verbal output accounts for the role of the verbal processes in reading performance. Hulme and Snowling (1992) posited that impairments in verbal output may affect word blending during reading. In the early stages of reading, children often use a phonological strategy in which they sound out each letter and keep it in the phonological loop (Baddeley & Hitch, 1974), until the next letter is read in order to blend them into a syllable or a word. If verbal output is impaired, the phonological information held in the phonological loop may be gradually degraded. If the sounded word does not match the target written word, it becomes challenging to build a broad and accurate sight word vocabulary.

Furthermore, the relationship between verbal processes of cross-modal PAL and reading may be bidirectional. Reading skills may influence verbal learning in two different ways: first, through the refinement of phonological representations (de Jong et al., 2000); and second, through the development of orthographic representations that are linked to phonological representations

(Perfetti & Lesley Hart, 2002). Indeed, first, research has shown that the presentation of the written word enhance verbal learning (Baron et al., 2018; Colenbrander et al., 2019). This phenomenon is called ‘orthographic facilitation’. Second, orthographic representations are automatically activated when participants are exposed to new words (Wegener et al., 2018). This phenomenon is called ‘orthographic skeleton’ and might improve verbal learning even if no written words are presented during verbal learning.

Figure 1. *Illustration of the components involved in visual-verbal PAL tasks.*

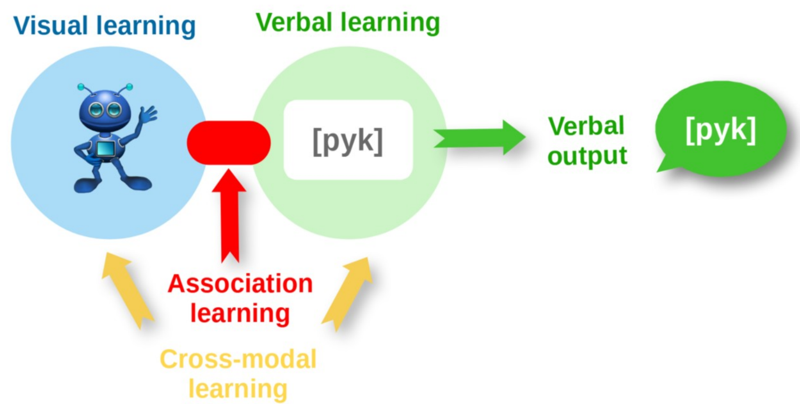
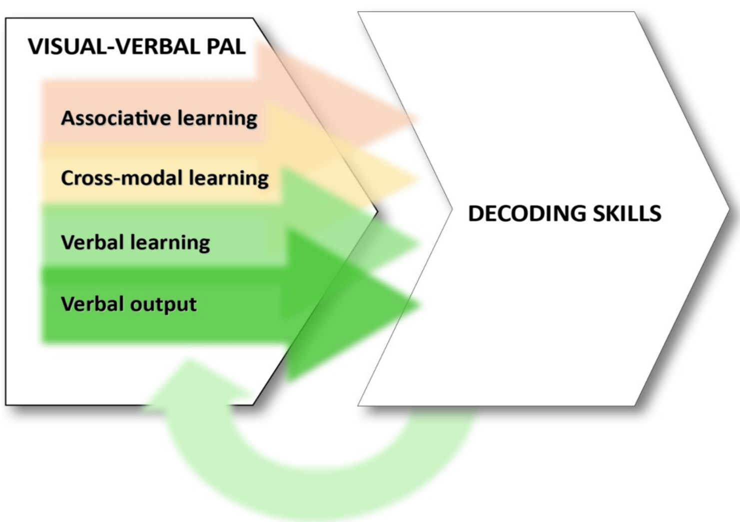


Figure 2. *What component explain the relationship between visual-verbal PAL and reading skills.*



V.4.2. Relationship Between Cross-Modal PAL and Other Reading Predictors

All reading predictors are intercorrelated (e.g. see correlation matrices in Lervåg et al., 2009). Thus, multiple confounding variables may account for the correlations between a given predictor and reading, rather than its own mechanisms. Cross-modal PAL tasks are no exception to this rule.

First, visual-verbal PAL was shown to predict letter knowledge which could be viewed as a visual-verbal PAL outcome (Roberts et al., 2018, 2019).

Then, previous studies have demonstrated that phonological awareness is a unique contributor to visual-verbal PAL over several variables (e.g. rapid automatized naming, phonological memory, nonverbal abilities, vocabulary; de Jong et al., 2000; Ehm et al., 2019; Thomson & Goswami, 2010; Windfuhr & Snowling, 2001). With a training design, de Jong et al. (2000) found that phonological awareness is causally related to verbal learning abilities. Having well-segmented phonological representations could facilitate the retention of new, well-specified words. The relationship between visual-verbal PAL and phonological awareness might thus be due to the verbal learning mechanism.

Phonological short-term memory has been found to be weakly to moderately correlated with visual-verbal PAL (Ehm et al., 2019; Lervåg et al., 2009; Mauer & Kamhi, 1996; Mayringer & Wimmer, 2000; Nielsen & Juul, 2016; Thomson & Goswami, 2010). Ehm et al. (2019) found that backward digit span contributed independently to visual-verbal PAL when controlling for phonological awareness, rapid automatized naming and inhibition. Phonological short-term memory was shown to be involved in new verbal label learning (Gathercole et al., 1997; Papagno et al., 1991; Papagno & Vallar, 1992) and more generally in vocabulary development (Gathercole, 2006; Gathercole et al., 1992, 1997; Gathercole & Baddeley, 1989; Papagno & Vallar, 1995). Therefore, phonological short-term memory may also be related to visual-verbal PAL via its verbal learning mechanism.

Rapid automatized naming and visual-verbal PAL were not consistently correlated in the literature. Some authors observed weak to moderate correlations (Ehm et al., 2019; Georgiou et al., 2017; Karipidis et al., 2017; Lervåg et al., 2009; Malone et al., 2019; Mayringer & Wimmer, 2000; Thomson & Goswami, 2010; H.-C. Wang et al., 2015; Warmington & Hulme, 2012), while many others reported non-significant correlations (Kalashnikova & Burnham, 2016; Liao et al., 2015; Litt et al., 2013; Nielsen & Juul, 2016; Poulsen et al., 2015, 2017; Poulsen & Elbro, 2018). Ehm et al. (2019) demonstrated that rapid automatized naming did not contribute uniquely to a learning score of visual-verbal PAL among other predictors such as phonological memory or phonological awareness. However, it contributed to a 'retrieval score' in which children were asked to name the same pictures as at the start of the PAL task, for four blocks of trials, but without feedback or reinforcement of learning. Some authors suggested that while crossmodal PAL could capture the ability to create new associations in the memory (and, most of the time, new visual and verbal representations), rapid automatized naming could capture the efficiency of the link between these representations (Georgiou et al., 2017; Poulsen et al., 2015).

Finally, vocabulary was correlated with visual-verbal PAL in previous studies (Gathercole et al., 1997; Gellert & Elbro, 2013; Lervåg et al., 2009), a relationship that might be bidirectional. On the one hand, vocabulary may provide lexical cues for word learning (Gathercole, 2006). Vocabulary development also contributes to the refinement of phonological representations (Walley et al., 2003), which in turn contribute to word learning (de Jong et al., 2000). On the other hand, visual-verbal PAL, and more specifically its verbal learning mechanism, may predict vocabulary development (Gellert & Elbro, 2013; Krepel et al., 2021).

In summary, all of these reading predictors may be confounding variables of the relationship between visual-verbal PAL and reading.

Let's Recap

- The relationship between multimodal PAL and decoding skills is not the result of a global, unitary component. Rather, it can be explained by several mechanisms (Figure 1 and 2):
    - Associative learning
    - Cross-modal associative learning
    - Verbal learning
    - Verbal output (in the case of visual-verbal PAL)
- In the case of verbal mechanisms, the relationship with decoding skills may be bidirectional.
- It may also be confounded with other main predictors of decoding skills: phonological awareness, rapid automatized naming, phonological memory, vocabulary as well as nonverbal abilities.

V.5. What Can be the Contribution of Cross-Modal PAL in French Orthography?

As mentioned above, the weight of reading predictors may vary depending on orthographic transparency (Caravolas et al., 2013; Landerl et al., 2013, 2019; Moll et al., 2014; Vaessen & Blomert, 2010; Ziegler et al., 2010). Although several studies have shown that visual-verbal PAL makes a unique contribution to word reading, most have been conducted in opaque orthographies (in English with children aged between 7 and 12 years old in each study: Hulme et al., 2007; Litt et al., 2013; Warmington & Hulme, 2012; Windfuhr & Snowling, 2001; in Danish: Poulsen & Elbro, 2018). To our knowledge, only one study examining the unique contribution of visual-verbal PAL in reading has been conducted in a language with a transparent orthography, Norwegian. It found no contribution of visual-verbal PAL to reading fluency scores in grades 2 and 3 (Lervåg et al., 2009).

The opacity of French orthography is often considered as intermediate according to different classification methods (e.g. Borgwaldt et al., 2005; Schmalz et al., 2015; Seymour et al., 2003). Thus, neither the results obtained for English and other opaque orthographies, nor those for Norwegian can be easily generalized to French. In the following paragraphs, we explore the potential role of visual-verbal PAL mechanisms in reading, taking into account the characteristics of the French orthography compared to English, which is an example of highly opaque orthography.

As mentioned above, both cross-modal associative learning and verbal learning may account for the relationship between visual-verbal PAL and word reading ability. These two mechanisms might be more involved in opaque orthographies, as cross-modal associative learning might be expected to be more involved in orthographies with more written and phonological units to map. Because grapheme-phoneme correspondences are less predictable in English (for a review, see Schmalz et al., 2015), readers have to process larger orthographic units, which increases the number of correspondences between written and phonological units to be learned (see the 'Grain Size Theory' of Ziegler & Goswami, 2005). As a result, cross-modal associative learning may be less critical in French than in English.

As already emphasized, verbal learning is thought to support the orthographic learning of written words, especially irregular words for which the sublexical reading procedure is not efficient (Elbro & de Jong, 2017). There are very few irregular words in French as compared to English or even other languages known to be transparent, such as German (for a review, see Schmalz et al., 2015). However, the 'spelling pronunciation' framework of Elbro and de Jong (2017) may also be useful for words with 'contextual graphemes'. In French, contextual graphemes (e.g. the letter 'g') are read differently depending on the following vowels. For example, a 'g' followed by an 'e' or an 'i' is pronounced /ʒ/, while in other cases it is pronounced /g/. Children often make mistakes when reading words with contextual graphemes. For example, children who have not encoded the orthographic representation of 'fragile' are likely to pronounce /fʁagil/ instead of /fʁaʒil/[2] if they do not apply contextual rules. As with irregular words, /fʁagil/ could be an alternative phonological representation for 'fragile' (its "'spelling pronunciation'") and become a cue for finding the correct phonological representation, at least until children master the contextual rules.

In summary, it is possible that cross-modal PAL skills contribute to reading success in French through verbal learning mechanisms. Indeed, learning 'spelling pronunciation' may be useful to support the recognition of irregular words as well as words with contextual graphemes.

Let's Recap

- Cross-modal associative learning may be less important for decoding in French than in opaque orthographies.
- Verbal learning may support irregular word reading and reading words with contextual graphemes.

2 All characters between slashes are transcribed in the International Phonetic Alphabet.

V.6. Research Objectives of the Second Axis

The common objective of this research axis and the first one was to determine whether cross-modal PAL can contribute to decoding skills in French, as most studies have been conducted in more opaque orthographies than French. The second aim was to better understand why cross-modal PAL contributes to decoding skills. To this end, we conducted three studies.

The first was a systematic review, which consisted of assessing the state of evidence in the literature for each possible explanation of the relationship between visual-verbal PAL and decoding skills.

The second was to investigate the sub-mechanisms of visual-verbal PAL in word and pseudoword reading skills in French primary school children, namely the associative learning component, the cross-modal associative learning component, the verbal learning component and the verbal output component.

Finally, a third study was carried out to reproduce the results obtained in the previous study and to investigate in more detail the role of verbal learning in the reading of simple words (regular words without contextual graphemes) and complex words (regular words with contextual graphemes and irregular words).

Part 2. Experimental Part

I. Introduction

This experimental part is divided into two axes, the same as those presented in the theoretical part. The first axis aimed at identifying some contextual, cognitive and linguistic predictors of decoding skills in additional language learners newly schooled in France (EANA). We focused on primary school children. At the same time, we explored certain adaptations of the test instruments to limit the biases associated with the amount of exposure to French and the phonological distance between the mother tongue and French. Among these adaptations, we proposed to test the contribution of visual-verbal paired associate learning (PAL) skills which were expected to be significant predictors of decoding skills in EANA children. It was thought to be well suited for EANA children because it does not rely on knowledge of French and it is possible to create verbal items with universal phonological properties. However, the mechanisms explaining this relationship remain poorly understood. The aim of the second axis was therefore to determine which component of visual-verbal PAL could explain its relationship with decoding skills in French primary school children.

We carried out a research project called 'TANMALL' (literally, in French, ‘The place of a novel word learning task among the cognitive predictors of written language development classically studied: a cross-sectional study with EANA and non-EANA children’), which allowed us to achieve all the research objectives of the first axis and some of the second. For the sake of simplicity, we have therefore presented below the main methodological features of the TANMALL project. We will then turn to the objectives of the different research areas.

II. The TANMALL Project

The TANMALL project was designed to contribute to our two research axes: explore the predictors of reading achievement in EANA children and the mechanisms involved in the relationship between visual-verbal PAL and reading. This section aimed to present the main methodological features. It has been reviewed by the local ethics committee (reference: 2021-466-S90).

II.1. Participants

II.1.1. Inclusion and Exclusion Criteria

French children in grades 1 and 2 were eligible. As reading is taught in first and second grade in France, we considered the children to be representative of beginning readers, as were the EANA children. This allows us to match the two groups in terms of their exposure to reading instruction in French.

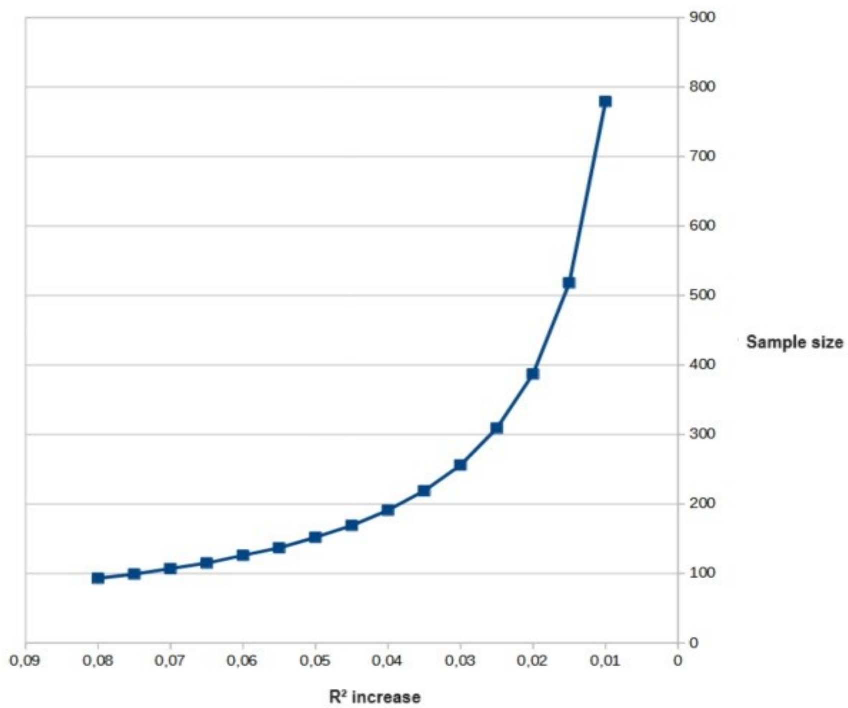
Grade 1 French children were only tested in the second term of school to ensure that they had developed minimum decoding skills to complete reading tasks. French children in Grade 2 were tested throughout the year. There were no exclusion criteria.

EANA children were included in the study if they had at least 4 months of reading instruction (excluding holidays) to ensure that they had at least the same exposure to learning to read as the French children in the control group. Although the French children were sampled until the end of the second grade (~16 months excluding holidays), we chose to include all EANA children who attended primary school and for whom the duration of primary school attendance was up to 24 months (excluding holidays) because of the difficulty in recruiting EANA children.

II.1.2. Sample Size Estimation

Power analysis was performed using GPOWER (Erdfelder et al., 1996; Family test: F-test; statistical test: Linear multiple regression, fixed model, R^2 increase) and effect sizes (R^2 change) available in the literature of visual-verbal PAL in similar analyses than ours (Poulsen & Elbro, 2018; Windfuhr & Snowling, 2001). We focused on the contribution of visual-verbal PAL as it was a variable of interest in both axes of this research. Alpha risk and power were set at 0.05 and 0.80, respectively. R^2 increase varied from 0.02 to 0.06 in the literature, which corresponds to sample estimations of 387 and 126 participants respectively in each group (French and EANA children). We targeted the average effect size found in the literature (an R^2 increase of 0.04), which corresponds to a sample estimate of 196 participants in each group.

Figure 3. *Sample size estimation in function of expected R^2 increase.*



II.1.3. Sampling Procedure

Regarding French children, data were mainly collected between February and July 2021 and

2022 in French elementary schools. Regarding EANA children, data collection ended in April 2023. We have requested permission from the school district inspectors and teachers to carry out the study in their schools and classrooms. The academic services dedicated to the reception of EANA children in French schools (the CASNAV) enabled us to identify the schools in which EANA children were enrolled. Information letters and consent forms were then sent children’s families. EANA children were identified The EANA families were contacted by the UPE2A teachers who helped them to understand and complete the forms.

As with any study involving school-based interventions, the sampling procedure was incompatible with purely random selection. To address the generalizability of our results, we asked the participants’ families to complete questionnaires on the following points:

- the languages spoken,
- whether children have consulted a speech therapist for speech or language difficulties,
- the socioeconomic status because it was shown to contribute to both oral and written language skills (Buckingham et al., 2013; Calvo & Bialystok, 2014; Hoff, 2003). We operationalized it by the educational level of the parents coded according to the international ISCED classification (OECD et al., 2015).

As there was a lot of missing data on the educational level of the parents, we also reported the school status (priority education area or not) and its ‘social position indicator’ (Rocher, 2023). In France, priority education areas correspond to areas that may be socially disadvantaged. The state allocates more resources to schools in these areas and the maximum number of pupils per class is halved compared to other areas. The 'social position indicator' is an index assigned to each French school that aggregates socioeconomic and cultural information about children (Rocher, 2023). If the social position indicator was not available for a given school, we used the average social position indicator of the district.

Additional questions were asked to specify schooling background of EANA children:

- Did they go to school before arriving in France? If so, at what levels?
- Did they start learning to read in a language other than French? If so, in which language(s)?

II.1.4. Total Sample

The aim of this section was to describe briefly the overall sample from which subsamples were selected in the following sections.

Children were sampled in 36 French districts, 55 schools and 64 classes around Lille, Amiens, Paris, Nancy, Tours and Lyon. With the help of psychology and speech therapy students (6 internships and 4 master's theses; cf. Table 1), 438 children were tested over a three-year period.

Table 1. *Breakdown of participant inclusions between experimenters.*

	2020–2021			2021–2022			2022–2023	Total
	Monolinguals	*Bilinguals*	*EANA*	*Monolinguals*	*Bilinguals*	*EANA*	*EANA*	
Students	30	12	0	69	28	39	61	239
Matthieu Bignon	55	31	7	27	6	73	0	199
Total	85	43	7	96	34	112	61	438

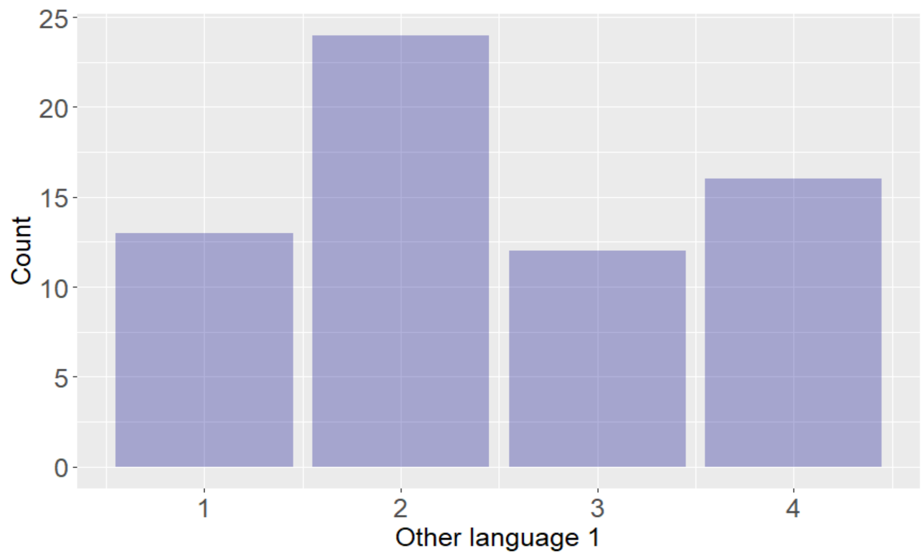
As shown in Table 1, 176 children were monolingual, 80 were exposed to another language at home and were referred to as 'bilingual' for simplicity and 180 children were EANA. The main characteristics of each group are provided in the Table 2.

French bilingual children spoke 27 different languages (details are provided in the Appendix I). Most of the children spoke only one other language than French at home, whereas 13 children spoke a second other language. As shown in Figure 4, the level of bilingual children in their first and second other languages was fairly evenly balanced between children who barely understood the other languages and those who were very comfortable speaking them. It should be noted, however, that slightly more children were more comfortable in comprehension than in expression. EANA children spoke 57 different languages other than French (details are also provided in the Appendix

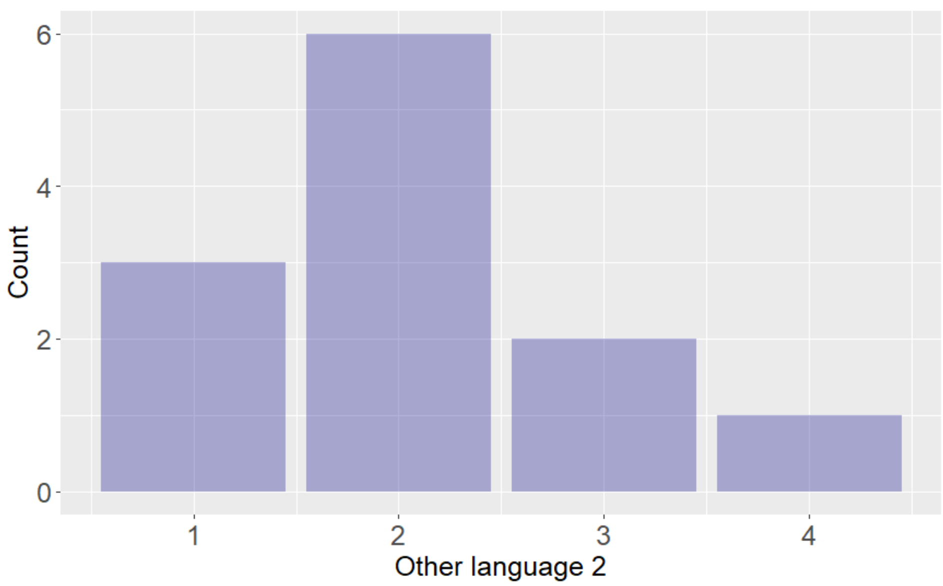
I). Sixty-nine children spoke at least two other languages than French. Information about the level in the other languages spoken present a lot of missing data (see Figure 5). Not surprisingly, EANA children were very comfortable in the main first language.

Figure 4. *Subjective assessment of the level in the other languages used than French by French bilingual children.*

a) In the first other language spoken (missing values = 15).



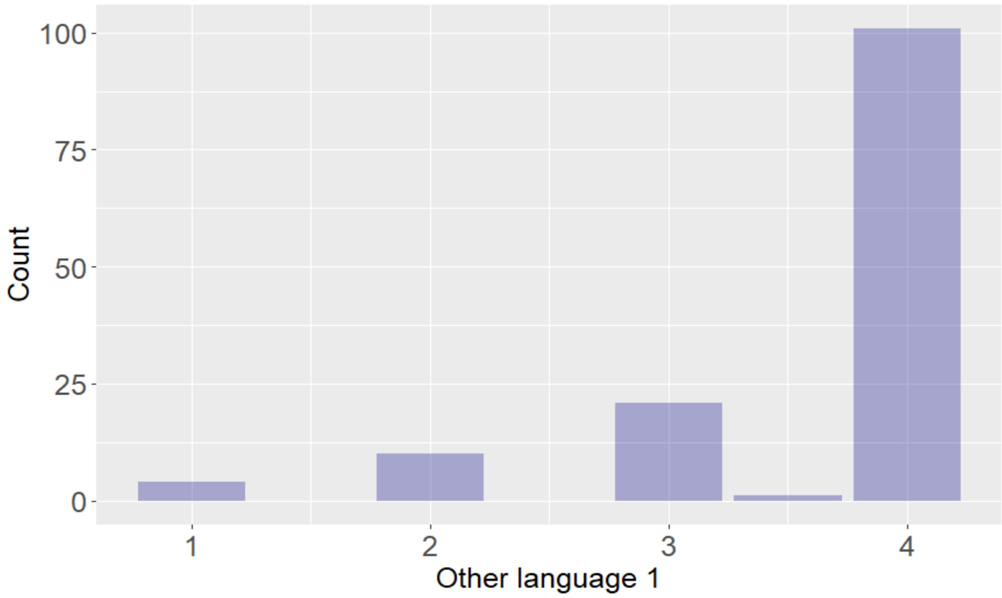
b) In the second other language spoken (missing values = 1).



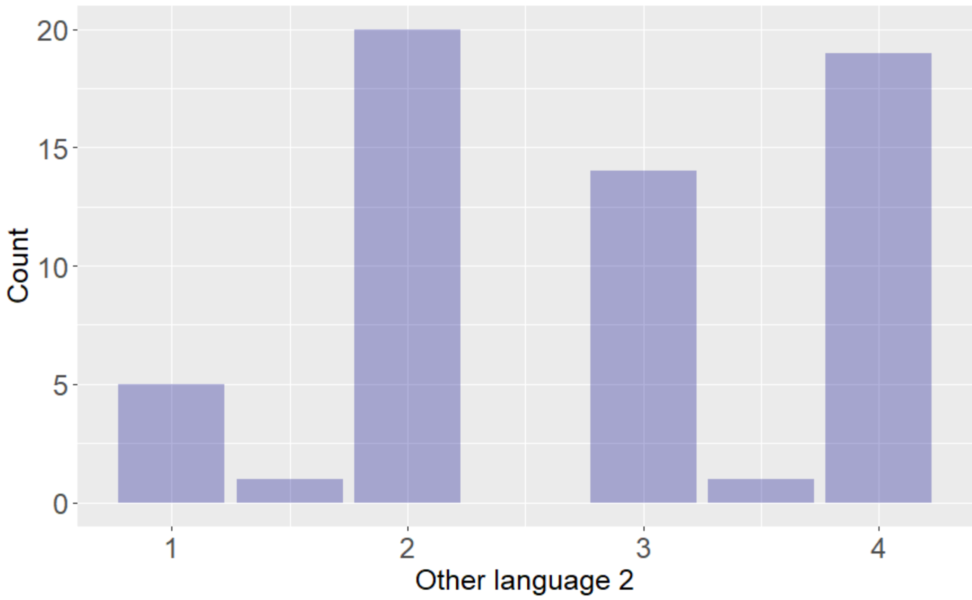
Note. 1 = Understands the language but doesn't speak it; 2 = Understands the language and can say a few words; 3 = Can use the language for everyday conversation; 4 = Is very comfortable communicating in the language.

Figure 5. *Subjective assessment of the level in the other languages used than French by EANA children.*

a) In the first other language spoken (missing values = 43).



b) In the second other language spoken (missing values = 9).



Note. 1 = Understands the language but doesn't speak it; 2 = Understands the language and can say a few words; 3 = Can use the language for everyday conversation; 4 = Is very comfortable communicating in the language.

The groups were rather matched in terms of duration of primary school attendance. The mean age of French children was lower than the mean age of EANA children. Mean grade level of French children was also lower than the mean grade level of the EANA children. In fact, French children were sampled only in grades 1 (178 children) and 2 (78 children) whereas EANA children were sampled across all primary school grades (see Figure 6). The socioeconomic status of the EANA children was lower than that of the French children. They were sampled more often in priority education areas than French children (Figure 7), and the average social position indicator of the school they attended was lower than for French children. Finally, some children were receiving speech therapy for language difficulties during or before the study (Table 3).

Table 2. *Main characteristics of the children recruited in the TANMALL project.*

	Monolingual (N=176)			**Bilingual (N=80)**			**EANA (N=180)**		
Variables	***NA***	***mean (sd)***	***min-max***	***NA***	***mean (sd)***	***min-max***	***NA***	***mean (sd)***	***min-max***
Age (months)	1	85.91(6.09)	77-99	0	86.51(6.78)	75-110	0	111.84(19.69)	75-191
Mean grade	0	1.28(0.45)	1-2	0	1.36(0.48)	1-2	0	2.97(1.39)	1-5
Duration of primary school attendance	0	8.68(3.05)	4.05-15.15	0	9.39(4.19)	4.76-25.55	1	8.97(5.03)	1.61-28.3
Social position indicator	0	112.83(17.41)	65-133.6	0	103.52(20.98)	65-133.6	0	89.26(18.67)	65-124.8
Parental educational level (ISCED)	17	5.65(1.61)	0-8	13	5.1(1.96)	0-7.5	180	NA	NA

Note. NA = missing data.

Table 3. *Number of children receiving speech therapy for language difficulties during or before the research.*

Speech and language therapy for language or speech difficulties (during the research or before)	**Monolingual (N=176)**	**Bilingual N=80)**	**EANA (N=180)**
No	149	59	166
Yes	18	5	4
Missing data	9	16	10

Figure 6. *Number of EANA children per grade.*

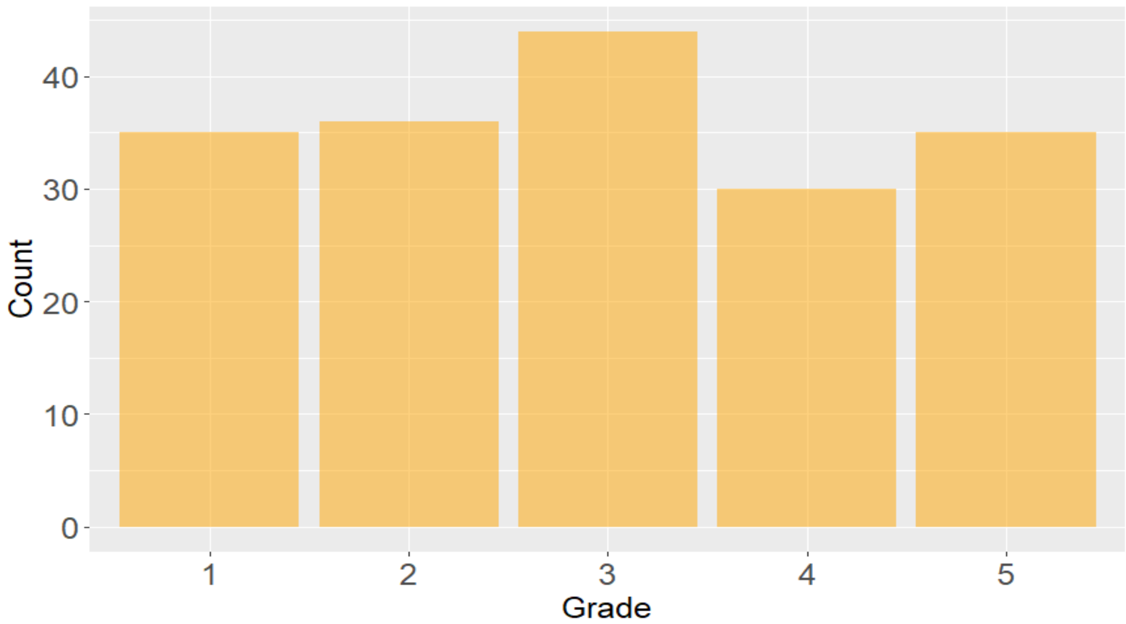
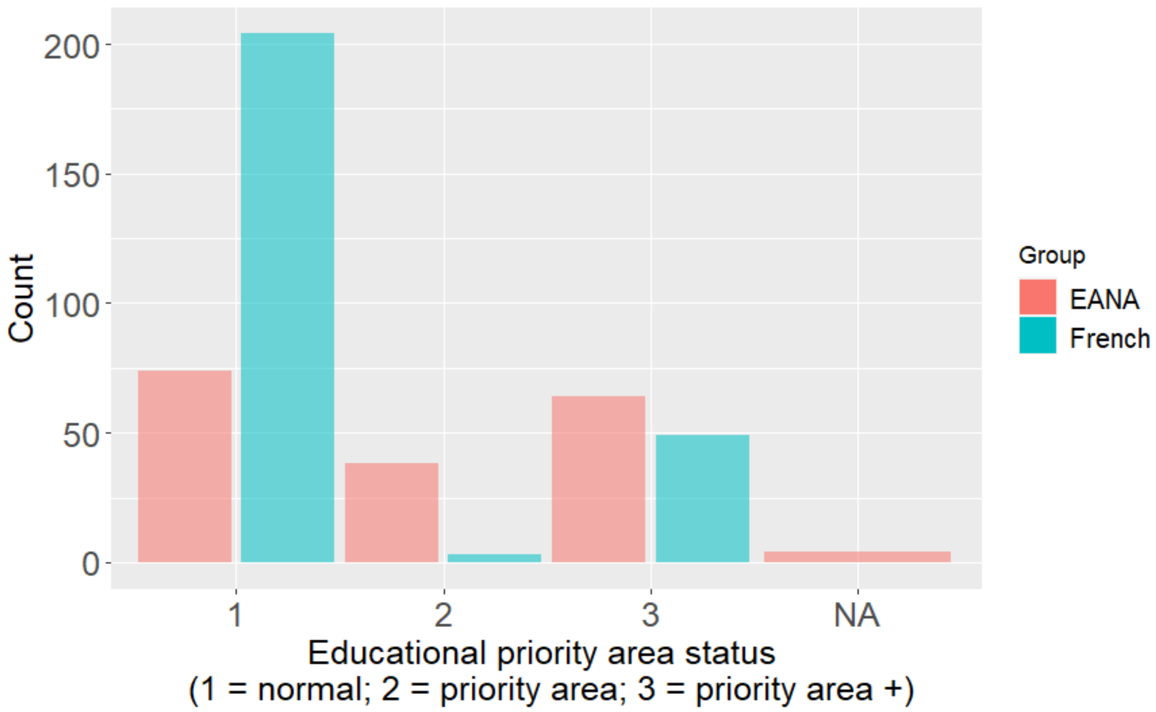


Figure 7. *Number of children recruited in priority education area per group.*



Note. A = Missing data

II.2. Measures

Tests involving verbal responses were audiotaped so that the examiners could refer to the recordings if they had doubts about certain answers or needed to check their transcriptions.

The ‘maximum’ values in brackets represent the maximum possible score, not the maximum score achieved by the participants.

II.2.1. Nonverbal Abilities

Nonverbal abilities were tested using Raven’s Coloured Progressive Matrices (subtests A, AB and B; Raven et al., 1998). Each of the 36 items consisted in choosing from the best of six options to fill in the missing part of an abstract picture or a matrix. The first four items were practice items. They were therefore excluded from the total score (maximum = 34).

II.2.2. Phonological Awareness

Three subtests from the French EVALEC battery were administered (Sprenger-Charolles et al., 2010). Each subtest started with five practice items. All items were presented orally using an audio recording. (1) The first subtest was a syllable deletion task in which children had to remove the first syllables of 10 three-syllable nonwords and to pronounce the remaining nonwords (e.g. /zofity/→/fity/)[3]. (2) The second subtest was a phoneme deletion task in which children had to retrieve the first phoneme of 12 CVC nonwords and pronounce the remaining syllable (e.g. /zak/→/ak/). (3) The third subtest was a phoneme deletion task in which children had to retrieve the first phoneme of 12 CCV nonwords and pronounce the remaining syllable (e.g. /sti/→/ti/). One point was awarded for each correct answer. The final score was obtained by adding the scores of the three tasks (maximum = 34).

3 All characters between slashes are transcribed in the International Phonetic Alphabet.

II.2.3. Rapid Automatized Naming (Plaza & Robert-Jahier, 2006)

The children were given a table (6 × 8) with four numbers repeated out of sequence 12 times each (1, 3, 9 and 7) and a table (6 × 8) with four letters repeated out of sequence 12 times each (A, B, C, U). They had to read them out loud as quickly as possible. Before naming each list, they were familiarized with the letters. This was done by reading each character slowly with corrective feedback. They were then trained to name the characters quickly in a series of 6 characters.
The score was the average time taken to read both lists. In the analyses, we inverted this mean time to obtain positive correlation coefficients, as with the other variables. The number of errors was only available for 107 participants, but was very low for both tasks (mean ~ 1, SD ~ 1).

II.2.4. Phonological Short-Term Memory

This ability was assessed with a nonword repetition task adapted from dos Santos and Ferré (2018). The children were asked to repeat 31 nonwords containing between one and three syllables. The syllabic structures varied in complexity from one nonword to another: CV, CCV, CVC, CCVC, CCVCC. The children responded to all items regardless of their performance. The advantage of this task for an additional language learner is that it essentially contains the most universal phonemes: /p/, /t/, /k/, /s/, /a/, /i/, /u/ (cf. Tables 4 and 5) and /f/ which is less universal but was chosen by the author to obtain an obstructive/fricative contrast. Using rather universal phonemes may limit phonological substitutions due to the linguistic distance between the mother tongue and French. One point was awarded for each nonword repeated correctly (maximum = 31).

Table 4. *Percentage of languages in the world that contain each French consonant or semi-consonants (on 625 languages).*

Sons	**/ɥ/**	**/ʁ/**	**/v/**	**/z/**	**/ʒ/**	**/f/**	**/g/**	**/ʃ/**	**/b/**	**/d/**	**/w/**	**/l/**	**/s/**	**/j/**	**/p/**	**/m/**	**/n/**	**/k/**	**/t/**
% of languages	0	5	17	31	33	34	55	56	63	63	76	76	83	89	90	96	97	98	99

Notes. Values were obtained thanks to the Lapsyd database (Maddieson et al., 2013, 2014).

Table 5. *Percentage of languages in the world that contain each French vowel (on 625 languages).*

Sons	**/œ̃/**	**/ɑ̃/**	**/œ/**	**/ø/**	**/y/**	**/ɔ̃/**	**/ɛ̃/**	**/ə/**	**/ɔ/**	**/ɛ/**	**/e/**	**/o/**	**/u/**	**/i/**	**/a/**	**/e/ ou /ɛ/**
% of languages	0.2	1	2	5	5	8	8	21	36	40	66	70	87	95	95	86

Notes. Values were obtained thanks to the Lapsyd database (Maddieson et al., 2013, 2014).

II.2.5. Vocabulary

This task was based on the EVIP test (Dunn et al., 1993), which is the French equivalent of the Peabody Picture Vocabulary Test (Dunn, & Dunn, 1981). Fifty items were selected mainly from the B version of the EVIP, taking into account their level of difficulty for primary school children (through a pilot study) and their relevance for French children (as the test was designed for French-speaking children in Canada). The 50 items were presented to the children. A gradual increase in difficulty compared to the original version was maintained. A new cut-off criterion was proposed, i.e., based on the same pilot study, it seemed reasonable to stop the task after five consecutive errors (maximum score = 50).

II.2.6. Word Reading

This task was based on the LEXORT lists of the EVALEC battery (Sprenger-Charolles et al., 2010). Four lists of 12 increasingly difficult words were presented (highly consistent words without digraphs, highly consistent words with digraphs, words with contextual graphemes, and irregular words). One point was awarded for each word read correctly (maximum score = 48).

II.2.7. Nonword Reading

This task was based on the LEXORT lists of the EVALEC battery (Sprenger-Charolles et al., 2010). Three lists of 12 increasingly difficult nonwords were presented (highly consistent nonwords without digraphs, highly consistent nonwords with digraphs and nonwords with contextual graphemes). These lists were matched with the first three word reading lists: the initial letters, the number of letters and phonemes, as well as syllable and bigram frequency. One point was awarded for each nonword read correctly (maximum = 36).

II.2.8. Visual-Verbal Paired Associate Learning

This task was adapted from visual-verbal paired associate learning tasks used in the literature (see for example Litt et al., 2019). It was computerized and answers were audiotaped. Participants learned four visual-verbal pairs, i.e., the name of four imaginary pictures (two imaginary animals and two imaginary plants). The names consisted of four disyllabic nonwords made up of quasi-universal phonemes: /piku/ and /ati/ for the imaginary animals; /tema/ and /upe/ for the imaginary plants[4]. Given that /e/ and /ɛ/ are not always distinguished according to the regional origin of French speakers and that they are both present in almost 86% of languages (cf. Table 5), we decided to use them. This allowed us to create more distinct nonwords to facilitate learning. Note that even though we chose the /e/ sound, we didn't count any errors if it was substituted with /ɛ/. Furthermore, we chose only simple syllables (vowel only or consonant and vowel) which are also universal (Maddieson, 2013).

The task consisted of four phases repeated eight times (eight blocks): a learning phase, a naming phase, an auditory recognition phase and a designation phase (see Figure 8 for an illustration).

Learning Phase. Pictures appeared one after the other on the screen. The names were presented simultaneously and orally by the computer twice and had to be repeated by the children. No feedback was provided. The order of the presentation of the pairs was fixed across participants but varied across blocks. No scores were computed in these phases.

Naming Phase. Each picture appeared on the screen and had to be named by the participants. No feedback was provided. The order of the presentation of the pairs was fixed across participants but varied across blocks. One point was awarded for each picture correctly named. The final score was

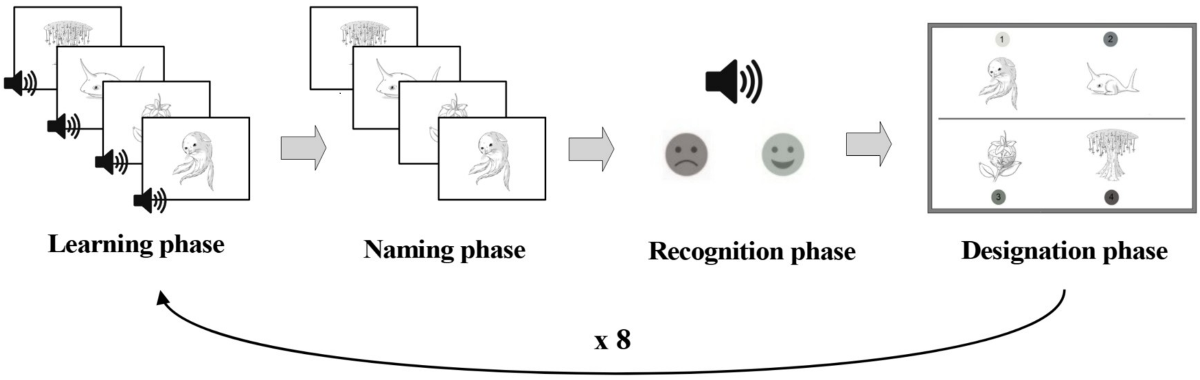
4 All characters between slashes are transcribed in the International Phonetic Alphabet.

computed by summing the scores across the eight blocks (max = 32). This is the most commonly used score in the literature on the relationship between visual-verbal PAL and reading.

Auditory Recognition Phase. This phase was designed to capture the verbal learning mechanism of the visual-verbal PAL task. In each block, the four target nonwords were presented among four distractors, which varied across blocks. The order of the presentation of the targets and distractors was fixed across participants but varied across blocks. The main rule for creating the distractors was to change one syllable of each target while keeping the same structure (e.g. the distractor for /piku/ could be /taku/, the distractor for /upe/ could be /ipe/). The children responded by pressing a green key for targets or a red key for distractors on the keyboard. Separate scores for targets and distractors were calculated by summing either the number of correct target identification or the number of correct distractor rejections.

Designation Phase. This phase was designed to capture the cross-modal associative learning mechanism of the visual-verbal PAL task. It consisted of four trials. Each trial consisted of the four pictures appearing simultaneously on the screen. At the same time, participants heard one of the target nonwords. They had to press the key which corresponded to the correct picture. Although the order in which the pictures (targets and distractors) appeared simultaneously on the screen varied from trial to trials, within and between blocks, it was fixed between participants. The spoken presentations of the nonwords were also randomized across blocks but fixed between participants. One point was awarded for each picture correctly designated. The final score was calculated by summing the scores across the eight blocks (max = 32).

Figure 8. *Illustration of the visual-verbal PAL paradigm.*



II.2.9. Reliability of the Measures

The level of reliability for all measures is shown in Table 6. We have separated French and EANA children because we might expect some differences between the two groups. In the next section, we will present a flexible scoring procedure for vowel substitutions. In short, this procedure allows some errors to be ignored. This might have affected the reliability of the tasks. For this reason, we also calculated Cronbach's α for the flexible scoring. Reliability was acceptable for most of the measures although it was rather low for the nonword repetition tasks for French children.

II.3. Procedure

The children were tested at their schools. The tests took between an hour and an hour and a half, depending on the speed of the participants. If necessary, the tests were split into two sessions. The order of the tests was fixed, alternating between easy and more difficult tests to maintain motivation. The participants thus completed the various tests in the following order: nonverbal abilities, vocabulary, paired-associate learning, rapid automatized naming, phonological awareness, nonword repetition, word and nonword reading.

Table 6. *Reliability for all measures of the TANMALL project.*

	N		$\alpha_{\text{strict scoring}}$		$\alpha_{\text{flexible scoring}}$	
	French	**EANA**	**French**	**EANA**	**French**	**EANA**
Word reading	254	174	.91	.96	.90	.96
Nonword reading	253	175	.84	.92	.84	.93
Nonverbal abilities	256	179	.84	.88	_	_
Phonological Awareness	251	174	.86	.94	.86	.94
Rapid Automatized Naming[a]	252	175	r = .73, p <.001	r = .80, p <.001	_	_
Nonword repetition	254	176	.66	.84	.66	.81
Vocabulary	254	177	.84	.90	_	_
PAL: Naming	251	178	.90	.89	.90	.90
PAL: Naming bis[b]	251	178	.74	.67	.73	.73
PAL: Auditory	239	172	.86	.89	_	_
PAL: Auditory bis[b]	239	172	.66	.72	_	_
PAL: Designation	245	178	.88	.89	_	_
PAL: Designation bis[b]	245	178	.81	.84	_	_

[a] Reliability for rapid automatized naming was estimated with the correlation between the average time taken to read both lists (letters and digits).
[b] Since the four items were repeated eight times across testing phases, reliability for each phase could be inflated. We thus computed two reliability indicator for each phase: (1) one on all trials of a given phase, considering that the items were all independent (e.g. the item ‘piku’ in the first block was considered different from the item ‘piku’ in other blocks in a given phase); (2) one on the mean scores of each item in a given phase across all blocks (i.e., the reliability calculation was performed on four recomputed items: the average scores on all blocks for each item).

III. First Axis: Predicting Reading Development in EANA Children.

III.1. Introduction

The aim of this experimental part was to pave the way for future work on the development of tools for the early identification of children at risk of reading failure. Identifying EANA children at risk of reading failure is important so that they can be offered targeted and intensive interventions. This could take the form of an easier access to speech and language therapists for individualized treatment.

First, we wondered how to adjust the scoring for verbal output because EANA children produce phonological substitutions due to the phonological distance between the languages (p. 71). Then, using these adjustments, decoding performance on word and nonword reading tasks were compared with that of French children (p. 82). Based on the observations of Armagnague and Rigoni (2018), we hypothesized that EANA children would have decoding difficulties compared to French children who had benefited from the same duration of reading instruction. We also investigated contextual and cognitive-linguistic factors that might influence decoding skills (p. 91). Assessing these predictive factors when the children arrive could allow early identification of children at risk of reading failure. The tests were adapted for EANA children using either universal verbal items or a flexible scoring procedure. We also investigated the contribution of visual-verbal PAL skills to decoding skills, which are well adapted to EANA children. Finally, we proposed a reflection on the possibility of creating universal instruments that do not require the creation of standards specific to French or EANA children (p. 114).

III.2. Rational for a Flexible Scoring of Verbal Output for EANA Children

III.2.1. Introduction

An important limitation of using a language test that requires verbal output is that responses may be influenced by the phonological distance between the first languages and French in EANA children. Let us take an example. The verbal productions in Table 7 were produced by an EANA participant. Using a classical procedure to score these productions, he would get 0 for all these items. However, all the errors were substitutions for close vowels in French.

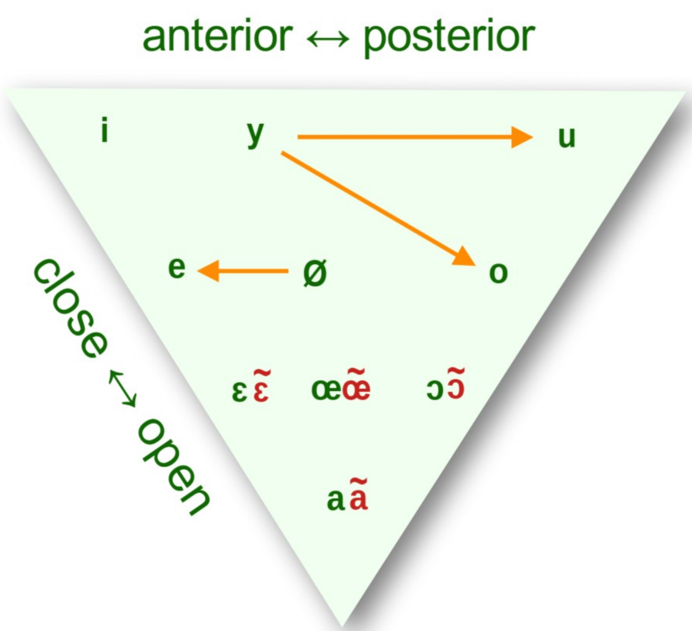
Table 7. *Some errors made by an EANA child.*

Verbal output (IPA)	Target (IPA)	Orthographic transcription
/pl**u**m/	/plym/	plume
/t**o**lip/	/tylip/	tulipe
/ʃ**e**val/	/ʃøval/	cheval

In fact, French vowels can be represented by an acoustic triangle (first description in Delattre, 1948; updated by Georgeton et al., 2012). Basically, this triangle was obtained by analyzing some important acoustic features of vowels called 'formants'. Formants can be defined as frequency bands of vocal harmonics that are specifically amplified by supraglottic anatomical structures. Formants give vowels their identity (Aalto et al., 2018).

The acoustic triangle represents vowels on two axes (horizontal or vertical), representing the frequency of two formants that discriminate vowels well. Interestingly, they also represent well two articulatory features of vowels: the front of the tongue and the openness of the mouth (Figure 9). The Figure 9 shows that the examples of errors in the Table 7 correspond to close vowels on the acoustic triangle. Consequently, these errors may be due to difficulties in discriminating and/or producing specific French vowels, but do not necessarily reflect decoding difficulties. Critically, they may also reflect the subjective perception of the examiner. For example, suppose a child produces a middle sound between /y/ and /u/. Then two experimenters may have different perceptions due to subtle differences in sound categorization. In fact, vowels are known to have lower inter-rater reliability than consonants (Stoel-Gammon, 2001). For this reason, and because we have observed empirically that sound substitutions often occur on vowels, we have not considered the case of consonants here.

Figure 9. *Adaptation of the acoustic triangle (Georgeton et al., 2012)*



How can we determine whether a child is making sound substitutions due to the distance between his or her first language and French? The solution we adopted was based on the assumption that if the substitutions were due to the phonological distance between the first languages and French, they would involve vowels close to each other in the acoustic triangle. We have therefore adopted a flexible notation that does not penalize vowel substitutions when they are replaced by neighboring vowels in the acoustic triangle. This solution has two advantages: the same criteria were used for all children, and it also makes it possible to deal with the variability in examiners' perceptions for the same verbal output.

The Table 8 shows all the possible substitutions for each target vowel. Note that we have not made a distinction between /ɛ̃/ and /œ̃/ because this distinction is almost never made in France today. The table then presents two sets of alternative sounds: a flexible one and a strict one. The flexible one follows the rules described above, i.e. a given vowel can be replaced by neighboring vowels. The strict version allowed certain regional substitutions. For example, /ɛ/ is often replaced by /e/ in northern France.

Table 8. *Possible alternatives for each targeted vowel.*

Target sound	Flexible alternatives	Strict alternatives
i	e-y	
e	i-ø-ɛ-ɛ̃	ɛ
ɛ	e-ɛ̃-a-ɑ̃	e
a	ɛ-ɛ̃-œ-ɔ-ɑ̃	
y	i-u-ø	
ø	y-e-o-ɔ̃-ɛ̃-œ	œ
œ	ɛ̃-ɛ-ø-ɔ-a-ɑ̃	ø
u	y-o-ɔ-ɔ̃	
o	ɔ̃-u-ø-ɔ	ɔ
ɔ	o-ɔ̃-œ-ɛ̃-a-ɑ̃	o
ɔ̃	ɑ̃-ɛ̃	
ɑ̃	ɑ̃-ɛ̃	
ɛ̃	ɑ̃-ɛ̃	
ʁ*	r-^{h}	

* We added the /ʁ/ because it was a classic consonantal substitution for which we had no doubt that it was linked to the mother tongue and not to the tasks.

The limitation of this solution is that it ignores the problem rather than analyzing each substitution in detail for each child. It is therefore possible that some of the information lost is important for the sensitivity of the measure. The aim of the analyses carried out here was therefore to check that the measures affected by this scoring had not lost sensitivity. Importantly, we also wondered whether the proportion of incorrect items corrected by flexible scoring would be higher for EANA children than for French children. This would confirm its relevance for EANA children.

III.2.2. Method

III.2.2.1 Participants

We selected a subsample from the participants included in the TANMALL project. Thirty-six participants were excluded because they did not meet the inclusion criteria, had missing data on the variable of interest or had incorrect pseudonymization codes. The final sample consisted of 157 EANA children and 243 French children (169 monolingual children and 74 were exposed to one or more additional language(s) at home, referred to as 'bilingual children' for simplicity). The characteristics of the groups were presented in the Table 9. The characteristics of the French sample as a whole (combining values for monolingual and bilingual children) are shown in Table 10.

Table 9. *Main characteristics of the final sample.*

	Monolingual (N=169)			**Bilingual (N=74)**			**EANA (N=157)**		
Variables	***NA***	***mean (sd)***	***min-max***	***NA***	***mean (sd)***	***min-max***	***NA***	***mean (sd)***	***min-max***
Age (months)	1	86.11(6.1)	77-99	0	87.19(6.52)	77-110	0	113.15(19.63)	75-191
Mean grade	0	1.29(0.45)	1-2	0	1.39(0.49)	1-2	0	3.06(1.38)	1-5
Duration of primary school attendance	0	8.76(3.08)	4.05-15.15	0	9.64(4.21)	4.76-25.55	0	9.27(4.5)	4.09-21.45
Social position indicator	0	113.15(17.13)	65-133.6	0	103.47(21.01)	65-133.6	0	88.71(18.44)	65-124.8
Priority education area	0	1.27(0.69)	1-3	0	1.71(0.94)	1-3	3	1.97(0.89)	1-3
Parental educational level (ISCED)	17	5.67(1.59)	0-8	13	5.17(2.01)	0-8	157	NA	NA

Note. NA = missing data.

Table 10. *Main characteristics of the French children.*

Variables	***Missing data***	***mean (sd)***	***min-max***
Age (months)	1	86.44(6.24)	77-110
Mean grade	0	1.32(0.47)	1-2
Duration of primary school attendance	0	9.03(3.49)	4.05-25.55
Social position indicator	0	110.16(18.91)	65-133.6
Education priority zone	0	1.41(0.8)	1-3
Parental educational level (ISCED)	30	5.52(1.73)	0-8

The groups were fairly well matched in terms of duration of primary school attendance. The mean age of French children (86.44 months) was lower than the mean age of EANA children (113.15 months). The socioeconomic status of the EANA children was lower than that of the French children. In fact, they were sampled more often in priority education areas than French children (Figure 10), and the average social position indicator of the school they attended (88.71) was lower than for French children (110.16).

III.2.2.2 Measures

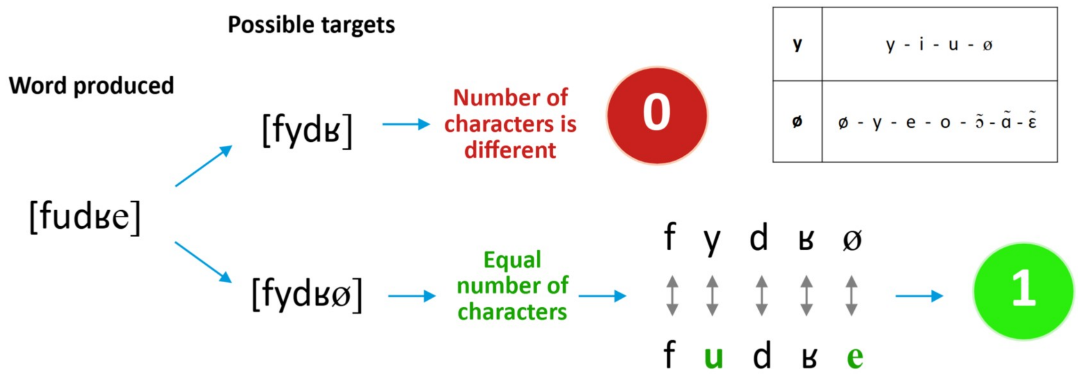
We analyzed the answers for word and nonword reading together thanks to a composite score, as it was not relevant here to distinguish between the two tasks. The reliability of the items of both tasks combined was excellent regardless of the scoring method (strict or flexible: $\alpha_{\text{strict and flexible}} = 0.97$). We also examined the answers at phonological awareness, nonword repetition and visual-verbal PAL. All these tasks are described in the general methodology section of the TANMALL project (see the section II.2, p. 63).

III.2.2.3 Implementation

To facilitate the scoring process and possible future adjustments, we created an algorithm in R that compares the transcriptions of the responses with the target transcriptions. The basic principles are shown in Figure 10.

First, the algorithm compares the number of characters in the transcription of the word produced and the possible targets. If the number of characters is different, the process stops for the target and a score of 0 is assigned. If the number of characters is similar, the process continues for the target. Next, each character in the word produced is compared with each character in the target. If they are different, the algorithm checks whether or not the substitution is allowed by the flexible notation. If it is, a score of 1 is assigned. If not, a score of 0 is assigned. The best score of all the possible targets is assigned to the item.

Figure 10. *An algorithm to apply the flexible scoring to the transcription of answers.*



III.2.3. Results

We examined whether flexible scoring changed the sensitivity of the tasks. First, we determined whether the sum of the mean flexible score and the standard deviation was greater than the maximum possible score. In the case of a normal distribution, this would mean that at least 84% of the data were below the maximum score. We performed the same analyses using a criterion of 1.65 standard deviations. This would mean that at least 95% of the data are below the maximum scores in the case of a normal distribution. The results are shown in Table 11. With a criterion of 1 standard deviation, no ceiling effect was found. At the criterion of 1.65 standard deviations, we found ceiling effects for reading, phonological awareness and nonword repetition in French children and for phonological awareness and nonword repetition in EANA children. However, the ceiling effects were not due to flexible scoring, as they were already observed with strict scoring. Moreover, the corresponding scores were never increased by more than 1.5 points with the use of flexible scoring, which is very little. A graphical representation of the distributions before and after the application of flexible scoring is shown in Figure 11.

Furthermore, we wondered whether the flexible scoring would benefit the EANA children more than the French children. The Table 11 also shows the mean strict and flexible scores obtained in each group for reading, phonological awareness, nonword repetition and visual-verbal PAL. It also shows the proportion of items that were finally scored as correct when the flexible score was applied to each task. Missing data correspond to proportions that could not be calculated because the children did not make any mistakes.

We observed that the flexible scoring corrected significantly more items in all EANA children than for French children in all tasks: reading ($t(325.07) = 4.11$, $p < .001$, $d = 0.42$), phonological awareness ($t(228.35) = 7.09$, $p < .001$, $d = 0.76$), nonword repetition ($t(218.60) = 7.59$, $p < .001$, $d = 0.91$) and visual-verbal PAL ($t(192.96) = 6.53$, $p < .001$, $d = 0.72$).

III.2.4. Discussion

We wondered whether our proposal for flexible scoring could help to deal specifically with vowel substitutions due to the phonological distance between the first languages of EANA children and French, without altering the sensitivity of the tasks. Indeed, we observed that the proportion of items corrected by flexible scoring was higher in EANA children than in French, suggesting that it corrected specific errors in EANA children. Furthermore, we observed that it did not change the sensitivity of the different tasks. Slight ceiling effects were found with a criterion of 1.65 standard deviations above the mean, but these were not primarily due to the flexibility of the scoring and were not very pronounced. This suggests that it may be possible to apply such a scoring method to existing standardized tests without altering the comparison with the norm. It should be noted that comparing the performance of EANA children with monolingual norms raises other issues, which we will discuss in the last section of this first experimental axis (cf. section III.5, p. 114). Finally, the results suggest that flexible scoring has an impact on nonword repetition and visual-verbal PAL, even though these items were designed with quasi-universal phonemes. For example, the nonword /piku/ was often pronounced /piko/, even during the repetition phases of the PAL task. It is possible that the children produced allophonic variants of /u/ that were perceived as /o/ by the examiners. Similarly, some children added a nasal character to /a/ in /tema/. This could be an assimilation mechanism between the nasal consonant /m/ that preceded /a/ in /tema/. If there is no nasal vowel in the children's first languages, it is possible that they do not consider nasal features to be phonologically discriminative. They would then perceive and produce /a/ and /ɑ̃/ or /ɛ̃/ as allophonic equivalents, as French speakers sometimes replace /ɛ/ with /e/ or /o/ with /ɔ/.

It should be noted that in some cases this type of scoring can ignore errors that are genuinely related to the skills being tested. For example, it is common for French children to confuse the graphemes 'ail', which is pronounced /aj/, and 'eil', which is pronounced /ɛj/. Flexible notation can ignore these errors because /a/ and /ɛ/ are considered acoustically close vowels. In other words, although flexible notation does not change the overall sensitivity of the measurements, it may change the qualitative analysis of the errors to some extent. Furthermore, the use of flexible scoring does not mean that difficulties related to phonological distance between languages cannot be investigated, or that specific interventions to address these errors cannot or should not be implemented. It is simply a matter of finding a way of distinguishing between the skills targeted by the test and errors related to the characteristics of the first languages.

To take this a step further, we have identified a number of ways in which the current flexible scoring proposal could be improved. Firstly, we could compare the phonological tables of each first language with French and apply flexible scoring only to French sounds that are absent in the first languages. Thanks to the Lapsyd project (Maddieson et al., 2014), we have access to the phonological tables of hundreds of languages. It is then possible to apply this 'restrictive' flexible notation to many languages and to use the current notation for languages for which we do not have access to phonological tables. Note, however, that if some languages allow allophonic variations for some vowels (such as /e/ and /ɛ/, /ø/ and /œ/, or /o/ and /ɔ/ in French) in the first language and not in French, this might not be taken into account. Secondly, we could test the same principles for consonants. One difficulty is that close consonants can often be real decoding errors for French children, such as confusion between ‘m’ and ’n’, 'b' and ‘d', and all pairs of voiced and voiceless consonants such as ‘p’ and ‘b’. Finally, it is important to note that some substitutions may also be because some children have already started to learn to read in the Latin alphabet, but with different grapheme-phoneme correspondences.

Main results

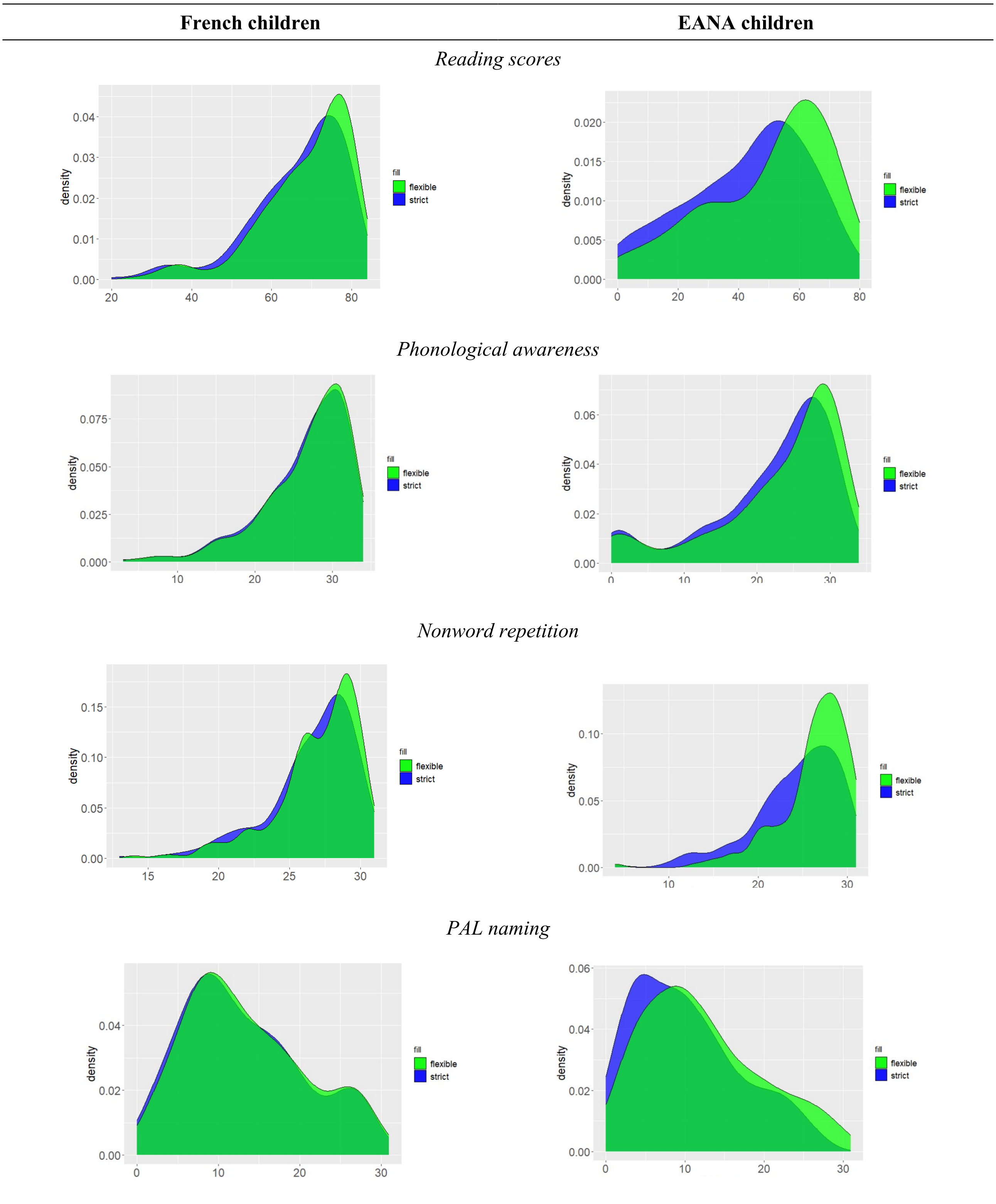
- The proportion of items corrected by flexible scoring was higher for EANA children than for French children, suggesting that it corrected specific errors in EANA children.
- The flexible scoring did not change the sensitivity of the different tasks.

Table 11. *Between group comparison of the scores obtained at the tasks requiring verbal output and gains obtained thanks to the flexible scoring.*

	French children					EANA children					Comparison			
Variables	**NA**	**mean(sd)**	**min-max**	**mean + 1sd**	**mean + 1.65 sd**	**NA**	**mean(sd)**	**min-max**	**mean + 1sd**	**mean + 1.65 sd**	***t***	**df**	***p***	**cohen's d**
Reading (max = 84)														
Reading (strict)	0	66.74(11.91)	20-83	78.65	**86.39**	0	42.91(20.01)	0-78	62.92	75.93	-13.46	227.97	<.001	-1.45
Reading (flexible)	0	68.68(11.36)	26-84	80.04	**87.42**	0	49.71(20.39)	0-80	70.1	83.35	-10.64	219.12	<.001	-1.15
Reading gain (raw)	0	1.95(1.62)	0-8			0	6.8(5.25)	0-29			11.25	175.46	<.001	1.25
Reading gain (proportion)	0	13.9(13.68)	0-100			0	19.78(14.14)	0-56.52			4.11	325.07	<.001	0.42
Phonological awareness (max = 34)														
Phonological awareness (strict)	0	26.54(5.61)	3-34	32.15	**35.80**	0	22.02(8.64)	0-34	30.66	**36.28**	-5.81	240.97	<.001	-0.62
Phonological awareness (flexible)	0	26.75(5.57)	4-34	32.32	**35.94**	0	23.16(8.87)	0-34	32.03	**37.80**	-4.53	235.8	<.001	-0.48
Phonological awareness gain (raw)	0	0.21(0.51)	0-4			0	1.14(1.23)	0-5			8.94	190.89	<.001	0.98
Phonological awareness gain (proportion)	4	3.52(9.35)	0-50			1	13.34(15.57)	0-60			7.09	228.35	<.001	0.76
Nonword repetition (max = 31)														
Nonword repetition (strict)	0	26.67(3.07)	13-31	29.74	**31.74**	0	24.34(4.89)	4-31	29.23	**32.41**	-5.33	235.9	<.001	-0.57
Nonword repetition (flexible)	0	27.02(2.97)	14-31	29.99	**31.92**	0	26.23(4.1)	4-31	30.33	**33.00**	-2.09	260.5	0.04	-0.22
Nonword repetition gain	0	0.35(0.72)	0-6			0	1.89(2.27)	0-11			8.23	176.49	<.001	0.91
nonword repetition gain (proportion)	8	8.61(16.98)	0-100			6	28.15(28.57)	0-100			7.59	218.6	<.001	0.83
PAL naming (max = 32)														
PAL naming (strict)	0	13.12(7.42)	0-30	20.54	25.36	0	10.14(6.79)	0-27	16.93	21.34	-4.13	353.94	<.001	-0.42
PAL naming (flexible)	0	13.46(7.41)	0-31	20.87	25.69	0	12.2(7.46)	0-31	19.66	24.51	-1.66	331.41	0.1	-0.17
PAL naming gain (raw)	0	0.34(0.92)	0-7			0	2.06(2.82)	0-14			7.38	177.46	<.001	0.82
PAL naming gain (proportion)	0	2.12(7.07)	0-80			0	11.28(16.62)	0-88.89			6.53	192.96	<.001	0.72

Note. NA = missing data

Figure 11. *Density curves for strict and flexible scoring per group.*



III.3. Comparisons of Word and Nonword Reading Skills between EANA and French Children

III.3.1. Introduction

The aim of this chapter was to compare the decoding skills of EANA and French children. In general, there is no difference between additional language learners and monolingual children (Melby-Lervåg & Lervåg, 2014). Children learning to read in an additional language develop similar decoding skills to children learning to read in their L1 and at the same rate (for a review, see Geva et al., 2019). However, these findings contradict the observations made with EANA children (Armagnague & Rigoni, 2018).

These discrepancies may be related to the fact that EANA children represent a relatively different population from the children studied in previous studies. Indeed, among the populations of children learning an additional language in the meta-analysis by Melby-Lervåg and Lervåg (2014), very few arrived late in the country where they were tested (i.e. during the primary school years). Moreover, the samples never specifically targeted these children.

Unlike the additional language children in previous studies, EANA children, by definition, have had no exposure to French prior to entering primary school. They therefore start to learn to read without any oral language background. However, as we have seen, vocabulary can support word reading via the 'Set for Variability' mechanism (Tunmer & Chapman, 2012a). Indeed, some studies have shown that the level of vocabulary in the additional language is correlated with decoding skills (Arab-Moghaddam & Senechal, 2001; Geva & Farnia, 2012; Gottardo, 2002; Kremin et al., 2019; Yeong et al., 2014; Zhao et al., 2017; Cheung et al., 2010; Y. Liu et al., 2017; but see Geva et al., 2000) even when controlling for phonological awareness (Gottardo, 2002; Y. Liu et al., 2017; Zhao et al., 2017), rapid automatized naming and phonological short-term memory (Jean & Geva, 2009).

It should be noted that vocabulary in a given language is more predictive of reading success in that language than in the other language spoken (Arab-Moghaddam & Senechal, 2001; Erdos et al., 2011; Gottardo, 2002; Lindsey et al., 2003; Zhao et al., 2017). This is consistent with the Set for Variability account, according to which vocabulary allows the correct phonological form of a word to be recovered from an erroneous recoding procedure (Tunmer & Chapman, 2012a). This correct phonological form is language dependent and cannot rely on the first language vocabulary knowledge. Thus, if EANA children's difficulties in learning to decode are indeed due to a lack of vocabulary, we would expect them to score lower than French children mainly on word reading and not on pseudoword reading, which cannot be supported by vocabulary.

The aim of the analyses presented in this section was to compare the decoding level of EANA children with that of French children, for the same length of time spent learning to read in French. As we recruited EANA children in UPE2A that follow them from their arrival until two years after their arrival (three years in very rare cases), the comparison therefore focuses on beginning readers.

Our data also allowed us to separate the group of French children into a monolingual group and a group of French children exposed to another language at home (hereafter referred to as 'bilingual children', for simplicity). According to Armagnague and Rigoni (2018), we expected that EANA children would score lower than French children on word reading tasks. We expected that the difference between the groups would be smaller or absent for nonword reading skills, as they are not supported by vocabulary skills. Finally, we expected that bilingual and monolingual children would obtain similar scores in both word and nonword reading tasks (Geva et al., 2019; Melby-Lervåg & Lervåg, 2014).

III.3.2. Method

III.3.2.1 Participants

We selected a subsample from the participants included in the TANMALL project. Twenty-five participants were excluded because they did not meet the inclusion criteria, had missing data on the variable of interest or had incorrect pseudonymization codes. Following Berger and Kiefer's (2021) guidelines for identifying outliers, we excluded 20 participants whose reading scores were 2.24 standard deviations above or below the mean of their language group. The final sample consisted of 154 EANA children and 225 French children (166 monolingual children and 71 bilingual children).

The characteristics of the monolingual, bilingual and EANA children are presented in the Table 12. The characteristics of the French sample as a whole (combining the values for monolingual and bilingual children) are presented in Table 13.

Table 12. *Main characteristics of the final sample.*

	Monolingual (N=166)			**Bilingual (N=71)**			**EANA (N=154)**		
Variables	***NA***	***mean (sd)***	***min-max***	***NA***	***mean (sd)***	***min-max***	***NA***	***mean (sd)***	***min-max***
Age (months)	1	86.11(6.12)	77-99	0	86.63(6.14)	76-122	0	113.47(19.71)	75-191
Nonverbal abilities	1	21.26(5.17)	9-32	0	20.00(5.52)	4-30	0	19.49(5.99)	7-31
Mean grade	0	1.28(0.45)	1-2	0	1.38(0.49)	1-2	0	3.08(1.39)	1-5
Duration of primary school attendance	0	8.76(3.1)	4.05-15.15	0	9.45(3.87)	5.8-25.55	0	9.20(4.52)	4.09-21.45
Social position indicator	0	112.95(17.05)	65-133.6	0	104.07(20.96)	65-133.6	0	88.99(18.49)	65-124.8
Priority education area	0	1.28(0.69)	1-3	0	1.72(0.94)	1-3	3	1.95(0.88)	1-3
Parental educational level (ISCED)	16	5.67(1.62)	0-8	12	5.31(1.84)	0-7.5	154	NA	NA

Note. NA = missing data

The groups were fairly well matched in terms of duration of primary school attendance and nonverbal abilities. However, the mean age of the French children (86.27 months) was lower than the mean age of the EANA children (113.47 months). The socioeconomic status of EANA children was also lower than that of French children as indicated by the average social position indicator of the school they attended (88.99) was lower than for French children (110.29).

Table 13. *Main characteristics of the French children.*

Variables	Missing data	mean (sd)	min-max
Age (months)	1	86.27(6.12)	76-102
Nonverbal abilities	1	20.88(5.30)	4-32
Mean grade	0	1.31(0.46)	1-2
Duration of primary school attendance	0	8.97(3.36)	4.05-25.55
Social position indicator	0	110.29(18.71)	65-133.6
Education priority area	0	1.41(0.8)	1-3
Parental educational level (ISCED)	29	5.57(1.69)	0-8

III.3.2.2 Measures

We analyzed word and nonword reading scores. We used flexible scoring for both groups. A detailed description of the tasks can be found in the general method section of the TANMALL project (see the section II.2, p. 63).

III.3.3. Results

III.3.3.1 Comparing Groups on Reading Scores

The Table 14 presents descriptive statistics for the reading scores of the monolingual, bilingual French children and EANA children. The Figures 12 shows box plots of the Z-scores in the word and nonword reading tasks for each group.

We conducted a two-way ANOVA on flexible reading scores, with linguistic status (monolingual, bilingual, EANA) as a between-group factor and task (word reading or nonword reading) as a within-group factor. Additional information on data preparation is provided in the Appendix II, p. 273. There was a main effect of language status, $F(2,390) = 84.00$, $p < .001$, but not of the task, $F(2,390) = 0.01$, $p > .05$, or of the interaction term, $F(2,390) = 2.41$, $p > .05$. Post hoc pairwise comparisons with Bonferroni correction showed that French monolingual and bilingual scores were significantly higher than those of EANA children, whatever the task (word or nonword reading). Conversely, monolingual and bilingual children obtained similar scores (Table 15).

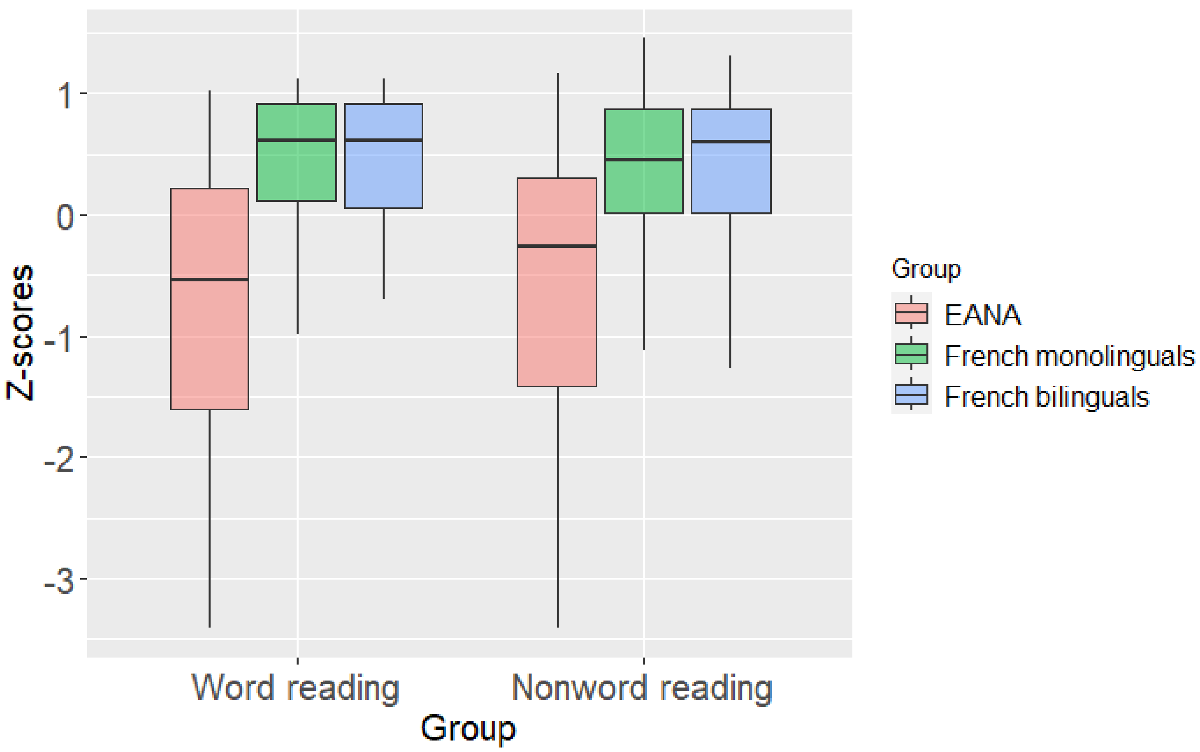
Table 14. *Descriptive table of the scores obtained by each group in each reading task.*

	Monolingual (N=166)		Bilingual (N=71)		EANA (N=154)	
Variables	***mean (sd)***	***min-max***	***mean (sd)***	***min-max***	***mean (sd)***	***min-max***
Word reading (strict)	40.84(5.7)	25-48	40.31(5.68)	27-48	26.74(11.36)	1-46
Nonword reading (strict)	27.64(4.45)	15-36	27.52(4.62)	14-35	17.58(8.21)	0-34
Word reading (flexible)	41.56(5.39)	27-48	41.31(5.09)	30-48	29.81(11.23)	3-47
Nonword reading (flexible)	28.70(4.3)	18-36	28.70(4.45)	17-35	21.48(7.98)	2-34

Table 15. *Pairwise comparison t-test with bonferroni correction.*

Task	Group 1	Group 2	n1	n2	*p*	*p*.adj (bonferroni)
Word reading	EANA	monolinguals	154	166	<.001	<.001
Word reading	EANA	bilinguals	154	71	<.001	<.001
Word reading	monolinguals	bilinguals	166	71	0.661	1.000
Nonword reading	EANA	monolinguals	154	166	<.001	<.001
Nonword reading	EANA	bilinguals	154	71	<.001	<.001
Nonword reading	monolinguals	bilinguals	166	71	0.946	1.000

Figure 12. *Comparison between groups on word and nonword reading scores.*



III.3.3.2 Complementary Analyses

It can be argued that differences between the groups may be due to (at least in part) differences in the social position indicator of the schools where the children were recruited. Indeed, different social position indicators may reflect differences in school experiences. Children attending a primary school with a high social position indicator status may face higher expectations from teachers and benefit from higher quality language exchanges with other children than in schools with a low social position indicator status. Indeed, we observe that word reading scores were correlated, albeit weakly, with the social position indicator for French children ($r = .13$, $p = .04$) but not for EANA children. Note, however, that the correlations between the social position indicator and nonword reading were not significant in either group (Table 16). Looking at the graphical representation of reading scores by group as a function of the social position indicator, we see that at every level of the social position indicator, EANA children score lower than French children. Moreover, the 0.95 confidence intervals around the straight line representing the scores of EANA children do not overlap with that of French-speaking children.

Figure 13. *Relation between reading scores and social position indicator (IPS) per group.*

Word reading scores **Nonword reading scores**

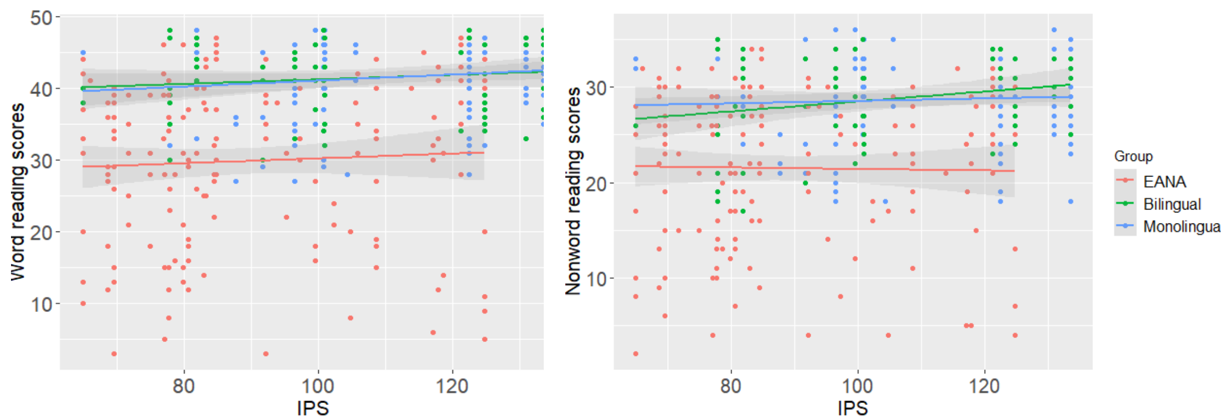


Table 16. *Correlations between reading scores and the social position indicator (IPS) per group.*

Variables	Word reading	Nonword reading	IPS
Word reading	_	.89***	.10
Nonword reading	.69***	_	.04
IPS	.13*	.12	_

Notes. Correlations above the diagonal correspond to EANA children. Correlations below the diagonal correspond to French children; * $p < .05$; ** $p < .01$; *** $p < .001$

III.3.4. Discussion

The aim of these analyses was to compare the decoding level of EANA children with that of French and bilingual children, for the same amount of time spent learning to read in French (less than 3 years of schooling at primary school). We found that EANA children had lower reading scores than French children while bilingual and monolingual French children did not differ between each other. These results are in line with previous research in which additional language learners who were exposed to the additional language since kindergarten (at least) has not shown any difference with monolingual children in decoding skills (Geva et al., 2019; Melby-Lervåg & Lervåg, 2014). However, we confirm the observations of Armagnague & Rigoni (2018) which suggest that EANA children may have difficulties in decoding skills. Note that the difference between French and EANA children does not seem to be explained by the social position indicator of the school.

Furthermore, we hypothesized that word reading scores would differ more between EANA and French children than nonword reading scores. Indeed, French children benefit from their vocabulary knowledge to support word reading, in part due to the "Set for Variability" mechanism (Tunmer & Chapman, 2012a, 2012b). EANA children would not benefit from their vocabulary knowledge, as they had very little exposure to French compared to French children. On the contrary, we expected them to read nonwords as efficiently as French readers, since it does not require vocabulary knowledge. However, we found that EANA children had difficulties with both word and nonword reading skills compared to French children, suggesting that vocabulary knowledge is not the best explanation to account for these differences. To be more nuanced, we could also hypothesize that vocabulary plays a role in both word and nonword reading: a direct role in word reading through the 'Set for Variability' mechanism and an indirect role in nonword reading. In fact, the refinement of grapheme-to-phoneme conversion rules thanks to the 'Set for Variability' might also benefit nonword reading. For example, if children read the French word 'éléphant' as follows: /elepɑ̃/ instead of /elefɑ̃/. The 'Set for Variability' mechanism may help them to recognize the real word and retrieve the correct pronunciation. At the same time, they may notice that the grapheme 'ph' is pronounced /f/, which may generalize to nonword reading skills. Vocabulary level could then be correlated with both word and nonword reading scores. Another explanation would also be that word and nonword production may be facilitated by phonotactic regularities knowledge in French which was shown to be associated with vocabulary level (e.g. J. Edwards et al., 2004; Estes et al., 2016; Munson et al., 2005). Indeed, the nonwords of the EVALEC reading tasks (Sprenger-Charolles et al., 2010) were matched to real words on the basis of bigram frequency, which may have indirectly led to a good match with French phonotactic regularities. In the following section, we have tested the contribution of vocabulary to both word and nonword reading skills in EANA and French children.

Finally, the scores obtained by EANA children are highly heterogeneous (the standard deviation of EANA children's scores is around twice that of French children's scores, Table 14). Thus, before looking at the "classic" cognitive-linguistic predictors of decoding skills, we examine some contextual factors that may account for this heterogeneity and explain, at least in part, why EANA children's scores are lower than those of French children.

Main results

- EANA children had lower reading scores than French children while bilingual and monolingual French children did not differ between each other.
- EANA children had difficulties with both word and nonword reading skills compared to French children, suggesting that vocabulary knowledge is not the best explanation to explain their difficulties with decoding skills.

III.4. Predicting Reading Achievement in EANA Children with Contextual and Cognitive-Linguistic Factors

III.4.1. Introduction

We found that EANA children had lower decoding performance (word and nonword reading tasks) than French children who were equally exposed to reading instruction in French. These difficulties may have implications for academic success, given that reading is the preferred medium for conveying course content and instructions. It is therefore essential to identify the factors that explain these differences and how they predict reading development in EANA children, to identify children at risk of reading failure as early as possible and to provide intensive, targeted intervention. This section therefore aims to examine some contextual factors and the main cognitive and linguistic predictors of decoding in EANA children. The characteristics of these different predictors are summarized below (for a more detailed description, see the Theoretical background, p. 21).

The first factor that may influence reading outcomes is the fact that EANA children may or may not have attended school before arriving in France. In fact, almost 20% of EANA children had never attended school before arriving in France (Brun, 2023). Children who have attended school may find it easier to adapt to the French school environment than others. They are also more likely to have started learning to read in another language, which may make it easier to learn to read in French (Melby-Lervåg & Lervåg, 2011). Therefore, it was expected that children who have attended school and/or learned to read in another language before arriving in France obtained higher scores at decoding tasks than others.

Then, EANA children who arrived in France early (during or before first grade) may have an advantage over older children because they can benefit from explicit reading instruction at the same time as their French peers. In addition, it’s easier to learn a new language at an early age, in part because of critical periods of neurological maturation (Birdsong, 2018).

Finally, one might expect that children whose first language is phonologically distant from French would have more difficulty learning French than children whose language has similar characteristics (Koda & Zehler, 2008; Lado, 1957). Although it is beyond the scope of this research to compare a specific language with French, it may be interesting to determine whether the linguistic family (i.e. Indo-European or not) of the first language can influence the reading achievement of EANA children. Similar criteria have been used in previous studies (Bialystok et al., 2010; Melby-Lervåg & Lervåg, 2014). It would also be interesting to determine whether the writing system of the first language influences the acquisition of reading in French, especially in the case of children who started learning to read in their first language before arriving in France. Indeed, it has been shown that children who learn to read in an alphabetic system transfer their skills to the other one (Bialystok et al., 2005; Melby-Lervåg & Lervåg, 2011).

Then, we examined the relationship between some cognitive-linguistic, namely phonological awareness, rapid automatized naming, phonological memory and vocabulary, which have been shown to predict reading achievement in both monolingual children (e.g. Lervåg et al., 2009; Melby-Lervåg & Lervåg, 2012; Ouellette & Beers, 2010; Parrila et al., 2004; Poulsen & Elbro, 2018; Ricketts et al., 2007) and additional language learners (e.g. Chiappe, Siegel, & Gottardo, 2002; Comeau et al., 1999; Geva & Farnia, 2012; Gottardo et al., 2008; Jongejan et al., 2007; Y. Liu et al., 2017; MacKay et al., 2023; Muter & Diethelm, 2001). From a theoretical point of view, it was interesting to test all of these predictors to better understand their involvement in the reading skills in EANA children. In particular, we previously hypothesized that vocabulary might be correlated with both word and nonword reading scores in EANA (see p. 88). This might explain, at least in part, why they performed less well than French children on both tasks. Moreover, the teachers we met in the UPE2A expressed some concern about the predictive power of cognitive-linguistic factors. Indeed, given the great heterogeneity of the EANA children in terms of the contextual factors we identified and others such as reasons for migration, social difficulties, etc., we might expect the predictive power of cognitive-linguistic factors to be lower than for French children. It would therefore be interesting to compare the predictive power of these cognitive and linguistic factors in both groups.

Note that even though correlations between cognitive-linguistic predictors and decoding skills were expected in the present study, this does not mean that all of these measures can be used as a screening at the arrival of the children. In fact, rapid automatized naming and vocabulary depend on the amount of exposure to French. It would not be appropriate to use them at a time close to the arrival of the children. It is therefore important to look at additional predictors that may be less influenced by the amount of exposure to French. We therefore tested the contribution of visual-verbal paired associate learning (PAL) scores to decoding skills. Indeed, it has been shown to be a correlate of decoding skills in various orthographies as English (e.g. Warmington & Hulme, 2012), Danish (e.g. Poulsen & Elbro, 2018), or Chinese (e.g. Georgiou et al., 2017). Moreover, it is easily adaptable for EANA children. First, it does not rely on linguistic knowledge, as it consists of learning the associations between pictures and nonwords. Second, nonwords can be created using universal sounds and syllable structures.

III.4.2. Method

III.4.2.1 Participants

We selected a subsample from the participants included in the TANMALL project. Seventy-two participants were excluded because they did not meet the inclusion criteria, had missing data on the variable of interest or had incorrect pseudonymization codes. The final sample consisted of 129 EANA children and 237 French children (165 monolingual children and 72 bilingual children). The characteristics of French and EANA children are presented in the Table 17. The groups were fairly well matched in terms of duration of attendance at primary school. However, the mean age of the French children (86.47 months) was lower than the mean age of the EANA children (113.37 months). Critically, the average social position indicator of the school they attended (88.78) was lower than for French children (110.19).

Table 17. *Main characteristics of the final sample.*

	French (N=237)			EANA (N=129)		
Variables	***NA***	***mean (sd)***	***min-max***	***NA***	***mean (sd)***	***min-max***
Age (months)	0	86.47(6.26)	77-110	0	113.37(17.56)	76-154
Mean grade	0	1.32(0.47)	1-2	0	3.21(1.33)	1-5
Duration of primary school attendance	0	9.06(3.51)	4.05-25.15	0	9.47(4.65)	4.09-21.45
Social position indicator	0	110.19(18.94)	65-133.6	0	88.78(18.69)	65-124.8
Priority education area	0	1.41(0.80)	1-3	1	1.95(0.89)	1-3
Parental educational level (ISCED)	29	5.52(1.74)	0-8	129	NA	NA

Note. NA = missing data

III.4.2.2 Measures

We used the scores of the following measures: word and nonword reading, nonverbal abilities, phonological awareness, rapid automatized naming, nonword repetition, vocabulary and the naming measure of visual-verbal PAL. We applied the flexible scoring of verbal output for both groups. A detailed description of the tasks can be found in the general method section of the TANMALL project (see the section II.2, p. 63). To simplify the analyses of the contextual factors, we created a composite decoding score that aggregates the word and nonword reading scores (α = .96). To do this, we averaged their Z values.

Information on contextual factors was obtained from questionnaires completed by the families of EANA children with the help of UPE2A teachers. Languages spoken, other than French, were also reported. We asked whether the child had attended school in another country or had started to learn to read in French or in another language (and which one) before arriving in France. We determined the top-level family of languages thanks to the Glottolog website (Hammarström et al., 2023).

To test the effect of the characteristics of the writing systems of the other languages spoken by the children, we created two variables: (1) one focused on the fact that the children were exposed to an alphabetic system or not, and (2) the other focused on the fact that the children were exposed to a Latin system or not. We checked whether the writing systems were alphabetic or Latin thanks to the language descriptions provided by the project 'Langues et Grammaire du Monde dans l'Espace Francophone' (LGMEF, 2019) and on the online encyclopedia 'Wikipedia' ('Wikipédia', 2023). If multiple writing systems were possible for a given language, we automatically coded 'not available' for whether the writing system was Latin or not. Next, we checked whether they were all alphabetic. If so, we considered the writing systems to be 'alphabetic'. If not, we also considered the information as 'not available' (more details are provided in the Appendix III, p. 275).

III.4.2.3 Data analyses

Multiple Regression Analyses

Multiple linear regression analyses were used to model the relationship between the different factors identified and reading achievement. The p-values of the beta coefficients were estimated using a nonparametric bootstrap, which allowed us to dispense with the assumptions of normality and homoscedasticity of the residuals (Fox & Weisberg, 2002). We conducted analyses with 5000 bootstraps.

All dichotomous variables were coded as -0.5 and 0.5 (contextual factors and language group). This allowed us to test the main effects of a given variable in both groups as a whole when that variable is involved in an interaction term. Otherwise, a simple effect for a modality would appear instead of the main effect.

Outliers

Examination of univariate and multivariate outliers was performed following the guidelines of

Aguinis et al. (2013). Univariate outliers were detected to identify and correct errors in the coded data. We used the standard deviation cut-off of 2.24 SD, following the simulations of Berger and Kiefer (2021). We chose not to exclude univariate outliers because they do not necessarily impact the reliability of correlational analyses (for example, a participant may have very low values for both the dependent and predictor variables, which is relevant). We thus chose to detect significant influential points (or 'multivariate outliers') with standardized beta coefficients (DFBETAS) and excluded them. We excluded participants with DFBETAS higher or lower than 3 SD from the mean DFBETAS in each variable (for more details see Appendix IV). Traditionally, outliers are excluded prior to analysis. However, using the DFBETAS procedure implies that regression analyses have already been carried out (because we need the slope estimates). In addition, the outliers detected may differ from one model to another. We have therefore chosen to present the models estimated with and without excluding the outliers and to specify the number of outliers detected.

III.4.3. Results and Intermediate Discussions

We first presented the analyses of the contextual factors in EANA children. We then examined the contribution of the cognitive-linguistic factors in EANA and French children. Finally, we ran a model including both cognitive-linguistic and contextual factors.

III.4.3.1 Contextual Factors

In this section, we focused on the contribution of the contextual factor which may influence decoding skills.

Results

We tested the contribution of several dichotomous contextual predictors of decoding ability in EANA children: having learned to read or been schooled before arrival, having arrived after the first grade, having been exposed to an Indo-European language, having been exposed to a different alphabetic/non-alphabetic or Latin/non-Latin writing system (the number of participants per modality for each variable is provided in the Table 18). Decoding skills were operationalized by the composite reading score.

Table 18. *Number of participants per modality of the contextual factors.*

Variables / Modalities	No	Yes
Schooling prior to arrival	20	109
Reading learning prior to arrival	46	83
Arrival after the first grade	30	99
Exposed to another Indo-European language	69	60
Exposed to another alphabetic orthography	31	98
Exposed to another Latin orthography	80	49

We computed simple correlations between the composite decoding score and the various contextual predictors (see Table 19). All the correlations were rather weak, probably partly because they were calculated on dichotomous variables. Reading scores were correlated with the fact that children had started to learn to read and were in school before arriving in France. It was also correlated with the fact that children were (potentially) exposed to a Latin writing system. Importantly, many of the correlations between contextual factors were significant. It is therefore important to conduct multiple regression analyses to limit confounding and suppression effects.

Table 19. *Simple correlations between contextual factors and reading scores in EANA children.*

Variables	1	2	3	4	5	6	7	8
1. Reading		.05	.00	.28**	.38***	.34***	.13	.01
2. Social position indicator	.05		-.07	.09	.18*	-.11	.23*	.10
3. Duration of primary school attendance	.00	-.07		-.07	-.03	.01	-.05	-.07
4. Schooling prior to arrival	.28**	.09	-.07		.53***	.27**	.10	.11
5. Reading learning prior to arrival	.38***	.18*	-.03	.53***		.32***	.18*	.11
6. Arrival after the first grade	.34***	-.11	.01	.27**	.32***		.00	-.09
7. Exposed to another Indo-European language	.13	.23*	-.05	.10	.18*	.00		.49***
8. Exposed to another alphabetic orthography	.01	.10	-.07	.11	.11	-.09	.49***	
9. Exposed to another Latin orthography	.24**	-.02	-.17*	.20*	.25**	-.10	.20*	.44***

Note. * $p < .05$; ** $p < .01$; *** $p < .001$

We conducted a multiple regression analysis to explain the reading scores by all the contextual factors, controlling for the social position indicator of the schools and the duration of primary school attendance in France. Since the effects of the two variables on the writing systems to which the children were exposed were strongly confounded (children exposed to a Latin system were necessarily exposed to an alphabetic system), we estimated their contribution in two separate models. The variable on exposure to a Latin orthography was included in the first model (Table 20), and the variable on exposure to an alphabetic orthography was included in the second model (Table 21).

Table 20. *Multiple regression analyses: effect of all contextual factors in reading scores (including the variable on the fact that children had been exposed to a Latin orthography).*

	Model with all participants			**Model excluding 10 very influential participants.**		
Independent Variables	***β***	***p***	***ΔR²***	***β***	***p***	***ΔR²***
(Intercept)	-1.26	.016		-1.46	.002	
Social position indicator	0.00	.623	-0.50	0.00	.314	-0.10
Duration of primary school attendance	0.01	.568	-0.44	0.02	.271	0.01
Schooling prior to arrival	0.16	.656	-0.47	0.28	.369	-0.01
Reading learning prior to arrival	0.47	.088	1.81	0.27	.272	0.25
Arrival after the first grade	0.80	.004	6.68	0.97	.000	11.82
Exposed to another Indo-European language	0.09	.651	-0.50	0.23	.190	0.43
Exposed to another Latin orthography	0.50	.008	3.25	0.47	.009	3.62
R² adjusted			20.37			29.04

Table 21. *Multiple regression analyses: effect of all contextual factors in reading scores (including the variable on the fact that children had been exposed to an alphabetic orthography).*

	Model with all participants			**Model excluding 11 very influential participants.**		
Independent Variables	***β***	***p***	***ΔR²***	***β***	***p***	***ΔR²***
(Intercept)	-1.02	.063		-1.40	.003	
Social position indicator	0.00	.960	-0.68	0.00	.398	-0.21
Duration of primary school attendance	0.00	.877	-0.67	0.02	.338	-0.17
Schooling prior to arrival	0.25	.509	-0.22	0.25	.434	-0.12
Reading learning prior to arrival	0.60	.025	3.57	0.59	.013	3.95
Arrival after the first grade	0.65	.015	4.34	0.77	.001	7.65
Exposed to another Indo-European language	0.23	.268	0.10	0.27	.146	0.65
Exposed to another alphabetic orthography	-0.14	.553	-0.46	-0.09	.661	-0.53
R² adjusted			16.66			28.74

First, children who arrived after the first year had higher scores than those who arrived during or before the first year. Second, the fact that children had started learning to read before arriving in France contributed significantly to decoding scores in the second model. Finally, children exposed to a Latin system obtained higher scores than others, while exposure to an alphabetic system made no contribution.

We conducted a final complementary analysis to compare the reading scores of the 31 children who had started to learn to read in a Latin orthography before arriving in France and the 237 French children. One EANA child was excluded because it was an outlier at the cut-off of 2.24 SD. Although the EANA children selected for this analysis had the most favorable characteristics for learning to read in French and were matched with French children in terms of duration of attendance at primary school ($t_{welch}(33.61)=-0.24$, $p=.81$, $d = -0.05$) and nonverbal abilities ($t_{welch}(38.01)=0.90$, $p=.38$, $d = 0.17$) they had lower word ($t_{\mathrm{welch}}(36.09)=-4.18$, $p<.001$, $d = -0.83$) and nonword ($t_{welch}(35.57)=-3.07$, $p=.004$, $d = -0.62$) reading scores than French children.

Discussion

These analyses allowed us to test the contribution of several contextual factors to the decoding skills of EANA children: arrival after first grade, having learned to read or having been schooled before arrival, exposure to an Indo-European language, exposure to an alphabetic/non-alphabetic or Latin/non-Latin writing system.

Firstly, children who arrived after first grade scored higher than those who arrived during or before first grade. This result is quite unexpected, as children who arrived after the first grade did not benefit from explicit instruction to read in French as French children did. Furthermore, it could be expected that learning a new language is more difficult at an older age (Birdsong, 2018; Bylund et al., 2021; Ingvalson et al., 2014; Qureshi, 2016). We hypothesize that older children may have simply more literacy experience. Moreover, they may be more aware of the importance of the school and its consequences for their future lives. They may therefore be more motivated and engaged in learning than younger children. It could also be that older children have better general cognitive skills. Complementary analyses confirmed partially this view showing that the effect of the grade of arrival disappear when nonverbal abilities were controlled in the model controlling for the exposure to an alphabetic orthography (Table 23) but not in the model controlling for the exposure to a Latin orthography (Table 22).

Secondly, we observed that having attended school before arriving in France was a positive correlate of decoding skills. However, this relationship seems to be mainly explained by the fact that the children had started to learn to read before arriving in France since it was not a significant predictor in the multiple regression analyses.

Thirdly, the children who had started learning to read before arriving in France had an advantage over the other children, regardless of the writing system to which the children had been exposed (i.e. alphabetic or not, Latin or not). This result suggests that learning to read involves universal mechanisms that could be transferred to all languages spoken by children (Cummins, 1979; Geva & Ryan, 1993). However, we could argue that exposure to a logographic system would be less crucial than exposure to an alphabetic system (Melby-Lervåg & Lervåg, 2011). Indeed, cross-linguistic transfer between alphabetic languages may be due, at least in part, to the fact that learning in an alphabetic language improves phonemic awareness, which may be beneficial for learning to read in an additional alphabetic system. In contrast, learning to read in a logographic system does not improve phonemic awareness (Cheung et al., 2001; Cheung & Chen, 2004). As a result, it may be more difficult to learn to read in a new alphabetic system if you were previously exposed to a logographic system rather than another alphabetic system.

Table 22. *Multiple regression analyses: effect of all contextual factors in reading scores controlling for nonverbal abilities (including the variable on the fact that children had been exposed to a Latin orthography).*

	Model with all participants			Model excluding 11 very influential participants.		
Independent Variables	***β***	***p***	***ΔR²***	***β***	***p***	***ΔR²***
(Intercept)	-2.02	.000		-2.00	.000	
Nonverbal abilities	0.07	.000	9.61	0.08	.000	13.76
Social position indicator	0.00	.693	-0.49	0.00	.357	-0.09
Duration of primary school attendance	0.00	.841	-0.56	0.01	.563	-0.35
Schooling prior to arrival	0.03	.954	-0.57	-0.07	.775	-0.45
Reading learning prior to arrival	0.34	.183	0.68	0.38	.095	1.27
Arrival after the first grade	0.50	.068	2.06	0.60	.013	3.75
Exposed to another Indo-European language	-0.05	.783	-0.53	0.05	.798	-0.45
Exposed to another Latin orthography	0.43	.015	2.33	0.43	.008	3.01
R^2 adjusted			29.98			46.25

Table 23. *Multiple regression analyses: effect of all contextual factors in reading scores controlling for nonverbal abilities (including the variable on the fact that children had been exposed to an alphabetic orthography).*

	Model with all participants			Model excluding 10 very influential participants.		
Independent Variables	***β***	***p***	***ΔR²***	***β***	***p***	***ΔR²***
(Intercept)	-1.83	.001		-1.70	.001	
Nonverbal IQ	0.07	.000	10.76	0.08	.000	16.55
Social position indicator	0.00	.426	-0.21	-0.01	.105	0.86
Duration of primary school attendance	0.00	.837	-0.57	0.01	.589	-0.41
Schooling prior to arrival	0.10	.737	-0.52	-0.10	.690	-0.45
Reading learning prior to arrival	0.44	.071	1.69	0.62	.006	4.45
Arrival after the first grade	0.35	.206	0.74	0.25	.323	0.26
Exposed to another Indo-European language	0.09	.627	-0.49	0.13	.452	-0.26
Exposed to another alphabetic orthography	-0.18	.455	-0.23	-0.27	.166	0.44
R^2 adjusted			27.41			41.41

Importantly, only three children in our sample were potentially exposed to logographic systems: the Chinese or, to some extent, the Japanese (because Japanese has a logographic and a syllabic writing system). Most of the children who were not exposed to alphabetic systems were instead exposed to quasi-alphabetic systems such as 'abjad' or 'abugida'. In abjad systems, letters are mainly consonants, and it is optional to write vowels, which are mainly represented by diacritical marks. Similarly, in abugida systems, consonants form the basis of letters and are supplemented or modified according to the vowels with which they are associated. However, vowels are not optional (see Figure 14 for examples of Arabic abjad and Ghez abugida letters). Although these writing systems are not alphabetic, they do encode oral language at the phoneme level. Thus, learning to read in these languages may strengthen phonemic awareness (see for example Abou-Elsaad et al., 2016), which is crucial for learning to read in an alphabetic system such as French. This may explain why, in the present analyses, we did not differentiate between children exposed to alphabetic and nonalphabetic writing systems.

Figure 14. *Examples of letters in Arabic abajd and Ghez abugiga.*

Note. Consonant are represented in blue and vowels in red.

It should be noted, however, that children who had been exposed to the Latin writing system before arriving in France had an advantage over other children, provided they had started to read in this system. This may be explained by the fact that they did not have to learn new characters. Moreover, grapheme-phoneme correspondences may be similar between languages, despite some incongruence (e.g. the letter 'e' may be pronounced /ø/ in French, /i/ in English, /e/ in Spanish, and so on).

Finally, the family of languages spoken does not explain any differences between children in reading. This suggests that, overall, children progress equally well in French regardless of their mother tongue. However, it cannot be excluded that the criterion 'Indo-European or not' is too coarse. It would be interesting to explore, in collaboration with linguists, a criterion that better reflects the typological proximity of languages to French and that could contribute to reading scores.

As a complementary analysis, we selected a subsample of EANA children who had started to learn to read in a Latin script before arriving in France and who arrived after the first grade. As seen earlier, these EANA children scored higher than the others. However, they still scored lower than French children on both nonword and word reading tasks. This clearly indicates that other factors related to the EANA experience may have an impact on reading scores. For example, past research suggests that refugees obtained lower literacy achievement than other newcomers (Gagné et al., 2021), probably due to traumatic events in their countries of origin or during migration can lead to serious mental disorders (Fazel et al., 2005). The level of perceived violence (e.g. racist insults) and relational engagement (e.g. trust in adults at school, friendships) can affect children's engagement in learning (Suárez-Orozco et al., 2009). Family resources such as educational level of parents, the number of adults in the household, school mobility has also an impact on academic achievement (Suárez-Orozco et al., 2010).

III.4.3.2 Cognitive-Linguistic Factors

In this section, we investigated the contribution of the cognitive-linguistic factors in EANA and French children.

Results

The Table 24 provided the scores obtained by French and EANA children in all tasks.

Simple correlations were computed between age, social position indicator of schools, duration of primary school attendance, age and all task scores. Almost all variables were correlated in both groups, justifying the need to conduct multiple regression analyses to determine the uniqueness of the contribution of each variable.

Table 24. *Descriptive table on all variables of interest for French and EANA children.*

	French children (237)		EANA children (129)	
Variables (maximum possible score)	**mean (sd)**	**min-max**	**mean (sd)**	**min-max**
Social Position Indicator	110.19(18.94)	65-133.6	88.78(18.69)	65-124.8
Duration of primary school attendance	9.06(3.51)	4.05-25.15	9.47(4.65)	4.09-21.45
Age (months)	86.47(6.26)	77-110	113.37(17.56)	76-154
Word reading (48)	40.65(6.72)	14-48	29.78(11.88)	0-47
Nonword reading (36)	28.04(5.37)	10-36	21.38(8.42)	0-34
Nonverbal abilities (32)	20.76(5.29)	4-32	19.62(6.16)	6-30
Phonological Awareness (34)	26.75(5.58)	4-34	23.7(8.62)	0-34
Rapid Automatized Naming (mean time in seconds)	32.84(7.98)	18.5-79	32.35(10.53)	15.5-82
Nonword repetition (31)	27(3)	14-31	26.6(3.84)	4-31
Vocabulary (50)	31.01(6.34)	13-46	18.42(7.87)	0-35
PAL: Naming (32)	13.41(7.43)	0-31	12.62(7.59)	1-31

We therefore performed multiple regression analyses to explain word and nonword reading scores with the group (French or EANA), school social position indicator, duration of primary school attendance, age, nonverbal abilities, phonological awareness, rapid automatized naming, nonword repetition, vocabulary and visual-verbal PAL (naming) as independent variables. We also tested for interactions between all of these variables and the group. Models for word reading and nonword reading are shown in the Table 26.

With respect to word reading, all scores made a significant unique contribution regardless of the group once the highly influential participants were removed. There were robust interaction effects between group and vocabulary level and PAL naming. After removing the highly influential participants, there were also interaction effects between group and rapid automatized naming, nonword repetition, and nonverbal abilities. When these models were tested in each group separately, it was found that the cognitive-linguistic predictors predicted larger amounts of variance in the EANA (69.65% above the social position indicator, age and duration of attendance at primary school) than in the French children (43.25% above the social position indicator, age and duration of attendance at primary school) in word reading, with the exception of nonword repetition, which predicted a larger amount of variance in the French children (Table 27).

Table 25. *Simple correlations between cognitive-linguistic factors and reading scores in EANA and French children.*

Variables	1	2	3	4	5	6	7	8	9	10	11
1. Word reading		.89***	.08	.06	.36***	.52***	.68***	-.67***	.42***	.38***	.52***
2. Nonword reading	.79***		.01	-.06	.21*	.45***	.60***	-.59***	.40***	.26**	.51***
3. Social position indicator	.16*	.12		-.07	-.13	.23**	.11	.01	.13	.04	.06
4. Duration of primary school attendance	.16*	.08	-.46***		.34***	.04	.02	-.12	.01	.28**	.00
5. Age (months)	.17*	.10	-.42***	.81***		.18*	.28**	-.45***	.26**	.19*	.26**
6. Nonverbal abilities	.36***	.26***	.12	.11	.18**		.41***	-.33***	.32***	.28**	.37***
7. Phonological awareness	.54***	.42***	.19**	-.07	-.02	.39***		-.51***	.51***	.18*	.33***
8. Rapid automatized naming	-.45***	-.46***	.03	-.15*	-.21**	-.22***	-.28***		-.33***	-.21*	-.32***
9. Nonword repetition	.47***	.36***	.06	.04	.06	.17*	.38***	-.31***		.15	.20*
10. Vocabulary	.34***	.20**	.30***	.01	.10	.35***	.31***	-.15*	.22***		.17
11. PAL: Naming	.37***	.29***	-.06	.21**	.25***	.26***	.30***	-.19**	.28***	.26***	

Note. Correlations for EANA children are provided above the diagonal. Correlations for French children are provided under the diagonal. * $p < .05$; ** $p < .01$; *** $p < .001$

With respect to nonword reading scores, phonological awareness, rapid automatized naming, nonword repetition, and PAL contributed to the model independently of the group. There was a robust interaction effect between group and PAL naming. When these models were tested separately in each group, we observed that the cognitive-linguistic predictors accounted for a greater proportion of the variance in nonword reading in the EANA children (62.68% above the social position indicator, age and duration of attendance at primary school) than in the French children (38.53% above the social position indicator, age and duration of attendance at primary school). Besides, the unique contributions of each predictor are broadly similar (or lower in the case of rapid naming) to those observed in the French children. Interestingly, vocabulary level appears to be a significant contributor to nonword reading in EANA children once influential participants were removed from the analyses. Finally, visual-verbal PAL explains a larger proportion of the variance in EANA children (5% compared to less than 1% in French children).

Table 26. *Multiple regression analyses: effect of cognitive-linguistic factors in word and nonword reading scores.*

	Word reading						Nonword reading					
	Model with all participants			Model excluding 38 very influential participants.			Model with all participants			Model excluding 39 very influential participants.		
Independent Variables	***β***	***p***	***ΔR²***	***β***	***p***	***ΔR²***	***β***	***p***	***ΔR²***	***β***	***p***	***ΔR²***
(Intercept)	-0.30	.013		-0.64	.001		0.75	.214		0.64	.155	
Group	0.01	.789	-0.07	0.23	.965	-0.06	1.29	.289	0.03	0.33	.708	-0.09
Social position indicator	0.00	.197	0.11	0.00	.021	0.24	0.00	.764	-0.11	0.00	.317	0.02
Duration of primary school attendance	0.01	.185	0.05	0.01	.22	0.02	0.00	.946	-0.13	0.01	.501	-0.06
Age (months)	0.00	.777	-0.07	0.00	.558	-0.04	-0.01	.264	0.03	-0.01	.060	0.24
Nonverbal abilities	0.09	.015	0.54	0.11	.001	0.91	0.08	.121	0.28	0.05	.185	0.08
Phonological awareness	0.28	<.001	4.71	0.26	<.001	4.11	0.23	<.001	3.15	0.22	<.001	2.92
Rapid automatized naming	-0.26	<.001	4.81	-0.28	<.001	5.20	-0.30	<.001	6.66	-0.33	<.001	7.54
Nonword repetition	0.08	.044	0.39	0.08	.016	0.40	0.09	.025	0.52	0.11	.010	0.79
Vocabulary	0.16	.001	1.04	0.11	.003	0.61	0.06	.267	0.05	0.07	.110	0.19
PAL: Naming	0.16	<.001	1.86	0.17	<.001	2.43	0.19	<.001	2.74	0.22	<.001	3.69
Interaction terms "group *":												
Social position indicator	-0.01	.129	0.16	0.00	.156	0.06	-0.01	.030	0.57	-0.01	.190	0.08
Duration of primary school attendance	-0.05	.018	0.42	-0.05	.003	0.45	-0.05	.078	0.28	-0.03	.239	0.07
Age (months)	0.01	.636	-0.06	0.00	.903	-0.06	0.00	.783	-0.12	0.00	.995	-0.11
Nonverbal abilities	0.10	.198	0.09	0.18	.002	0.56	0.08	.380	0.00	0.07	.391	-0.02
Phonological awareness	0.08	.312	0.03	0.05	.423	-0.01	0.07	.520	-0.06	0.07	.389	-0.03
Rapid automatized naming	-0.16	.082	0.39	-0.20	.002	0.64	-0.07	.577	-0.05	-0.03	.688	-0.09
Nonword repetition	-0.14	.105	0.30	-0.18	.003	0.56	-0.03	.793	-0.11	0.00	.978	-0.11
Vocabulary	0.19	.039	0.33	0.26	.001	0.86	0.16	.143	0.17	0.15	.109	0.21
PAL: Naming	0.16	.022	0.37	0.17	<.001	0.58	0.23	.013	0.84	0.26	<.001	1.24
R² adjusted			71.79			81.91			56.23			67.35

Table 27. *Multiple regression analyses: effect of cognitive-linguistic factors in word reading scores in both groups.*

	French children						EANA children					
	Model with all participants			Model excluding 26 very influential participants.			Model with all participants			Model excluding 16 very influential participants.		
Independent Variables	***β***	***p***	***ΔR²***	***β***	***p***	***ΔR²***	***β***	***p***	***ΔR²***	***β***	***p***	***ΔR²***
(Intercept)	-0.30	.664		-0.91	.082		-0.29	.032		-0.84	.002	
Social position indicator	0.01	.003	1.61	0.01	.001	2.84	0.00	.933	-0.25	0.00	.544	-0.10
Duration of primary school attendance	0.04	.021	1.19	0.03	.02	0.91	-0.01	.342	-0.02	-0.02	.134	0.16
Age (months)	0.00	.716	-0.17	0.01	.415	-0.10	0.00	.82	-0.24	0.00	.255	0.10
Nonverbal abilities	0.04	.279	0.09	0.02	.503	-0.12	0.14	.036	1.07	0.20	<.001	2.43
Phonological awareness	0.24	<.001	5.71	0.21	<.001	6.43	0.32	<.001	6.90	0.29	<.001	5.24
Rapid automatized naming	-0.18	<.001	4.79	-0.15	<.001	4.14	-0.34	<.001	7.50	-0.36	<.001	7.94
Nonword repetition	0.15	.001	3.21	0.16	<.001	5.87	0.01	.915	-0.25	-0.01	.876	-0.17
Vocabulary	0.06	.301	0.10	0.03	.466	-0.08	0.25	.001	2.80	0.22	.001	2.44
PAL: Naming	0.08	.015	1.06	0.07	.003	1.42	0.24	<.001	3.38	0.24	<.001	4.04
R² adjusted			48.81			55.80			69.79			82.29

Table 28. *Multiple regression analyses: effect of cognitive-linguistic factors in nonword reading scores in both groups.*

	French children						EANA children					
	Model with all participants			Model excluding 22 very influential participants.			Model with all participants			Model excluding 18 very influential participants.		
Independent Variables	***β***	***p***	***ΔR²***	***β***	***p***	***ΔR²***	***β***	***p***	***ΔR²***	***β***	***p***	***ΔR²***
(Intercept)	0.11	.956		0.17	.804		1.40	.025		1.09	.039	
Social position indicator	0.00	.075	0.58	0.00	.039	0.89	-0.01	.144	0.48	0.00	.317	-0.07
Duration of primary school attendance	0.02	.268	0.07	0.02	.354	-0.04	-0.02	.164	0.48	-0.02	.237	0.20
Age (months)	-0.01	.661	-0.22	-0.01	.562	-0.19	-0.01	.056	0.96	-0.01	.035	1.13
Nonverbal abilities	0.03	.493	-0.16	0.03	.312	-0.09	0.12	.162	0.54	0.15	.048	1.01
Phonological awareness	0.20	.003	2.98	0.16	.005	2.26	0.26	.002	4.51	0.24	.001	3.23
Rapid automatized naming	-0.27	<.001	9.01	-0.33	<.001	15.60	-0.34	<.001	7.38	-0.31	<.001	5.54
Nonword repetition	0.11	.057	1.10	0.10	.017	1.33	0.08	.243	0.08	0.14	.073	0.78
Vocabulary	-0.02	.782	-0.27	0.03	.543	-0.16	0.14	.099	0.63	0.18	.025	1.58
PAL: Naming	0.08	.051	0.70	0.06	.08	0.41	0.31	.001	5.75	0.32	<.001	6.62
R² adjusted			32.04			43.79			56.38			64.81

Discussion

We compared the contribution of main cognitive-linguistic predictors of decoding skills between EANA and French children.

The first important observation is that cognitive predictors explain a large proportion of the variance in reading in both groups. This suggests that using cognitive-linguistic tests would be effective to identify children at risk of reading failure even though many contextual factors are involved in the reading success of EANA children.

Phonological awareness and rapid automatized naming were the highest contributors to both word and nonword reading skills. Nonword repetition was moderately correlated with both word and nonword reading in both groups, but was a significant unique contributor only in French children. This finding is congruent with the literature in which phonological short-term memory has been shown to be correlated with word reading skills in additional language learners (Abu-Rabia & Siegel, 2002; Chiappe, Siegel, & Gottardo, 2002; Chiappe, Siegel, & Wade-Woolley, 2002; Geva & Farnia, 2012) but not systematically over other cognitive-linguistic factors (Geva et al., 2000; Lesaux & Siegel, 2003). Its contribution may be moderated by phonological awareness scores as they were correlated (Melby-Lervåg, 2012; Melby-Lervåg et al., 2012). Indeed, deletion tasks (syllable or sound deletion) require the participant to retain the nonwords presented in the phonological loop while deleting the targeted syllable or sound. We carried out complementary analyses showing that the contribution of nonword repetition appeared once we had removed the phonological awareness scores from the model.

We used a nonword repetition task because previous research operationalized phonological short-term memory in this way and found a unique contribution to decoding skills in first-grade French readers (Piquard-Kipffer & Sprenger-Charolles, 2013). Furthermore, the current nonword repetition task was well suited for EANA children as it consisted of universal phonemes (dos Santos

& Ferré, 2018). Nevertheless, as it does not contribute uniquely to decoding skills in EANA children, it may be interesting to adapt other phonological short-term memory tasks such as nonword span tasks, nonword matching tasks (for a description of the various paradigms used in the literature see Savage et al., 2007).

Interestingly, vocabulary was a significant contributor of word reading skills in EANA but not in French children. Other studies have found similar interaction between vocabulary skills and linguistic status in explaining reading skills, but the reading outcome was reading comprehension (Limbird et al., 2014; Verhoeven, 2000). We argued previously that vocabulary may be an important contributor of word reading skills through the 'Set for Variability' mechanism (Tunmer & Chapman, 2012a), then why is it not a significant predictor of reading in French? First, French has a rather transparent orthography (Borgwaldt et al., 2005; Schmalz et al., 2015; Seymour et al., 2003) while the studies concluding that vocabulary uniquely contributes to word reading were conducted mainly in English which has an opaque orthography (e.g. Ouellette, 2006; Ouellette & Beers, 2010; Ricketts et al., 2007). As a result, the ‘Set for Variability’ mechanism may support reading accuracy less well in French than in opaque orthographies, or at least may be used less consciously as a strategy to supplement decoding. Secondly, it is possible that the words selected for the reading tasks are sufficiently common for French children that vocabulary level does not explain inter-individual differences in reading. Put differently, the words known by all French children are not necessarily known by all EANA children. Thus, our tasks may have been more sensitive to revealing the relationship between vocabulary and reading in EANA than in French children.

Furthermore, the relationship may be reversed. Reading is a vector for learning vocabulary (D. Duff et al., 2015). However, this may only be true for EANA children with the best phonological recoding skills (nonword reading skills). Complementary analyses, however, showed that the contribution of vocabulary to word reading skills in EANA children did not interact with nonword reading (see Table 29). It is therefore possible that phonological recoding skills or the amount of reading experiences in French are not sufficient to promote vocabulary acquisition. Finally, as suggested in the section III.3, p. 82, it is possible that vocabulary support for word reading also indirectly benefits nonword reading by consolidating knowledge of grapheme-phoneme conversion rules through the 'set for variability' mechanism (Tunmer & Chapman, 2012a) or via the improvement of phonotactic regularities of French knowledge (e.g. J. Edwards et al., 2004; Estes et al., 2016; Munson et al., 2005). This account is supported by our data, as vocabulary was a unique contributor to nonword reading scores, but only after influential participants were removed from the analyses. Thus, contrary to what we had concluded in the section IV.2.2 (p. 19), the low vocabulary level in EANA children may explain, at least partly, differences between EANA children and French children in reading scores.

Table 29. *Multiple regression analyses: examining the contribution of the interaction between nonword reading scores and vocabulary level in word reading scores in EANA children.*

	EANA children					
	Model with all participants			**Model excluding 18 very influential participants.**		
Independent Variables	***β***	***p***	***ΔR²***	***β***	***p***	***ΔR²***
(Intercept)	-1.18	.005		-1.59	<.001	
Social position indicator	0.00	.128	0.18	0.00	.062	0.30
Duration of primary school attendance	0.00	.685	-0.10	0.01	.590	-0.07
Age (months)	0.01	.021	0.56	0.01	<.001	1.68
Nonverbal abilities	0.07	.097	0.19	0.10	.009	0.60
Phonological awareness	0.15	.001	1.32	0.17	<.001	1.97
Rapid automatized naming	-0.13	.012	0.83	-0.20	<.001	1.85
Nonword repetition	-0.04	.343	0.02	-0.07	.144	0.15
Vocabulary	0.17	.001	1.10	0.20	.001	1.75
PAL: Naming	0.04	.388	-0.02	0.03	.518	-0.06
Nonword reading	0.66	<.001	11.61	0.63	<.001	9.99
Nonword reading * Vocabulary	0.02	.556	-0.07	0.05	.143	0.05
R^2 adjusted	87.12			90.25		

Finally, we were interested in the contribution of visual-verbal PAL to word and nonword reading skills. It has been found to be a unique contributor of decoding skills in native children in other orthographies (Litt et al., 2013; Poulsen & Elbro, 2018; Warmington & Hulme, 2012; Windfuhr & Snowling, 2001), but its contribution has never been tested in French. The present study demonstrated that the visual-verbal PAL is a unique contributor to decoding performance in both French and EANA children. It was strongly correlated with word reading in EANA children ($r = .52$, $p < .001$) and add around 5 to 6 % of variance to models explaining respectively word and nonword reading scores, over other predictors. Thus, it can be added to other classical predictors to improve the identification of children at risk of reading failure. Visual-verbal PAL is well suited for EANA children because it does not rely on linguistic knowledge. In fact, it required the learning of nonwords composed of universal phonemes and syllabic structures. As a result, it may not be confounded with linguistic or socioeconomic status. An important implication is that it may be possible to constitute shared norms for both groups. Indeed, additional language learners have been found to perform similarly to monolingual children on word learning tasks, despite the fact that they obtained lower scores on a static assessment of vocabulary (Matrat et al., 2022). This account will be addressed in the following section (III.5, p. 114).

III.4.3.3 A General Model for EANA Children

Finally, we asked what the relative contribution of contextual and cognitive-linguistic predictors might be in word and nonword reading in EANA children.

Results

For simplicity, we used the decoding composite score as the dependent variable instead of both word and nonword reading. We then added the cognitive-linguistic and contextual factors to the model (Table 30). All of the cognitive-linguistic factors explained a significant amount of variance in decoding skills except for nonword repetition scores. Regarding the contextual factors, only the fact that the children had attended school before arriving in France has a effect.

Table 30. *Investigation of the relative contribution of contextual and cognitive-linguistic factors in decoding skills in EANA children.*

	Model with all participants			**Model excluding 17 very influential participants.**		
Independent Variables	***β***	***p***	***ΔR²***	***β***	***p***	***ΔR²***
(Intercept)	0.76	.235		0.99	.043	
Social position indicator	0.00	.377	-0.04	0.00	.304	0.02
Duration of primary school attendance	-0.02	.258	0.07	-0.02	.114	0.35
Age (months)	-0.01	.365	-0.05	-0.01	.081	0.49
Nonverbal abilities	0.12	.137	0.48	0.19	.003	2.02
Phonological awareness	0.31	<.001	6.05	0.33	<.001	5.89
Rapid automatized naming	-0.34	<.001	6.57	-0.42	<.001	8.11
Nonword repetition	0.07	.249	0.09	0.10	.173	0.35
Vocabulary	0.17	.049	1.07	0.17	.022	1.42
PAL: Naming	0.26	<.001	4.03	0.20	<.001	2.48
Schooling prior to arrival	-0.44	.039	0.95	-0.47	.007	1.49
Reading learning prior to arrival	0.15	.429	-0.04	0.07	.616	-0.15
Arrival after the first grade	0.14	.539	-0.16	0.00	.979	-0.21
Exposed to another Indo-European language	0.21	.133	0.33	0.14	.164	0.15
Exposed to another alphabetic orthography	-0.28	.147	0.45	0.00	.939	-0.21
Exposed to another Latin orthography	0.19	.281	0.14	-0.09	.498	-0.10
R^2 adjusted	66.75			80.14		

Discussion

These analyses showed that cognitive-linguistic predictors predict a large amount of variance in decoding skills in EANA children. This may be good news from a practical point of view. This would mean that, even some contextual information is missing for EANA children, the screening may be reliable. On a theoretical point of view, this does not mean that contextual factors had any influence on reading skills. Indeed, the relationship between reading skills and cognitive-linguistic predictors, at least with phonological awareness, is interactive (Cheung et al., 2001; Cheung & Chen, 2004; Morais et al., 1979). Therefore, we posited that our cognitive-linguistic tasks may have captured indirectly the variance of contextual factors we examined. Moreover, as previously mentioned, a larger set of contextual factors may be examined as the reasons for the migration (Gagné et al., 2021) and other social, economic, psychological factors.

Main results

- We examined the relationship between some contextual factors and decoding skills:
  - EANA children who had started to learn to read before arriving in France had higher reading scores than others.
  - Older EANA children scored higher than younger ones, probably because they had more reading experience, more cognitive ability or more motivation than younger children.
  - Children exposed to a Latin orthography before arriving in France scored higher than others.
  - The EANA children with the best decoding scores (the oldest EANA children who had started learning to read in a Latin orthography before arriving in France) nevertheless scored lower than the French children, suggesting that further research is needed to understand the reasons for this discrepancy.
- In addition to contextual factors, cognitive-linguistic measures were highly correlated with decoding skills in EANA children demonstrating their relevance for identifying early EANA children at risk of reading failure.
- The contribution of the visual-verbal PAL to decoding scores in EANA children was promising ($r = .52$, $p < .001$ and unique contribution around 4 to 7 %). It may be a good measure as part of other measures to identify early EANA children at risk for reading failure. Since it does not rely on linguistic knowledge and its items are nonwords with universal phonological properties, it may be possible to create universal norms. This would facilitate the constitution of the reference group if such a screening test was to be developed in the future.

III.5. From Correlational Analyses to Individual Tests and Comparison with a Control Group

III.5.1. Introduction

The fact that cognitive-linguistic factors correlate with the decoding skills of EANA children does not mean that additional language learners can be tested using current standardized tests. In fact, current test norms have mainly been constituted with native French speakers. They are therefore unlikely to be effective with EANA children, especially given their lack of exposure to French and the phonological distance between the two languages. In order to limit these biases, we adopted various solutions for the different cognitive-linguistic predictors tested, such as the use of flexible scoring of verbal productions, the use of items with universal phonemes and the examination of a relatively innovative predictor: visual-verbal learning abilities. We wonder whether, thanks to these adaptations, it would be possible to create universal norms for all the measures used in this study. By 'universal norms', we mean norms that could be independent of the linguistic status (EANA or native French). Universal norms would be of great practical interest in the design of standardized tools. Indeed, it would be possible to base the reference group on a French population that is more accessible than EANA children.

To answer this question, we compared the performance of EANA and French children on all cognitive-linguistic predictors, controlling for age, level of nonverbal intelligence, school social position indicator, and time spent in primary school. Secondly, we also controlled for reading level, since we know that the relationship between the predictors and reading can be interactive, especially with regard to phonological awareness (Cheung et al., 2001; Cheung & Chen, 2004; Morais et al., 1979). If the differences between the groups remain after controlling for reading scores, this would confirm that other factors related to language status explain the difference between the groups and prevent the establishment of universal norms.

Specifically, we hypothesized that we would not observe group differences in nonverbal abilities, which is not language dependent. EANA children might show lower performance in phonological awareness than French children, since their reading performance was lower than that of French children. This difference should disappear once reading ability is taken into account. Then, EANA children should be slower in rapid automatized naming. In fact, although the items are very familiar elements (letters and numbers), it may be more difficult to find and produce these words in French because of competition with their mother tongue or less exposure to these words than French children (Gibson et al., 2012, 2018; Keller et al., 2015; Yan & Nicoladis, 2009). This account suggests that the difference should not have disappeared once reading ability was taken into account. The nonword repetition was designed with universal phonemes and should not depend specifically on French knowledge. Thus, we hypothesized that no difference would be found regardless of the controls included in the comparisons. On the other hand, vocabulary is certainly less developed in EANA children than in French children, regardless of the variables controlled in the comparisons. In fact, we know that the level of vocabulary in a given language is lower among learners of additional languages or bilinguals than among monolingual native speakers at any age, even among children exposed to different languages at an early age (Bialystok et al., 2010; Bialystok & Luk, 2012; Thordardottir, 2011, 2017).

Finally, visual-verbal paired associate learning, or at least its verbal learning component, might be influenced by both reading ability and the level of phonological awareness. On the one hand, the acquisition of reading skills allows the development of orthographic representations that can support the acquisition of new words, even orally. Indeed, we know that orthographic representations are automatically activated when children are exposed to a new spoken word (Wegener et al., 2018) and, on the other hand, that orthographic cues improve verbal learning

(Baron et al., 2018; Colenbrander et al., 2019). In addition, reading acquisition may support the learning of new words by refining phonological representations (de Jong et al., 2000). Consequently, given that EANA children showed lower performance in reading, we hypothesized that they would also show lower performance in visual-verbal PAL, controlling for age. However, this difference may disappear once reading ability is controlled for. In addition, on an exploratory basis, we compared performance controlling for phonological awareness scores. This will provide an indication of the involvement of phonological competence and/or the importance of orthographic representations in learning new words.

III.5.2. Method

This section is based on exactly the same population and measures as the previous one. We examined the role of linguistic status (being EANA or French) thanks to multiple regression analyses to control the duration of primary school attendance, age, social position indicator and nonverbal abilities in all comparisons. The procedure for dealing with outliers was exactly the same as before.

III.5.3. Results

We examined the role of the linguistic status (being EANA or not) in all the cognitive-linguistic predictors, controlling for the social position indicator of the schools, the duration of primary school attendance, the age (months) and the nonverbal abilities. Obviously, nonverbal abilities were not controlled when it was used as a dependent variable. The results are shown in Table 31. It is important to note that this table should not be interpreted like the previous tables about multiple regression analyses. Dependent variables are shown in each row. The effects of the controlled factors are not shown as they are not relevant here. The effects reported are these of the linguistic status for each dependent variable. The results indicated that EANA children scored lower on all cognitive linguistic predictors except nonword repetition. The largest effect size was for vocabulary (ΔR^2 ~ 17 versus 1 to 4 for other variables).

Table 31. *Impact of the linguistic status on the various cognitive-linguistic predictors controlling for the social position indicator of the schools, the duration of primary school attendance, the age (months) and the nonverbal abilities (except for the model on with nonverbal abilities as dependent variable).*

	Impact of the linguistic status in all participants			Impact of the linguistic status excluding very influential participants.			
Dependent variables	β	p	ΔR^2	β	p	ΔR^2	**Excluded**
Nonverbal abilities	-0.39	.050	1.05	-0.32	.066	0.53	20
Phonological awareness	-0.69	.002	3.76	-0.37	.014	1.25	26
Rapid automatized naming	0.66	.002	3.40	0.37	.004	1.50	24
Nonword repetition	-0.44	.039	1.35	-0.21	.141	0.21	19
Vocabulary	-1.32	<.001	14.40	-1.45	<.001	16.60	23
PAL: Naming	-0.48	.004	1.70	-0.65	<.001	3.59	23

Note. This table should not be interpreted like the previous tables about multiple regression analyses. Dependent variables are shown in each row. The effects of the controlled factors are not shown as they are not relevant here.

Because differences between groups may be mediated by reading ability, at least for phonological awareness and visual-verbal PAL, we conducted a second set of comparisons controlling for reading ability (operationalized by the Reading Composite Score). The results are shown in Table 32. All the differences disappeared, except for the difference in vocabulary. The differences in nonverbal abilities remained marginally significant. Regarding visual-verbal PAL, the difference also disappeared after controlling for reading scores. In contrast, the difference remained when phonological awareness scores were controlled for instead of reading scores.

Table 32. *Impact of the linguistic status on the various cognitive-linguistic predictors controlling for the social position indicator of the schools, the duration of primary school attendance, the age (months), the nonverbal abilities (except for the model on with nonverbal abilities as dependent variable) and the reading composite score.*

	Impact of the linguistic status in all participants			Impact of the linguistic status excluding very influential participants.			
Dependent variables	***β***	***p***	***ΔR²***	***β***	***p***	***ΔR²***	**Excluded**
Nonverbal abilities	0.22	.238	0.11	0.30	.075	0.35	23
Phonological awareness	0.06	.763	-0.14	0.05	.691	-0.15	30
Rapid automatized naming	-0.12	.535	-0.09	-0.14	.270	0.01	25
Nonword repetition	0.12	.596	-0.13	0.33	.028	0.73	19
Vocabulary	-1.10	<.001	8.09	-1.16	<.001	8.98	26
PAL: Naming	0.03	.892	-0.22	0.00	.997	-0.21	29
PAL: Naming[a]	-0.34	.045	0.68	-0.46	.002	1.53	22

Note. This table should not be interpreted like the previous tables about multiple regression analyses. Dependent variables are shown in each row. The effects of the controlled factors are not shown as they are not relevant here.
[a] in this model we replaced the reading composite score by the phonological awareness score.

III.5.4. Discussion

This section was designed to explore the possibility of establishing universal norms for each predictor. Overall, we hypothesized that it would be possible to use universal norms if EANA and French children did not differ in their performance on all reading predictors, controlling for age, level of nonverbal intelligence, the social position indicator of the school, and time spent in primary school. This would have significant practical implications, as it is very difficult to sample EANA children. If the norms for native speakers are equivalent to those for EANA children, then it would be easier to create standardized screening tools than to use specific norms for EANA children.

Unfortunately, EANA children were found to score lower on all reading predictors except nonword repetition and nonverbal abilities. As a result, nonword repetition and nonverbal abilities are the only measure for which common norms seemed easy to establish. Ironically, nonverbal abilities are not a specific predictor of reading skills and nonword repetition was the ‘specific reading predictor' that explains the least unique variance in reading among EANA children (see the previous section on cognitive-linguistic factors of reading skills III.4.3.2 , p. 103).

However, all differences disappeared when reading skills were controlled for, with the exception of vocabulary knowledge, as expected. This means that it is possible to establish common norms for EANA and French children on nonverbal abilities, phonological awareness, rapid automatized naming, and visual-verbal PAL for young children who arrived in France before the start of the first grade and who have been exposed to reading instruction in French schools to the same extent as French children. As an approximation, it might also be possible to compare the performance of EANA children who have been exposed to reading instruction in alphabetic, abugida, or abjad[5] scripts with French children of a similar age. Importantly, rapid automatized naming carry on linguistic knowledge. Thus it cannot be used until several months or years of exposure to French (Geva et al., 2000). Examiners may ensure that items are well known by the children before using such a task. Additional research could examine until when EANA children catch up French children at rapid automatized naming, all other things being equal. Moreover, it may be more relevant to present rapid automatized naming tasks using alphanumeric items because it ensures that children were intensively exposed to it after only several months of schooling.

Note that the nonword repetition scores gave us a strange pattern: while no difference was found between groups when controlling for the duration of elementary school attendance, age and nonverbal abilities, we detected a difference when controlling for reading ability. We have no explanation for this.

Finally, standards could be set for different age groups of EANA children who have never started to learn to read. This presupposes a longitudinal study of the development of reading and different correlates of reading in EANA children at different ages of their arrival in France, as has

5 Quasi-alphabetic systems such as 'abjad' or 'abugida' are systems in which consonants form the basis of letters and vowels are represented by diacritics. In abjad, vowels are optional, while in abugida they are always represented.

been done in Canada for migrant children (Gagné et al., 2019, 2021). If we find measures in which EANA children progress at the same rate regardless of the age at which they arrive in France (at least for certain age groups), this will make it possible to establish norms according to the degree of exposure to reading instruction in French, rather than according to grade or age. However, such a procedure means that several months or years may have passed before children with reading difficulties are identified and receive additional help (from a speech therapist, for example).

All situations in between are much more difficult to deal with (e.g. children who have attended school only a few days a week or whose schooling has been interrupted several times). In this case, it may be relevant to used nonverbal abilities and nonword repetition tasks. Note that, even though the former was not thought to be a specific reading predictor or decoding skills and the latter did not present a unique contribution to decoding skills over all other predictors, they presented moderate to strong correlation to decoding skills. Moreover, we conducted a complementary analysis showing that both nonverbal abilities and nonword repetition explained around 33% of variance in decoding skills which are rather promising. The use of oral language assessment with parental questionnaires such as the ALDEQ (Paradis et al., 2010) or the PABIQ (Tuller, 2015) could also be informative step in identifying children with limited oral language skills in their first languages (Abutbul-Oz & Armon-Lotem, 2022) even though it provides only an indirect and limited insight into future reading achievement.

Main results

- EANA children scored lower on all reading predictors (phonological awareness, rapid automatized naming, vocabulary , with the exception of nonword repetition and nonverbal abilities).
- All differences disappeared when reading skills were controlled for, except for vocabulary knowledge, as expected.
- Thus, common norms can be established for French and EANA children for nonverbal abilities and nonword repetition.
- Common norms can be established for other tests (except for vocabulary) provided that both groups have benefited from the same amount of reading instruction and that EANA children have learned to read in alphabetic or abjad or abugida scripts.

III.6. Conclusion of the First Axis

The aim of this experimental part was to pave the way for future work on the development of tools for the early identification of children at risk of reading failure. Identifying EANA children at risk of reading failure is important so that they can be offered targeted and intensive interventions. This could take the form of easier access to speech therapists for individualized treatment.

First, we wondered if it would be possible to make the scoring of EANA children's verbal production more flexible by allowing certain vowel substitutions (see the section III.2, p. 71). We warned that the abilities targeted by the various tests of verbal production might be underestimated because of errors related to the phonological distance between the child's first languages and French. We suggested that these errors should be ignored in order to get an idea of the abilities specifically targeted by the tests, either in the reading scores or in the results for the various cognitive and linguistic predictors. The method we used corrected proportionally more errors in the EANA than in the French-speaking children, suggesting that it made it possible to target errors specific to the EANA in the phonological awareness, nonword repetition, visual-verbal PAL and reading tasks. Moreover, it did not seem to alter the sensitivity of the measures, and the scores of the French-speaking children varied very little after the application of this scoring. This suggests that it may be possible to apply such a scoring method to existing standardized tests without altering the comparison with the norm. It should be noted that there are other problems with comparing the performance of EANA children with monolingual norms, which will be discussed below.

We then wondered whether there were any differences between EANA children and other children in terms of decoding. Indeed, the literature suggests that second language learners perform similarly to other children in terms of decoding skills (Melby-Lervåg & Lervåg, 2014), but we underlined that the populations tested were different from EANA children (see III.3, p. 19). We had hypothesized that the word reading scores of EANA children would be lower than those of French children because they have less vocabulary to draw on to correct grapheme-phoneme conversion errors. On the other hand, we expected them to have similar levels of nonword reading. However, our expectations were contradicted by the data, which suggest that EANA children have more difficulty reading both words and nonwords than French-speaking children, even after applying a flexible phonological error scoring system. Moreover EANA children scores presented a large heterogeneity.

To account for the gap between EANA and French children decoding scores and heterogeneity in EANA scores, we examined a set of contextual factors (see the section III.4.3.2 , p. 96). Around 15% of the EANA children in our sample had not attended school and 37% had not started learning to read before arriving in France. Children who had been to school, and especially those who had already started to learn to read, especially in the Latin alphabet, performed better in reading than other children. Indeed, the skills acquired in the first language can support the development of skills in the additional language, especially when the characteristics of the languages are similar (S. C. Chung et al., 2019; Melby-Lervåg & Lervåg, 2011). Surprisingly, children who arrived early (before or during first grade) also score slightly lower than older children. We hypothesized that this might be related to the fact that older children have more motivation, cognitive resources or simply because they have had more literacy experiences. We have pointed out that many other contextual factors can influence school results, such as the reason for migration, family resources, relational commitment, etc. (Fazel et al., 2005; Gagné et al., 2021; Suárez-Orozco et al., 2009, 2010).

Then, we wondered if cognitive-linguistic scores may predict decoding skills in EANA as well as in French children. We examined the 'classic' cognitive-linguistic reading predictors: phonological awareness, rapid automatized naming, phonological short-term memory and vocabulary level (e.g. Araújo et al., 2015; Bus & van IJzendoorn, 1999; Ricketts et al., 2007; Swanson et al., 2009). We have also examined visual-verbal PAL skills because it as found to uniquely contribute to decoding skills in past studies (e.g. Warmington & Hulme, 2012) and it was expected to be not biased by linguistic knowledge or typological distance between first languages and French. We found that all of these predictors predicted reading success in both French and EANA children, with the exception of phonological memory, which was operationalized by a nonword repetition task with universal properties. We suggested that future work should examine other phonological short-term memory tasks to see if they might contribute more significantly to the predictive models in EANA. Then, we observed that vocabulary contributes to both word and nonword reading skills in EANA children, which may partly explain why they scored lower than French children on both word and nonword reading tasks. Interestingly, visual-verbal PAL was a significant and substantial unique predictor over other reading predictors in EANA children which suggest that it could be used in combination with other measures to predict future reading achievement, at least in EANA children.

Finally, we wondered how these correlational results could be translated into an approach for early identification of reading difficulties (see III.5, p. 114). The main difficulty lies in establishing standards that would allow EANA children to be compared with a sufficiently reliable control group (Hogan et al., 2017). We have seen that it is possible to establish universal norms for nonverbal abilities and nonword repetition, at least when applying flexible scoring for verbal production. It also seems possible to establish universal norms (or to compare EANA children with children of the same age or of a similar school level) for phonological awareness, rapid automatized naming and visual-verbal PAL, provided that the EANA children have received the same amount of reading instruction in French (for example, if they arrived before the start of first grade) or in a language with an alphabetic writing system, abjad or abugida. For children for whom the amount reading instruction was not comparable to that of French children or for whom instruction was carried out in a logographic system, our results suggest that only the assessment of nonverbal abilities and nonword repetition can be used with universal norms. It can be complemented by the use of parental questionnaires, which can help identify linguistic difficulties in the first language (Abutbul-Oz & Armon-Lotem, 2022). Finally, for children who have never started learning to read and who arrived after the Grade 1, standards should be set that take into account the length of time EANA children have been in school in France, rather than their age or grade level, even if this means that children with learning difficulties will be identified once the difficulties have appeared, rather than at an early stage.

There are several avenues open to us for future work:

- Following EANA children longitudinally from their arrival in France.
- Testing a wider range of contextual factors thanks to questionnaires or semi-structured interview with families.
- Administering measures of the following cognitive-linguistic predictors with universal properties as soon as they arrive: non-verbal IQ, phonological awareness, phonological short-term memory (choosing complementary measures to nonword repetition), visual-verbal PAL, and determine whether they predict future reading success.
- Examining if common norms for EANA and French can indeed be established for these predictors, provided that EANA children arrived before the first grade or, if they are older, providing that they had learned to read in an alphabetic or related system.
- Attempting to establish norms for reading tasks and predictors by duration of French learning for children who arrived during or after the first grade and has never started learning to read.

We might also consider creating a universal nonword reading task on the same principles as the tasks used in our work, i.e. using universal phonemes and syllabic structures. This would simplify nonwords considerably. These measures could therefore take the form of fluency tasks that retain variance even when reading accuracy reaches a ceiling. There is no need to meet EANA children to validate the principle of such tasks. It might be interesting to test French children with a task of this nature and a standardized reading test, and see whether performance correlates - and hopefully strongly.

In this section, we provided promising results regarding the contribution of visual-verbal PAL to reading scores and argued that it was a task well suited to additional language assessment. However, the mechanisms by which visual-verbal PAL contributes to reading skills remained unclear. The second section of the experimental part aimed to fill this gap.

IV. Second Axis: Examining the Role of Visual-Verbal Paired Associate Learning in Word reading Skills in Primary Schooled Children

IV.1. Introduction

Although the visual-verbal PAL task is a promising tool for screening children at risk for reading difficulties, there is still some way to go before we fully understand the reasons for its relationship with decoding ability. In the theoretical section, we have seen that a large number of hypotheses can be formulated and tested (see the section V.4, p.42).

First, we emphasized that paired learning tasks are complex tasks involving multiple mechanisms: general and cross-modal associative learning, verbal learning, verbal output. Each step can explain the relationship between reading and visual-verbal PAL. Second, we underlined that verbal processes may be either a causal predictor of reading performance or vice versa. Third, we hypothesized that the contribution of visual-verbal PAL may be confounded with other reading predictors (letter knowledge, phonological awareness, rapid automatized naming, phonological short-term memory, and vocabulary).

In this experimental part, we presented a systematic review aimed at making the state of the available evidence for each of these hypotheses. We then presented some data obtained in the course of the TANMALL project to investigate the relationship between cross-modal associative learning, verbal learning and verbal output to word and nonword reading in beginning French readers. Finally, a third study was conducted to reproduce the results of the previous study and to investigate in more detail the role of verbal learning in the reading of simple words (regular words without contextual graphemes) and complex words (regular words with contextual graphemes and irregular words).

IV.2. A Critical Review of The Role of Cross-modal Paired Associate Learning in Reading Acquisition in Alphabetic Scripts

This section has been submitted to Scientific Studies of Reading and is still under review (Bignon et al., under review).

IV.2.1. Introduction

This section aimed at presenting a systematic review designed to examine the evidence supporting each proposed mechanism explaining the relationship between cross-modal PAL and word-level reading skills (such as word and nonword reading accuracy or fluency, orthographic learning, orthographic knowledge) in children from kindergarten to primary school, learning to read in alphabetic scripts. We focused on the potential mechanisms mentioned earlier including the associative learning process, the cross-modal learning process and the verbal account (which included verbal learning processes, verbal output processes, and the bidirectional relation between reading and the verbal processes) as well as the relation between cross-modal PAL and other reading predictors (for more details, see the section V.4, p.42). We followed Preferred Reporting Items for Systematic reviews and Meta-Analyses guidelines (PRISMA; Page et al., 2021).

IV.2.2. Method

IV.2.2.1 Study Search and Selection

We conducted a systematic review following the PRISMA guidelines (Page et al., 2021), which include a checklist of 27 items and a flow diagram. The literature search was performed using Scopus, Web of Science and PsycINFO. Our study focused on peer-reviewed articles published in English until 2023. The keywords we chose were linked to three main topics: cross-modal PAL, reading development and childhood. They were articulated with logical operators (see Table 33).

We applied additional filters within the databases to narrow down the results to the psychological and educational fields.

Table 33. *Keywords and Logical Operators Used*

<table>
<tr><th colspan="3">Cross-modal PAL</th><th></th><th>Reading Development</th><th></th><th>Childhood</th></tr>
<tr><td colspan="3">‘paired associate learning’</td><td rowspan="7">AND</td><td>read*</td><td rowspan="7">AND</td><td>preschool</td></tr>
<tr><td colspan="3">OR</td><td>OR</td><td>OR</td></tr>
<tr><td>‘cross-modal’</td><td rowspan="5">AND</td><td>binding</td><td rowspan="5">orthography*</td><td>school</td></tr>
<tr><td>OR</td><td>OR</td><td>OR</td></tr>
<tr><td>audiovisual</td><td>association</td><td>child*</td></tr>
<tr><td>OR</td><td>OR</td><td>OR</td></tr>
<tr><td>visual AND (verbal OR auditory)</td><td>integration</td><td>kindergarten</td></tr>
</table>

A total of 1,939 published records were screened following a standardized search process. Thirty-four articles published between 1972 and 2021 were included in the present systematic review (see Figure 15).

Studies providing comparisons between good and poor readers encompassed a wide variety of poor reading profiles (from undiagnosed poor readers to reliably diagnosed dyslexic children). For the sake of simplicity, the phrases ‘good reader’ and ‘poor reader’ are used here in all cases.

IV.2.2.2 Data Extraction

A systematic data extraction procedure was used to determine the main characteristics of each of the 34 articles. Considering the variability of the cross-modal PAL used in the literature, the characteristics of the task were reported (such as general procedure, nature of stimuli and responses, number of pairs and of test blocks) in the Supplementary Material A. Various categories of information were then collected:

(1) sample characteristics: number of participants, age, school level, language in which the assessments were administered for all studies with an additional focus on the following exclusion criteria for studies comparing poor and good readers: sensory impairment (SI), speech or oral

language impairment (S/OLI), neurological impairment (NI) or intellectual disabilities (ID), and groups matched on IQ or nonverbal abilities.

(2) consistency level of the writing system according to the authors (rather transparent or opaque).

(3) nature of the reading measures collected, i.e., word or nonword reading accuracy, fluency or speed, orthographic knowledge or learning.

(4) nature of the PAL tasks, including the stimuli and responses involved.

(5) type of statistical analyses and summary of the main results.

IV.2.2.3 Transparency and Openness

All extracted data are available in Table 35. This study was not preregistered. A detailed description of the cross-modal PAL tasks is available in the Table 34.

Figure 15. *Flow Diagram*

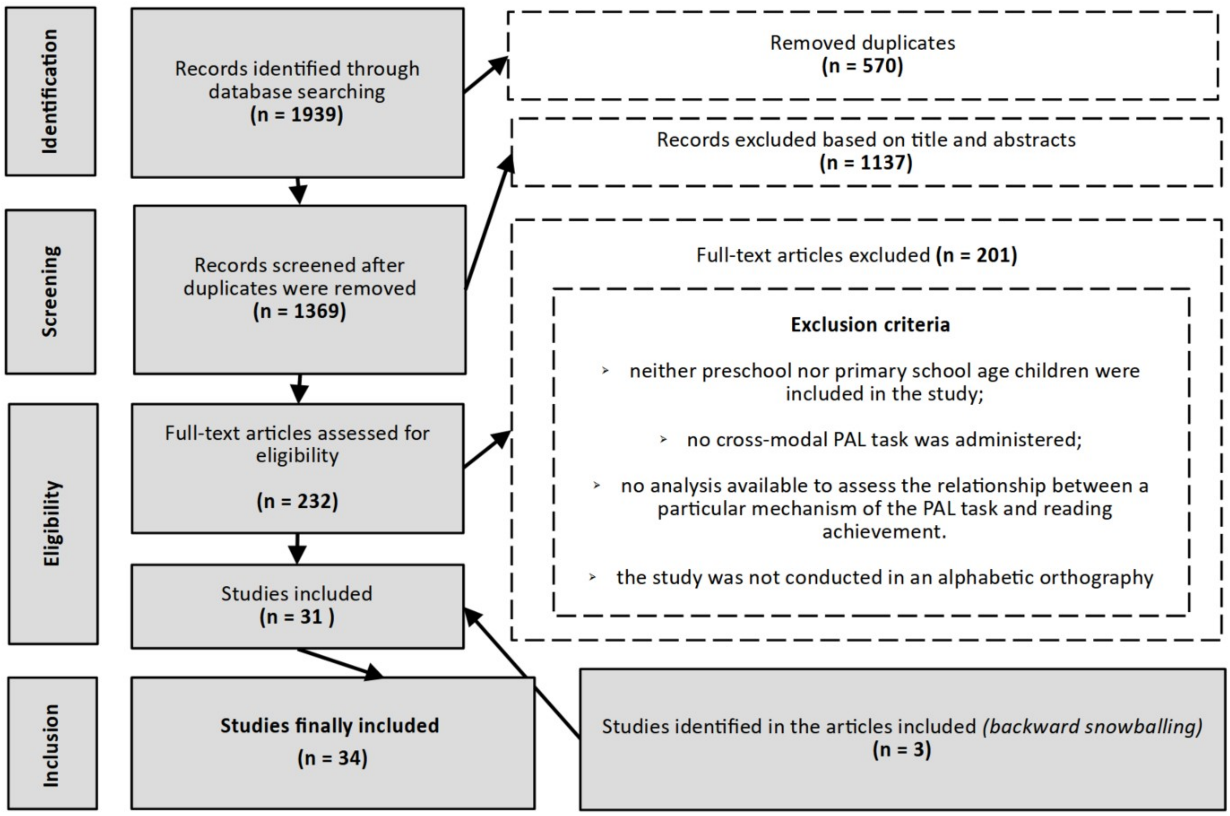


Table 34. *PAL Tasks Characteristics.*

First Author, Year[a]	Verbal stimuli	Visual stimuli	Number of pairs	Test of learning	Number of test blocks	Reinforcement type[b]	Criterion	Scoring procedure[c]	Comment
Aguiar & Brady, 1991	nonwords	Imaginary animals or objects	3	Naming	10	2	Two consecutive successes for all items	B	Two identical PAL tasks with two sets of different pairs. In each task, a presentation block was followed by naming blocks. A recognition phase with a designation task was completed after the naming blocks. The six pictures were displayed and the six nonwords were pronounced one by one. The child designated the right picture every time.
Bartholomeus & Doehring, 1972	Nonsense CVC syllables	Nonsense shapes	4	Judgment of associations	6	2	22 successful trials out of 24 in one series or seven series completed	I	Four learning series with 28 trials. The four associations to be learnt were presented on the first four trials of each series. The 24 further trials consisted of a judgement task with immediate corrective feedback. (12 correct pairings and 12 incorrect pairings) The four series presented the same pairs. The criterion was met when the participant completed 22 trials out of 24 in one series. If the criterion was not met after the four series were presented, the first three series were repeated until the criterion was met or until the seventh series was presented.
B. W.-Y. Chow, 2014	Nonsense syllables	Novel symbols	6	Designation	3	NA	None	I	A presentation block followed by test blocks.
Clayton et al., 2018	Phonemes	Symbols	4	Naming	6	1	None	I	
	nonwords	Symbols	4	Naming	6	1	None	I	
	nonverbal sound	Symbols	4	Naming	6	1	None	I	
Elbro & Jensen, 2005	Names	Faces	5	Naming	15	NA	Two consecutive successes for all items	B	A presentation block followed by test blocks.

First Author, Year[a]	Verbal stimuli	Visual stimuli	Number of pairs	Test of learning	Number of test blocks	Reinforcement type[b]	Criterion	Scoring procedure[c]	Comment
	Pseudonames	Faces	4	Naming	15	NA	Two consecutive successes for all items	B	A presentation block followed by test blocks.
N. C. Ellis & Large, 1987	Nonsense names	Nonsense shapes	NA	Naming	NA	NA	NA	NA	A presentation block followed by test blocks.
	Nonsense names	Nonsense shapes	NA	Designation	NA	NA	NA	NA	A presentation block followed by test blocks.
N. Ellis & Large, 1988	Nonsense names	Nonsense shapes	NA	Naming	NA	NA	NA	NA	A presentation block followed by test blocks.
	Nonsense names	Nonsense shapes	NA	Designation	NA	NA	NA	NA	A presentation block followed by test blocks.
Hulme et al., 2007 (1)	Nonsense CVC syllables	Abstract shapes	4	Naming	6	1 and 2	None	I	
Hulme et al., 2007 (2)	Nonsense CVC syllables	Abstract shapes	5	Naming	5	1 and 2	None	I	
Huschka et al., 2021	Nonsense CV syllables	Common figures	3	Naming	Learning phase : 10 Retrieval phase : 7	2	Retrieval phase : stop if seven consecutive errors	I	The learning phase consisted of naming each presented figure 10 times in random order with corrective feedback. The retrieval phase consisted of naming each figure four times in random order without corrective feedback. The total score was the average of the Z-scores from the learning phase and the recovery phase.

First Author, Year[a]	Verbal stimuli	Visual stimuli	Number of pairs	Test of learning	Number of test blocks	Reinforcement type[b]	Criterion	Scoring procedure[c]	Comment
Kalashnikova & Burnham, 2016	Nonsense CVC syllables	Pictures of novel objects	4	Naming	NA	2	Two consecutive successes for all items	B	Four phases: introduction, learning, comprehension and production. Introduction phase: participants were presented the pairs twice and repeated the nonwords in the second presentation. Learning phase: the children named the pictures. Corrective feedback was provided. This phase stopped when the child named all the pictures in two consecutive trials without help. The comprehension phase was composed of two blocks of trials: one was a reinforcement block. Each picture learnt was presented once with a common object. The nonwords learnt were pronounced and the child selected the right object. The second block consisted of four retention trials (one for each pair) and only the test objects were matched. The production phase consisted of presenting each picture twice and asking the children to name them.
	nonwords CCVCV	Unfamiliar letters	3	Naming	10	2	Two consecutive successes for all items	I	A presentation block followed by test blocks.
Lervåg et al., 2009	nonwords CCVCV	Photos of children	3	Naming	10	2	Two consecutive successes for all items	I	A presentation block followed by test blocks.
	nonwords CCVCV	Pictures of fantasy animal	3	Naming	10	2	Two consecutive successes for all items	I	A presentation block followed by test blocks.
Litt et al., 2013	Legal CVC syllables	Abstract symbols from extinct languages	6	Naming	5	2	None	I	Two presentation blocks followed by test blocks.

First Author, Year[a]	Verbal stimuli	Visual stimuli	Number of pairs	Test of learning	Number of test blocks	Reinforcement type[b]	Criterion	Scoring procedure[c]	Comment
Litt & Nation, 2014 (1)	Legal CVC syllables	Abstract symbols from extinct languages	6	Designation	5	2	None	I	Two presentation blocks followed by test blocks.
	Legal CVC syllables	Abstract symbols from extinct languages	6	Naming	5	2	None	I	Two presentation blocks followed by test blocks.
	Legal CVC syllables	Abstract symbols from extinct languages	6	Designation	5	2	None	I	Two presentation blocks followed by test blocks.
Litt & Nation, 2014 (2)	Legal CVC syllables	Abstract symbols from extinct languages	4	Naming	5	2	None	I	Two presentation blocks followed by test blocks.
	Legal CVC syllables	Abstract symbols from extinct languages	5	Designation	5	2	None	I	Two presentation blocks followed by test blocks.
Litt & Nation, 2014 (3)	Legal CVC syllables	Abstract symbols from extinct languages	5	Naming	5	2	None	I	Day 1: nonwords preexposure. Day 2: PAL: two presentation blocks followed by test blocks.
Litt et al., 2019	Confoundable nonwords	Abstract symbols from extinct languages	NC	Designation Naming	NC	2	Two consecutive successes for all items out of three trials	I/B	Exposure phase: presentation of the four pairs. Learning phase: it consisted of a designation task. The participants were shown the four symbols and had to select the right one according to the nonwords heard. The learning phase stopped when children identified the right symbols in two

First Author, Year[a]	Verbal stimuli	Visual stimuli	Number of pairs	Test of learning	Number of test blocks	Reinforcement type[b]	Criterion	Scoring procedure[c]	Comment
	Non-confoundable nonwords	Abstract symbols from extinct languages	NC	Designation Naming	NC	2	Two consecutive successes for all items out of three trials	I/B	consecutive trials. Corrective feedback was provided. Reinforcement phase: two block trials following the same procedure as the exposure phase. Test blocks: the same procedure as the learning phase but no feedback was provided. Two blocks and in each block, the four pairs were tested. Naming blocks: two blocks in which the participants had to name each symbol without corrective feedback. The participants then completed five additional naming blocks in which corrective feedback was provided. These trials stopped when each symbol was correctly named in two consecutive blocks.
Malone et al., 2019	Nonsense CVC syllables	Abstract symbols from extinct languages	4	Naming	5	2	None	I	Two presentation blocks before test blocks.
	Nonsense CVC syllables	Abstract symbols from extinct languages	4	Designation	5	2	None	I	Two presentation blocks before test blocks.
Mayringer & Wimmer, 2000 (1)	Multisyllabic pseudowords	Drawings representing children	3	Naming	7	2	Two consecutive successes for all items	I	A presentation block followed by test blocks.
	Multisyllabic real names	Drawings representing children	3	Naming	7	2	Two consecutive successes for all items	I	A presentation block followed by test blocks.
	Multisyllabic pseudowords	Drawings representing children	3	Naming	7	2	Two consecutive successes for all items	I	A presentation block followed by test blocks. In the test blocks, the examiner pronounced the first syllable of the target to provide a retrieval cue.

First Author, Year[a]	Verbal stimuli	Visual stimuli	Number of pairs	Test of learning	Number of test blocks	Reinforcement type[b]	Criterion	Scoring procedure[c]	Comment
Messbauer & de Jong, 2003	Two syllables familiar real names	Drawings representing children	3	Naming	7	2	Two consecutive successes for all items	I	A presentation block followed by test blocks.
	High frequency names	Animal pictures	4	Naming	6	2	None	I	A presentation block followed by one test block. Then, pairs were presented another time, followed by five test blocks.
	Pseudonames	Animal pictures	4	Naming	6	2	None	I	A presentation block followed by one test block. Then, pairs were presented another time, followed by five test blocks.
Mourgues et al., 2016	Spanish words	Picture representing the Spanish words	cf. comment	Designation	cf. comment	1 and 2	None	I	Eight blocks of trials were completed. Each of the first four blocks introduced four images and name associations to be learnt. In the first block, only four pictures were shown, then eight in block 2, 12 in block 3 and finally 16 in block 4. The last four blocks contained all 16 pairs to be learnt. Each block began by a presentation of the pairs by the examiner, followed by a designation phase in which children had to designate the picture corresponding to the name pronounced.
	Letter sounds	Braille letters	cf. comment	Designation	cf. comment	2	None	I	Six blocks: the first three presented Finnish sounds and Braille letters pairs, the last three presented Arabic sounds and Braille letters. Each block consisted of designation trials. The children had to choose the right letter among three when the target sound was presented. One pair was targeted per block. If the child gave the correct answer three consecutive times, then the following block began with a new pair to be learnt. Corrective feedback was provided in each trial.
Nilsen & Bourassa, 2008	Nonsense words	Black-and-white designs	4	Naming	10	2	None	I	Two presentation blocks before test blocks.
Poulsen et al., 2017	Nonsense syllables	Cartoons of non-familiar animals	3	Naming	15	2	Three consecutive successes for all items	I	cf. Nonword PAL task in Nielsen (2016)

First Author, Year[a]	Verbal stimuli	Visual stimuli	Number of pairs	Test of learning	Number of test blocks	Reinforcement type[b]	Criterion	Scoring procedure[c]	Comment
Poulsen & Elbro, 2018	Nonsense syllables	Cartoons of non-familiar animals	3	Naming	15	2	Three consecutive successes for all items	I	cf. Nonword PAL task in Nielsen (2016)
Ramaa et al., 1993	Real letter names in Kannada	Kannada-like symbols	NA	Naming	NA	NA	NA	NA	New symbols associated with sounds (number of pairs not given). In the first task, pairs were learnt and then letterlike shapes were combined into words of two to four letters. Children had to give the sound of each letterlike shape. In the second task, letterlike shapes were presented separately. After a learning phase, the children had to name each letterlike shape.
Rudel et al., 1976	Braille letter names	Braille letters	6	Naming	3	1 and 2	None	I	/
Samuels, 1973	Vowels	Colors	5	Naming	10	NA	NA	I	A presentation block followed by the test blocks.
	Real CVC words	Abstract figures	4	Naming	20	NA	Three consecutive successes for all items	I	A presentation block followed by the test blocks.
Singleton et al., 2000	CVC nonwords	Letter-like shapes	4	Designation	1	NR	None	NA	One trial consisted of a presentation block followed by a test block. Several trials were proposed. In each one, the pairs were different. In the first trials, only two pairs were presented and in the latter trials, four pairs were presented.
Toffalini et al., 2019	nonwords	Nonsense shapes	1 à 6	Naming	cf. comment	NR	cf. comment	The highest number of pairs learnt in one trial.	Two tasks with different mapping directions (verbal-visual or visual-verbal). These tasks were span tasks. Presentation phases and test phases were reiterated with an incremental number of pairs to be learnt (pairs were different across trials). Testing phases were either designation tasks or naming tasks depending on whether the mapping direction condition was verbal-visual or visual-verbal.
	nonwords	Nonsense shapes	1 à 6	Designation	cf. comment	NR	cf. comment	The highest number of pairs learnt in one trial.	

First Author, Year[a]	Verbal stimuli	Visual stimuli	Number of pairs	Test of learning	Number of test blocks	Reinforcement type[b]	Criterion	Scoring procedure[c]	Comment
Torgesen & Murphey, 1979	Real words without concrete referent	Letterlike shapes	6	Naming	6	2	Two consecutive successes for all items	I	Familiarization with verbal responses. Then, one presentation block of the pairs followed by testing trials.
	CVC nonsense syllables	Letterlike shapes	4	Naming	9	2	Two consecutive successes for all items	I	Familiarization with verbal responses. Then, one presentation block of the pairs followed by testing trials.
	nonverbal mouth sounds	Letter-like shapes	6	Naming	6	2	Two consecutive successes for all ite6ms	I	Familiarization with verbal responses. Then, one presentation block of the pairs followed by testing trials.
Vellutino, Harding, et al., 1975	Bisyllabic nonwords	Geometric nonsense shapes	4	Naming	15	1	Two consecutive successes for all items	I	Two presentation blocks before test blocks.
Vellutino, Steger, et al., 1975	Nonsense syllables	Imaginary animal pictures	4	Naming	10	2	Two consecutive successes for all items	I	One presentation block followed by test blocks.
		Trigrams with unfamiliar symbols	4	Naming	10	2	Two consecutive successes for all items	I	One presentation block followed by test blocks.
	nonverbal oral responses	Nonsense shapes	4	Naming	10	2	Two consecutive successes for all items	I	One presentation block followed by test blocks.
Vellutino et al., 1995 (2)	Real known words	Chinese ideograms	7	Naming	10	2	Three consecutive successes for all items	I	The participants learnt the words to be paired before the PAL task. Then, one presentation block followed by test blocks.

First Author, Year[a]	Verbal stimuli	Visual stimuli	Number of pairs	Test of learning	Number of test blocks	Reinforcement type[b]	Criterion	Scoring procedure[c]	Comment
Vellutino et al., 1995 (3)	Concrete known words	Words recoded in a novel alphabet	6	Naming	8	2	None	I	Two presentation blocks before test blocks.
	Abstract known words		6	Naming	8	2	None	I	Two presentation blocks before test blocks.
Wang et al., 2017	Nonsense CVC syllables	Eight-point black shapes	4	Naming	5	2	None	I	Pre-exposure to nonwords, then two presentation blocks followed by five test blocks.
Warmington & Hulme, 2012	CVC nonsense syllables	Pictures of novel objects	8	Naming	10	1 and 2	Two consecutive successes for all items	I	
Wass et al., 2019	CVC nonsenses syllables	Eight-point black shapes	4	Naming	5	2	None	I	Two presentation blocks before test blocks.
Windfuhr & Snowling, 2001	nonwords	Abstract visual shapes	4	Naming	20	2	None	I	One presentation block followed by test blocks.

[a] Sometimes an article reports on several experiments. We have referred to them by quoting the article in the usual way and adding in brackets the number of the experiment we were interested in. e.g. in Hulme et al., 2007, two experiments are reported. We referred to them as follows: Hulme et al., 2007 (1); Hulme et al., 2007 (2).

[b] 1 = presentation of the pairs before each block; 2 = corrective feedback for each trial; NA = information not available; NR = not relevant.

[c] I = number of items passed (or equivalent); B = number of block repetitions necessary to achieve criterion; NA = information not available

Table 35. *Characteristics and Main Results of the Studies Included*

Author, year[a]	D	Participants N, A, G, L1, exclusion criteria and control of nonverbal abilities (when relevant)	PAL tasks	Main results
Aguiar & Brady, 1991	C	N = 56 MA (SD) = 9.8 (0.1) G = 4 L1 = English (O) Two groups were created: the more skilled readers (N = 12, A = 9.8 (0.3), G = 4th) and the less skilled readers (N = 12, A = 9.8 (0.3), G = 4th) Exclusion criteria: S/OLI; ID	visual-verbal verbal-visual	**Correlational type**: NA; N = 56 visual-verbal-NWR: -.31 visual-verbal-WR: -.36 Recognition phase (verbal-visual skills): verbal-visual PAL-NWR: .27 verbal-visual PAL-WR: .36 **Two ANCOVA:** N = 12 per group (1) **Aim:** to explain the number of blocks of trials needed to achieve the criterion in visual-verbal PAL by group status, controlling for IQ. **Results:** more trials needed for less skilled readers. (2) **Aim:** to explain verbal-visual PAL scores by group status and controlling for IQ. **Results:** no significant differences between groups.
Bartholomeus & Doehring, 1972	C	N = 96 MA (min_max) = NA (7.3_7.6) G = 2 L1 = English (O) 4 task inter-participant conditions, in which 12 good readers and 12 excellent readers were compared. Exclusion criteria: SI No control of nonverbal abilities.	auditory V-visual V auditory V-visual NV auditory NV-visual V auditory NV-visual NV V = verbal NV = nonverbal	**ANOVA** **Aim:** to explain PAL scores by group status, PAL task, order of presentation of the stimuli. **Results:** main effect of group (excellent readers made fewer errors than good readers), no interaction between group and type of task.
Chow, 2014	C	N = 121 MA (SD) = 7 (NA) G = 2 L1 = Cantonese (O) L2 = English (O)	verbal-visual semantic-visual	**Two multiple regression analyses:** (1) **Aim:** to explain variance in Chinese WR by nonverbal abilities, Chinese PA, Chinese PSTM, semantic-visual PAL and verbal-visual PAL. **Results:** verbal-visual PAL did not contribute significantly but semantic-visual PAL, PA and PSTM did (respective beta coefficient: .11 (ns), .27, .25, .19) (2) **Aim:** to explain variance in English WR by nonverbal abilities, English PA, English PM, semantic-visual PAL and verbal-visual PAL. **Results:** PA and verbal-visual PAL contributed significantly (respective beta coefficients: .31, .20)

Author, year[a]	D	Participants N, A, G, L1, exclusion criteria and control of nonverbal abilities (when relevant)	PAL tasks	Main results
Clayton et al., 2018	C	N = 97 MA (SD) = 9.17 (0.92) G = 3 to 4 L1 = English (O)	phoneme–phoneme visual–phoneme auditory nonverbal–auditory nonverbal visual–auditory nonverbal nonword–nonword visual–nonword	**Synthesis of the simple correlations between PAL tasks and reading measures:** (verbal = phoneme or nonword) verbal-verbal PAL > visual-verbal PAL nonword-nonword PAL > nonverbal-nonverbal PAL Visual-nonverbal PAL was not correlated with reading measures. ***but*** phoneme-phoneme < nonverbal-nonverbal PAL
Elbro & Jensen, 2005	C	N = dyslexics: 19; controls: 19 MA (SD) = dyslexics: 12.08 (0.67); controls: 8.60 (0.42) G (min_max) = dyslexics: 4_5; controls: 2 L1 = Danish (O) Exclusion criteria: S/OLI No control of nonverbal abilities.	visual-nonname visual-name	Comparison between dyslexic readers and controls on PAL achievement using Mann-Whitney U-test: Dyslexic reader necessitate more block trials than controls to learn visual- nonname pairs. No difference between groups on the visual-name PAL task.
Ellis & Large, 1987	L	N = 40 MA (SD) = T1: 4.93; T2: 5.93; T3: 6.93 (0.2) G = T1: G1; T2: G2; T3: G3 L1 = English (O) Three groups of 5 children based on IQ and reading achievement at 8 years old: group A (high IQ, poor reader), group B (high IQ, good reader), group C (low IQ, poor reader) Exclusion criteria: SI; ID	visual-verbal verbal-visual	**ANOVA:** **Aim:** scores (stanine on each of the 44 tasks administered) explained by group status (A, B, C), year of assessment (T1, T2, T3) and task (x44) **Results:** no differences between groups on both PAL tasks

Author, year[a]	D	Participants N, A, G, L1, exclusion criteria and control of nonverbal abilities (when relevant)	PAL tasks	Main results
Ellis & Large, 1988	L	N = 40 MA (SD) = T1: 4.93; T2: 5.93; T3: 6.93 (0.2) G = T1: G1; T2: G2; T3: G3 L1 = English (O)	visual-verbal verbal-visual	**Correlational type: NA** visual-verbal PAL (at 5 years old) – WR (at 6 years old): NA (ns) **visual-verbal PAL (at 6 years old) – WR (at 7 years old): .48** verbal-visual PAL (at 5 years old) – WR (at 6 years old): NA (ns) **verbal-visual PAL (at 6 years old) – WR (at 7 years old): .57** Correlations remaining significant after controlling for IQ are in bold.
Hulme et al., 2007 (1)	C	N = 66 MA (SD) = 9.83 (1.11) G = NA L1 = English (O)	visual-verbal verbal-verbal visual-visual	Visual-visual PAL is less strongly correlated with reading performance than verbal-verbal PAL or visual-verbal PAL. **Three multiple regression models tested:** (1) **Aim:** to explain variance in WR by PA, visual-visual PAL, verbal-verbal PAL and visual-verbal PAL. **Results:** PA and visual-verbal PAL contributed significantly to WR (respective beta coefficients: .62 and .18) (2) **Aim:** to explain variance in irregular WR by PA, visual-visual PAL, verbal-verbal PAL and visual-verbal PAL. **Results:** PA and visual-verbal PAL contributed significantly to WR (respective beta coefficients: .42 and .23) (3) **Aim:** to explain variance in NWR by PA, visual-visual PAL, verbal-verbal PAL and visual-verbal PAL. **Results:** only PA contributed significantly to NWR (beta coefficients: .77)

Author, year[a]	D	Participants N, A, G, L1, exclusion criteria and control of nonverbal abilities (when relevant)	PAL tasks	Main results
Hulme et al., 2007 (2)	C	N = 127 MA (SD) = 8.92 (0.54) G = NA L1 = English (O)	visual-verbal verbal-verbal visual-visual	Visual-visual PAL is less strongly correlated with reading performance than verbal-verbal PAL or visual-verbal PAL. **Three multiple regression models tested:** (1) **Aim:** to explain variance in WR by PA, visual-visual PAL, verbal-verbal PAL and visual-verbal PAL. **Results:** PA and visual-verbal PAL contributed significantly to WR (respective beta coefficients: .61 and .21) (2) **Aim:** to explain variance in irregular WR by PA, visual-visual PAL, verbal-verbal PAL and visual-verbal PAL. **Results:** PA and visual-verbal PAL contributed significantly to WR (respective beta coefficients: .46 and .25) (3) **Aim:** to explain variance in NWR by PA, visual-visual PAL, verbal-verbal PAL and visual-verbal PAL. **Results:** only PA contributed significantly to NWR (beta coefficients: .71)
Huschka et al., 2021	L	N = 208 MA (SD) = T1: 5.60 (0.31); T2: 7.41 (0.30) G = T1: K; T2: G1 L1 = German (T)		
Kalashnikova & Burnham, 2016	C	N = controls: 15; poor readers: 15 MA (SD) = controls: 8.72 (1.53); poor readers: 8.7 (1.56) G = NA L1 = English (O) Exclusion criteria: None nonverbal abilities significantly higher in control group.	visual-verbal verbal-visual (retention trial after visual-verbal training)	**ANOVA** (1) **Aim:** to explain the number of trials needed to achieve the criterion on visual-verbal PAL task by group status. **Results:** poor readers needed more trials to achieve criteria. (2) **Aim:** to explain scores at the verbal-visual measure by group status and type of task (not relevant in this review) **Results:** main effect of task but not of group. /!\ ceiling effect!

Author, year[a]	D	Participants N, A, G, L1, exclusion criteria and control of nonverbal abilities (when relevant)	PAL tasks	Main results
Lervåg et al., 2009	L	N = T1: 228; T4: 197 MA (SD) = T1: 6.33 (0.28) G = T1: 1st term of G1; T2: 1st term of G2; T3: 3rd term of G2; T4: 1st term of G3 L1 = Norwegian (T) /!\ same sample as in: Lervag, 2010.	visual-verbal PAL	Structural Equation Modeling: Aim: to explain a reading latent variable (aggregating orthographic knowledge, text reading, NWR and single word decoding tasks scores obtained at T2) by predictors latent variables obtained at T1 as LK, PA, visual-verbal PAL, RAN, PSTM, verbal and nonverbal abilities. Results: only LK, PA and RAN contributed significantly to reading. Other latent variable regressions: Aim: to explain variance in each reading construct at T3 (OK, TR, NWR and single word decoding) by the same predictors as previously measured at T2. In these models, PAL never was a significant contributor. The same procedure was adopted to explain variance in reading at T4 by predictors measured at T2 and the same results were obtained.
Litt et al., 2013	C	N = 64 MA (SD) = 9.58 (0.78) G = NA L1 = English (O)	visual-verbal verbal-verbal visual-visual verbal-visual	Visual-visual PAL and verbal-visual was not correlated with WR, NWRF, WRF while visual-verbal was. Verbal-verbal PAL was correlated with WR and NWRF but not significantly to WRF (de spite a substantial trend). **Several regression analyses:** **Aim:** to explain variance in WR, WRF and NWRF by PA, RAN and visual-verbal PAL or verbal-visual PAL or verbal-verbal PAL or visual-visual PAL. **Results:** visual-verbal PAL contributes significantly to WR but not WRF or NWRF. The same pattern was observed for verbal-verbal PAL while neither visual-visual PAL nor verbal-visual PAL contributed to reading. **Structural Equation Modeling:** **Aim:** to explain variance in WR, WRF and NWRF by a latent variable for PA and for RAN, a latent variable for PAL verbal-output (taking scores at verbal-verbal PAL and visual-verbal PAL tasks) and visual-verbal PAL. **Results:** PA and RAN explain unique variance in WR, WRF and NWRF while the PAL verbal output explained variance only in WR. No additional variance was explained by visual-verbal PAL.
Litt & Nation, 2014 (1)	C	N = dyslexics: 18; controls: 18 MA (SD) = dyslexics: 10.14 (1.07); controls: 10.01 (0.87) G = NA L1 = English (O) Exclusion criteria: ID Groups matched on nonverbal abilities.	visual-verbal verbal-verbal visual-visual verbal-visual	**Logistic regression mixed effect:** **Aim:** to explain PAL achievement (by item) by modality of tasks (unimodal or cross-modal), necessity of an output (either visual or verbal), group status (dyslexics or controls), test block **Results:** main effect of ‘output’, group status and block. Two-way interaction between group and output. Test of simple main effect indicated that dyslexics had more difficulties than controls when verbal output was needed in the task but not with a visual output.

Author, year[a]	D	Participants N, A, G, L1, exclusion criteria and control of nonverbal abilities (when relevant)	PAL tasks	Main results
Litt & Nation, 2014 (2)	C	N = dyslexics: 18; controls: 18 MA (SD) = dyslexics: 10.13 (1.34); controls: 10.57 (1.00) G = NA L1 = English (O) Exclusion criteria: ID Groups matched on IQ.	visual-verbal verbal-verbal visual-visual verbal-visual	**Logistic regression mixed effect:** **Aim:** to explain PAL achievement (by item) by modality of tasks (unimodal or cross-modal), necessity of an output (visual or verbal), group status (dyslexics or controls), test blocks. **Results:** main effect of 'output' and blocks. Interaction between groups and blocks (groups differed on the last blocks), interaction between group and output (groups differed in verbal output condition but not in visual output). No interaction between groups and modalities.
Litt & Nation, 2014 (3)	C	N = dyslexics: 14; controls: 14 MA (SD) = dyslexics: 10.61 (0.62); controls: 10.30 (0.30) G = 4_5 L1 = English (O) Exclusion criteria: ID Groups matched on IQ.	verbal pre-exposure visual-verbal PAL verbal-visual (recognition task after visual – verbal training)	**Logistic regression mixed effect:** (1) **Aim:** to explain scores at verbal learning by group and block. **Results:** main effect of group and block but no interaction. (2) **Aim:** to explain scores at visual-verbal PAL by group and block. **Results:** main effects of group and block but no interaction. (3) **Aim:** to explain PAL scores by group, block and verbal learning. **Results:** item-specific relationship between verbal learning and PAL, no effect of group. (4) **Aim:** to explain recognition scores by group. **Results:** no significant differences between groups despite a tiny trend (dyslexics: M = 2.79/5, SD = 0.42; controls: M = 3.29/5, SD = 0.37)
Litt et al., 2019	C	N = poor readers: 14; controls: 14 MA (min_max) = poor readers: 10.4 (1.10); controls: 9.67 (0.78) G= NA L1 = English (O) Exclusion criteria: ID	verbal-visual visual-verbal (on the same pairs as verbal-visual PAL) Tasks administered twice: once with confusable nonwords, once with non-confusable nonwords	**Generalized linear mixed models:** (1) **Aim:** to explain verbal-visual scores by group (poor readers, controls) and condition (confusable/non-confusable). **Results:** main effect of condition (lower scores in the confusable condition) but not of group. No interaction between groups and conditions. (2) **Aim:** to explain visual-verbal scores by group (poor readers, controls), condition (confusable/non-confusable) and block. **Results:** main effect of condition, group and block. Interaction between condition and block. No other interaction. Poor reader obtained lower scores in both conditions.

Author, year[a]	D	Participants N, A, G, L1, exclusion criteria and control of nonverbal abilities (when relevant)	PAL tasks	Main results
Malone et al., 2019	C	N = 166 MA (SD) = 5.89 (0.61) Gmin_max = K3_G1 L1 = English (O)	visual-verbal verbal-visual magnitude-verbal magnitude-visual	**Correlational type: NA (control for age)** visual-verbal PAL-WRF: .43 verbal-visual PAL-WRF: .20 **Path model** **Aim:** to explain variance in WRF with PA, LK, RAN, visual-verbal PAL, verbal-visual PAL, magnitude-verbal, magnitude-visual (other predictors were included but were irrelevant for our purpose). **Results:** PA, LK, RAN, visual-verbal PAL and magnitude-verbal PAL contributed significantly to WRF (respective beta coefficients: .25, .15, .19, .10), not verbal-visual PAL.
Mayringer & Wimmer, 2000 (1)	C	N = dyslexics: 20; age controls: 20 MA = 9 G = G3 L1 = German (T) Exclusion criteria: ID Groups matched on nonverbal abilities.	visual-verbal with real names visual-verbal with non-names	**ANOVA** **Aim:** to explain PAL scores by group (dyslexics, controls) and task (names, non-names). It is unclear whether the ANOVA analyses were conducted separated or uniquely for the various conditions. Result: main effects of task and group. Dyslexics had much more difficulty than good readers. No interaction between task and group reported.
Messbauer & de Jong, 2003	C	N = dyslexics: 21; age controls: 21; reading controls: 21 MA (min_max) = dyslexics: 10.04 (0.59); age controls: 10.02 (0.44); reading controls: 7.85 (0.51) G = NA L1 = Dutch (T) Exclusion criteria: S/OLI; NI Dyslexics and age controls matched on nonverbal abilities but not the reading control group.	visual-visual visual-verbal with words visual-verbal with nonwords	**MANOVA** **Aim:** to explain PAL scores by reading group (dyslexics, reading controls, age controls) and type of learning (words, nonwords, symbols) **Results:** dyslexics obtained similar scores as age controls on visual-visual PAL. Dyslexics performed less well on both visual-verbal PAL tasks, but no interaction between groups and verbal PAL tasks was significant.

Author, year[a]	D	Participants N, A, G, L1, exclusion criteria and control of nonverbal abilities (when relevant)	PAL tasks	Main results
Mourgues et al., 2016	C	N = 110 MA (SD) = 13.08 (2.25) Gmin_max = 3_7 L1 = Chitonga (T)	verbal-visual x2	**Two multiple regression models:** (1) **Aim:** to explain WR by PA, RAN, PSTM, verbal-visual PAL (Spanish words), verbal-visual PAL (braille letters). **Results:** PA and verbal-visual PAL tasks were significant contributors (respective beta coefficients: .59, .18, .15) (2) **Aim:** to explain NWR by PA, RAN, PSTM, verbal-visual PAL (Spanish words), verbal-visual PAL (braille letters). **Results:** PA, PSTM and verbal-visual PAL (braille letters) were significant contributors (respective beta coefficients: .45, -.16, .17). **Two mediation analyses:** (1) **Aim:** to explain WR by PA, RAN, PSTM with verbal-visual PAL (Spanish words) and verbal-visual PAL (braille letters) as mediators. **Results:** direct effect of PA on WR, effect of PA on both PAL tasks, direct effect or both PAL tasks on WR. verbal-visual PAL (Spanish words) partially mediate the relation between PA and WR. (2) **Aim:** to explain NWR by PA, RAN, PSTM with verbal-visual PAL (Spanish words) and verbal-visual PAL (braille letters) as mediators. **Results:** direct effect of PA, PSTM and verbal-visual PAL (braille letters) on NWR. No mediation effect.
Nilsen & Bourassa, 2008	C	N = 46 MA (SD) = 6.32 (0.58) Gmin_max = K_G1 L1 = English (O)	visual-verbal PAL	Two multiple regression analyses: Aim: to explain variance in regular and irregular word learning by age, PA and visual-verbal PAL. Results: PA explained 6% of variance in regular word learning and visual-verbal PAL accounted for 14.4%. Only visual-verbal PAL contributed to irregular word learning and explained 25% of the variance.

Author, year[a]	D	Participants N, A, G, L1, exclusion criteria and control of nonverbal abilities (when relevant)	PAL tasks	Main results
Poulsen et al., 2017	L	N = 164 MA = T1: 6.10 G = T1: 3rd term of G0; T2: 2nd term of G1; T3: 3rd term of G2 L1 = Danish (O) Two groups were created: students who performed among the 15% lowest scores on WR(G2) (N = 24), students who performed among the 15% lowest scores in WRF (G2) (N = 24). /!\ same sample as in: Nielsen, 2016; Poulsen, 2018.	visual-verbal PAL	Four logistic regressions: 1) Aim: to predict the accuracy reading group at G2 by RAN, LK, PA, WR, visual-verbal PAL measured at G0. Results: only RAN and visual-verbal PAL were significant predictors. 2) Aim: to predict the accuracy reading group at G2 by RAN, LK, PA, visual-verbal PAL measured at G0 and WRF (G1). Results: only WRF was a significant predictor. 3) Aim: to predict the fluency reading group at G2 by RAN, LK, PA, WR, visual-verbal PAL measured at G0. Results: only RAN was a significant predictor. 4) Aim: to predict the fluency reading group at G2 by RAN, LK, PA, visual-verbal PAL measured at G0 and WRF (G1). Results: only WRF was a significant predictor.
Poulsen & Elbro, 2018	L	N = 137 MA (SD) = 6.83 à G0 (0.33) G = T1: 3rd term of G0; T2: 1st term of G1; T3: G5 L1 = Danish (O) /!\ same sample as in: Nielsen, 2016; Poulsen, 2017.	visual-verbal PAL	Four multiple regression analyses: (1) Aim: to explain WR (G1) by LK, PA, RAN and visual-verbal PAL measured at G0. Results: all predictors contributed significantly to the following respective beta coefficient: .26, .49, .11 and .14. visual-verbal PAL explained 2% of additional variance beyond the 61% of variance explained by the other predictors. (2) Aim: to explain WR (G5) by LK, PA, RAN and visual-verbal PAL measured at G0 and controlling for WR (G1). Results: WR (G1), RAN and visual-verbal PAL contributed significantly (respective beta coefficient: .30, .21, .29). Only decoding skills and visual-verbal PAL explained a significant percentage of variance (respective R^2: 20%, 6%) (3) Aim: to explain WR speed (G5) by LK, PA, RAN and visual-verbal PAL measured at G0 and controlling for WR (G1). Results: only RAN contributed significantly (beta coefficient: .27). Percentage of variance explained by PA, LK and RAN together: 6%. (4) Aim: to explain WR fluency (G5) by LK, PA, RAN and visual-verbal PAL measured at G0 and controlling for WR (G1). Results: RAN and visual-verbal PAL contributed significantly (respective beta coefficient: .42, .26). WR (G1) explained 11% of variance, PA, LK and RAN together explained 14% and visual-verbal PAL explained 6%.

Author, year[a]	D	Participants N, A, G, L1, exclusion criteria and control of nonverbal abilities (when relevant)	PAL tasks	Main results
Ramaa et al., 1993	C	N = dyslexics: 14; poor readers: 14; controls: 14 MA = dyslexics: 9.4; poor readers: 9.2; controls: 9.40 G = dyslexics: 3.43; poor readers: 3.29; controls: 3.14 L1 = Kannada (T) Exclusion criteria: ID Groups matched on nonverbal abilities.	visual-verbal (x2) visual-visual (equivalent, only one test session per pair)	**ANOVA** **Aim:** to explain each PAL scores by the groups. **Results:** no differences between groups on the visual-visual PAL, poor readers and normal readers obtained similar scores on visual-verbal PAL but dyslexics obtained lower scores than both of the other groups.
Rudel et al., 1976	C	N = dyslexics: 20; controls: 20 MA (SD) = dyslexics: 10.92 (1.17); controls: NA G = NA L1 = English (O) Exclusion criteria: None No control of nonverbal abilities.	tactual (Braille)-verbal visual (Braille)-verbal auditory (Morse)-verbal	Z-test to compare dyslexics' scores to those obtained by normal readers. Dyslexics obtained significantly lower scores on all three PAL tasks. No trend indicates that an interaction with the type of task exists, although this hypothesis was not tested.
Samuels, 1973	C	N = poor readers: 17; good readers: 39 MA = NA G = G2 L1 = English (O) Exclusion criteria: None	color-phonemes (easy), letterlike shapes-real word (complex, learning of CVC responses before doing the PAL task)	t-test to compare poor readers' scores to those of good readers. Poor readers obtained lower scores than good readers only on the complex PAL task, even after controlling for IQ.
Singleton et al., 2000	L	N = 421 MA (SD) = 5.94 (0.25) G = NA L1 = English (O)	visual-visual verbal-visual	The correlation between visual-visual PAL and reading performance was equivalent to that between verbal-visual PAL and reading performance. **Multiple regression analysis:** **Aim:** to explain WR (T2) by visual sequential memory for spatial and temporal positions, for colors, symbols, visual-visual PAL, verbal-visual PAL, PSTM, PA and phonological discrimination. **Results:** only PA was a significant contributor.

Author, year[a]	D	Participants N, A, G, L1, exclusion criteria and control of nonverbal abilities (when relevant)	PAL tasks	Main results
Toffalini et al., 2019	C	N = reading disabled children: 30; typical readers: 30 MA (SD) = reading disabled children: 11.22 (1.35); typical readers: 30 G (min_max) = 5.43 (4_7) L1 = Italian (T) Exclusion criteria: ID No control of nonverbal abilities.	visual-verbal binding span verbal-visual binding span	**Mixed-effects linear models:** **Aim:** to explain binding span scores by group, type of binding (visual-verbal or verbal-visual) and digit span, Corsi span, nonword span and shape span as covariates. **Results:** main effect of group and binding type. No interaction between variables. The nonword span also had a significant effect.
Torgesen & Murphey, 1979	C	N = poor readers: 19; good readers: 19 MA (SD) = poor readers: 9.33 (0.35); good readers: 9.25 (0.46) G = 4 L1 = English (O) Exclusion criteria: ID Groups matched on IQ.	letterlike shapes-words letterlike shapes-CVC nonwords letterlike shapes-nonverbal mouth sounds letterlike shapes – nonverbal mouth sounds-physical motion	**ANOVA** **Aim:** to explain PAL scores by group (poor readers, good readers) and type of task. **Results:** main effect of group and task. Significant interaction between both variables: differences between groups only for tasks requiring a verbal answer.
Vellutino, Harding, et al., 1975	C	MA (SD) = controls, visual-visual condition: 10.89 (0.88); controls, visual-verbal condition: 10.89 (0.67); poor readers visual-visual condition: 11.04 (1.13); poor readers, visual-verbal condition: 11.38 (0.98) In each of the four conditions: N = 30 G (SD) = 5.00 (1.00) L1 = English (O) Exclusion criteria: S/OLI Groups matched on nonverbal abilities.	visual-verbal visual-visual	**ANOVA** (1) **Aim:** to explain visual – visual scores by group **Results:** no effect of group (2) **Aim:** to explain visual-verbal PAL scores by group **Results:** main effect of group (3) **Aim:** to explain visual-verbal PAL scores by group using verbal IQ as covariate **Results:** main effect of group.

Author, year[a]	D	Participants N, A, G, L1, exclusion criteria and control of nonverbal abilities (when relevant)	PAL tasks	Main results
Vellutino, Steger, et al., 1975	C	N = 30 MA (SD) = controls, visual-auditory condition: 10.8 (0.95); controls, visual-verbal condition: 10.9 (0.83); poor readers visual-auditory condition: 11.3 (1.1); poor reader, visual-verbal condition: 11.5 (1.1) In each of the four conditions: G (SD) = 5.00 (1.00) L1 = English (O) Exclusion criteria: ID No direct evaluation of nonverbal abilities. Good and poor readers paired on nonverbal abilities, age and grade.	cartoon-verbal symbols-verbal visual-auditory nonverbal	**ANOVA** **Aim:** model specification unclear. **Results:** poor readers performed as well as normal readers in the nonverbal task. However, they obtained lower scores than good readers on visual-verbal PAL tasks.
Vellutino et al., 1995 (2)	C	Four groups: good and poor readers in G2 and G6. N = 15 in each group. MA = NA L1 = English (O) Exclusion criteria: SI; NI; ID Good and poor readers paired on nonverbal abilities.	visual-known words visual-unknown words	**ANOVA** **Aim:** to explain PAL scores PAL by group (poor or good readers), grade (2 or 6) and task. **Results:** main effect of grade, group, and task. Interaction between group and type of tasks. Poor readers obtained much lower scores on the task involving unknown words than on that involving known words.
Vellutino et al., 1995 (3)	C	Four groups: good and poor readers in G2 or 3 and G6 or 7. N = 14 in each group. MA = NA L1 = English (O) Exclusion criteria: SI; NI; ID Good and poor readers paired on nonverbal abilities.	visual-concrete words visual-abstract words	**ANOVA** **Aim:** to explain PAL scores by group (poor or good readers), grade (2 or 6) and task. **Results:** main effect of group, task and grade. No significant interaction between task and group.

Author, year[a]	D	Participants N, A, G, L1, exclusion criteria and control of nonverbal abilities (when relevant)	PAL tasks	Main results
Wang et al., 2017	C	N = 75 MA (min_max) = 9.42 (8.5_10.25) Gmin_max = 3_4 L1 = English (O)	visual-visual verbal-verbal visual-verbal	Visual-visual PAL was not correlated OK while visual-verbal and verbal-verbal PAL were.
Warmington & Hulme, 2012	C	N = 79 MA (min_max) = 9.83 (7.67_11.83) G = NA L1 = English (O)	visual-verbal PAL	**Four path analyses:** (1) Aim: to explain a WR composite score (WR and WRF) by PA, RAN, visual-verbal PAL and IQ. Results: RAN, visual-verbal PAL and IQ contributed significantly (respective beta coefficients: .49, .30, .20). (2) Aim: to explain a NWR composite score (NWR and NWRF) by PA, RAN, visual-verbal PAL and IQ. Results: PA, RAN, visual-verbal PAL were significant contributors (respective beta coefficients: .33, .38, .27). (3) Aim: to explain a reading accuracy composite score (WR and NWR) by PA, RAN, visual-verbal PAL and IQ. Results: RAN, visual-verbal PAL and IQ were significant contributors (respective beta coefficients: .41, .31, .23). (4) Aim: to explain a reading speed composite score (WRF and NWRF) by PA, RAN, visual-verbal PAL and IQ. Results: RAN and visual-verbal PAL were significant contributors (respective beta coefficients: .65, .30).
Wass et al., 2019	C	N = typically hearing: 35, hearing-disabled: 18 MA (SD) = typically hearing: 9.42 (0.29); hearing-disabled: 9.33 (0.34) G = NA L1 = English (O) Exclusion criteria: SI; S/OLI; ID No control of nonverbal abilities.	visual-visual verbal-verbal visual-verbal	visual-verbal PAL – NWR (composite score aggregating NWR and NWRF): .47 visual-verbal PAL-WR: .30 (ns) visual-verbal PAL-WRF: .32 (ns) visual-verbal PAL – OK: .22 (ns) visual-verbal PAL – OL (recognition): .41 visual-visual PAL – NWR (composite score aggregating NWR and NWRF): .28 (ns) visual-visual PAL-WR: .29 (ns) visual-visual PAL-WRF: .28 (ns) visual-visual PAL – OK: .35 visual-visual PAL – OL (recognition): .09 (ns) verbal-verbal PAL – NWR (composite score aggregating NWR and NWRF): .48 verbal-verbal PAL-WR: .50 verbal-verbal PAL-WRF: .43 verbal-verbal PAL – OK: .42 verbal-verbal PAL – OL (recognition): .41

Author, year[a]	D	Participants N, A, G, L1, exclusion criteria and control of nonverbal abilities (when relevant)	PAL tasks	Main results
Windfuhr & Snowling, 2001	C	N = 75 MA (min_max) = NA (7.08_11.92) G = NA L1 = English (O)	visual-verbal PAL	Three multiple regression analyses: (1) Aim: to explain WR by age, NVIQ, vocabulary, PA, PSTM, visual-verbal PAL. Results: visual-verbal PAL contributed significantly over the other predictors and accounted for 3% of additional variance in the model. (2) Aim: to explain NWR by age, NVIQ, vocabulary, PA, PSTM, visual-verbal PAL. Results: visual-verbal PAL contributed significantly over the other predictors and accounted for 2% of additional variance in the model. (3) Aim: to explain WR by NWR, PA and visual-verbal PAL. Results: visual-verbal PAL accounted for 8% of additional variance in the model.

Note. A = Age; C = Concurrent; D = Design; G = Grade; L = Longitudinal; L1 = Language in which the tests were administered; LK = Letter Knowledge; ID = intellectual disabilities; N = sample size; NI = neurological impairment; NWR = nonword Reading; NWRF = nonword Reading Fluency; O = Opaque orthography; OK = Orthographic Knowledge; OL = Orthographic Learning; PA = Phonological Awareness; PSTM = Phonological Short-Term Memory; SI = sensory impairment; S/OLI = speech or oral language impairment; T = Transparent Orthography; WR = Word Reading; WRF = Word Reading Fluency.

[a] Sometimes an article reports on several experiments. We have referred to them by quoting the article in the usual way and adding in brackets the number of the experiment we were interested in. e.g. in Hulme et al., 2007, two experiments are reported. We referred to them as follows: Hulme et al., 2007 (1); Hulme et al., 2007 (2).

IV.2.3. Results and Discussions

In the following sections, we present the evidence supporting each account for the relationship between cross-modal PAL and reading. We first focus on the hypotheses related to the processes involved in the tasks, including associative learning, cross-modal learning, verbal processes encompassing verbal learning and verbal output processes. Given the likelihood of a bidirectional relationship between verbal processes and reading, we also examined longitudinal studies. Furthermore, we explored the possibility that the relationship between cross-modal PAL and reading might be mediated by other key reading predictors.

IV.2.3.1 The Associative Learning Process

Reading could be viewed as an associative learning activity. One may therefore assume that the connection between cross-modal PAL and reading is due to general associative learning abilities. To test this hypothesis, different types of PAL tasks can be compared in terms of their contribution to reading skills. Since all PAL tasks require associative abilities, they are expected to be correlated with reading skills.

Results

It has been clearly demonstrated that the nature of the associated information is crucial to observe a relation with reading (e.g. Aguiar & Brady, 1991; Chow, 2014; Clayton et al., 2018; Elbro & Jensen, 2005; Kalashnikova & Burnham, 2016; Litt et al., 2019; Malone et al., 2019; Samuels, 1973; Torgesen & Murphey, 1979; Vellutino, Steger, et al., 1975). For example, authors have consistently found that visual-visual PAL was not correlated with reading skills (Litt et al., 2013; H.-C. Wang et al., 2017; Wass et al., 2019), or less strongly than visual-verbal PAL (Hulme et al., 2007; C. Liu et al., 2020; but see Singleton et al., 2000). Furthermore, good and poor readers obtained similar scores on visual-visual PAL tasks, whereas differences between groups were observed for cross-modal PAL (Litt & Nation, 2014; Messbauer & de Jong, 2003; Ramaa et al., 1993; Vellutino, Harding, et al., 1975). While this section focused on specific dissociation within PAL tasks (e.g. visual-visual versus visual-verbal), other dissociation may exist and will be addressed in the following sections.

Intermediate Discussion

The studies reviewed clearly indicate that the relationship between PAL and reading cannot be reduced to a simple construct of associative memory. Instead, they reveal that the links between PAL and reading are influenced by the nature of the associated information (e.g. visual or verbal).

IV.2.3.2 The Cross-modal Learning Process

The observation that not all PAL skills contribute to reading skills has led some authors to hypothesize that cross-modality, specifically associating verbal and visual information, plays a crucial role in this contribution (e.g. Hulme et al., 2007). This is plausible since reading involves cross-modal associative learning, with visual information (e.g. letters) being connected to verbal information (e.g. sounds).

Results

Various methodologies have been employed to investigate the role of cross-modality in the relationship between cross-modal PAL and reading. Some studies compared the contributions of unimodal and cross-modal PAL tasks to reading while others examined the different processes of cross-modal PAL within the paradigm itself.

Using the first methodology, Hulme et al. (2007) found that visual-verbal PAL correlated better with several reading measures (word reading, regular word reading, irregular word reading, nonword reading) than verbal-verbal PAL. Other studies observed similar or even better correlations for verbal-verbal PAL (Clayton et al., 2018; Litt et al., 2013; H.-C. Wang et al., 2017; Wass et al., 2019). In Rudel et al.'s study (1976), dyslexic children scored lower than good readers on both auditory-verbal and visual-verbal PAL tasks.

Multivariate correlational analyses provided similar insights. Hulme et al. (2007) found that cross-modal PAL uniquely contributes to reading over unimodal PAL. In contrast, Litt et al. (2013) observed that visual-verbal PAL and verbal-verbal PAL both contributed uniquely and similarly to word reading in separate models. A Structural Equation Modeling analysis also demonstrated that a 'verbal-output' latent variable aggregating visual-verbal and verbal-verbal scores contributed to reading. The addition of visual-verbal PAL to the model did not improve it. In a Structural Equation Modeling analyses, Clayton et al. (2018) also observed that only unimodal PAL tasks contributed to reading.

In the first two experiments of Litt and Nation (2014), poor readers struggled with both cross-modal and verbal-verbal PAL tasks. The difficulties observed in PAL tasks were not specific to a particular modality, suggesting that the difficulty of cross-modal PAL tasks does not depend solely on the modality of the mapping.

In some experiment, Litt and colleagues directly examined the processes involved in the cross-modal PAL rather than comparing different PAL tasks (i.e., knowledge of stimuli and responses independently of their association, memory of association by controlling for their knowledge of stimuli and responses; Litt et al., 2019; Litt & Nation, 2014). In their third experiment, Litt and Nation (2014) pre-exposed children to the verbal response of their visual-verbal PAL tasks before administering the PAL paradigm, resulting in a verbal learning score. Although poor readers obtained lower scores than good readers on the visual-verbal PAL task, this difference disappeared once the verbal learning score was controlled in the analyses. Litt et al. (2019) observe that dyslexic children required more trials than non-dyslexics to learn pairs during visual-verbal PAL. When they examined more specifically the cross-modal associative learning and nonword learning processes of the PAL task, they found that dyslexic children performed less well than good readers only in nonword learning.

Intermediate Discussion

Despite some inconsistencies, the relationship between reading skills and cross-modal PAL does not seem to be explained by cross-modal learning processes (Clayton et al., 2018; Litt et al., 2013, 2019; Litt & Nation, 2014; Rudel et al., 1976; but see Hulme et al., 2007). The discrepancies between studies, such as those by Hulme et al. (2007), Clayton et al. (2018) and Litt et al. (2013) are challenging to account for. Comparing several PAL tasks might be biased by several confounding factors such as sensibility or difficulty of the tasks, motivation and participant strategies. It might thus be more relevant to examine the specific processes involved in PAL tasks within the paradigm itself (e.g. see methodology of Litt et al., 2019; H.-C. Wang et al., 2015; S. Wang & Allen, 2018).

At the sublexical level, cross-modal associative learning may play a role, especially in letter learning (Roberts et al., 2018, 2019). However, this effect is likely to diminish as reading skills progress and letters become more familiar. Higher-level mechanisms come into play for complex graphemes or syllables. The process of mapping written to phonological units involves abstract letter identities (e.g. Dehaene et al., 2001), processed in clusters such as bigrams (Grainger & Ziegler, 2011) or syllables (Ferrand et al., 1996) and recognizing higher-level patterns such words (Dehaene et al., 2005). Cross-modal PAL may not reflect such abstract higher-level mechanisms which could explain why its relationship to word reading skills is not so clear.

IV.2.3.3 Verbal Processes

The hypothesis of the potential role of the verbal processes of PAL tasks in relation to reading was introduced by Litt et al. (2013). In this section, we summarize the studies that compared the contribution of PAL to reading achievement whether they involved verbal abilities or not and in the same mapping modality (uni- or cross-modal).

Results

Research has consistently suggested that the verbal demand accounts for the relationship between cross-modal PAL and reading, at least partially. In several studies (Litt et al., 2013; H.-C. Wang et al., 2017; Wass et al., 2019; but see Hulme et al., 2007), verbal-verbal PAL tasks showed higher correlation coefficients with reading than visual-visual PAL. Litt and Nation (2014) found that poor readers also obtained lower scores than controls on verbal-verbal but not on visual-visual PAL tasks. In two studies, conducted by Torgesen and Murphey (1979) and Vellutino, Steger, et al., (1975), poor readers obtained lower scores than good readers on cross-modal PAL tasks involving verbal material but not on those involving nonverbal auditory material (but see Bartholomeus & Doehring, 1972). Clayton et al. (2018) reported that the scores on a PAL task involving nonverbal auditory stimuli and responses were less correlated with word and nonword reading skills than the scores on a verbal-verbal PAL task.

Intermediate Discussion

Overall, these results suggest very consistently that the verbal processes of cross-modal PAL are necessary to explain its shared variance with reading development. This relationship can be explained in three different ways. The following sections present two potential mechanisms proposed by Litt et al. (2013) within the 'verbal account': the verbal learning and the verbal output processes. Additionally, since the relationship between the verbal processes and reading is likely to be bidirectional, we reviewed longitudinal studies in which PAL was measured in the early stages of reading acquisition and prior to them.

IV.2.3.4 Verbal Learning Process

The verbal learning process has been proposed as a significant factor in explaining the relationship with reading (e.g. Litt et al., 2013; Poulsen & Elbro, 2018; Wimmer et al., 1998). It has been hypothesized that verbal learning plays a crucial role in retaining the 'spelling pronunciation' of irregular words, making them easier to read (Elbro & de Jong, 2017).

Results

To assess the importance of verbal learning, studies have compared the contribution of PAL tasks involving new verbal material or real words. Elbro and Jensen (2005) found that poor English readers obtained similar scores to normal readers on a visual-word PAL task but lower scores on a visual-nonword PAL task. Similarly, Vellutino et al. (1995) found greater differences between good and poor English readers in the scores on a PAL task with unknown real words compared to the scores on a PAL task with known words. However, other studies conducted in a transparent orthography (i.e., Dutch) reported that poor readers experienced as much difficulty in both visual-word and in visual-nonword PAL tasks (Mayringer & Wimmer, 2000; Messbauer & de Jong, 2003).

Another approach to test the importance of verbal learning is to examine whether children have learned pseudowords paired with images. As mentioned previously, Litt and Nation (2014) discovered that the difference between poor and good English readers in a visual-verbal PAL task disappeared when controlling for the verbal learning process. Moreover, Litt et al. (2019) showed that poor readers obtained lower scores on the verbal learning measure of their visual-verbal PAL tasks but not on the cross-modal associative process.

Intermediate Discussion

Overall, verbal learning seems to explain partially the relationship between visual-verbal PAL and reading in opaque alphabetic scripts (Elbro & Jensen, 2005; Litt et al., 2019; Litt & Nation, 2014; Vellutino et al., 1995). However, verbal learning may not play a significant role in transparent orthographies (Mayringer & Wimmer, 2000; Messbauer & de Jong, 2003). This observation is in line with the theoretical account proposed by Elbro and de Jong (2017) whereby verbal learning is expected to support irregular word reading which are numerous in opaque orthographies (Schmalz et al., 2015).

IV.2.3.5 Verbal Output Process

Some authors have proposed that the impact of verbal process in visual-verbal PAL tasks of reading skills is driven by the verbal output (Litt et al., 2019). This hypothesis is based on the idea that verbal output is specifically impaired in dyslexia, affecting phonological memory (Hulme & Snowling, 1992).

Results

One way to test this hypothesis is to compare the contribution of verbal-visual PAL and visual-verbal PAL, as the former does not involve verbal output while the latter does. Verbal-visual PAL shows varying contributions to reading performance: it is sometimes less correlated with reading than visual-verbal PAL (Litt et al., 2013; Malone et al., 2019; but see Ellis & Large, 1988) and sometimes equally achieved by poor and good readers, while visual-verbal PAL is generally achieved better by good readers (Aguiar & Brady, 1991; Kalashnikova & Burnham, 2016; Litt et al., 2019; Litt & Nation, 2014; but see Ellis & Large, 1987; Toffalini et al., 2019).

Structural Equation Modeling was used by Malone et al. (2019) and showed that visual-verbal PAL contributes uniquely to word reading fluency beyond verbal-visual PAL, suggesting that the verbal output process plays a role. Similarly, Litt et al. (2013) found that visual-verbal PAL contributed to word reading above phonological awareness and rapid automatized naming while verbal-visual PAL did not.

Litt et al. (2019) suggested that verbal-visual PAL contributes less to reading than visual-verbal PAL as it is less sensitive to verbal learning. They therefore conducted a study comparing poor and good readers in a complex PAL paradigm involving both verbal-visual and visual-verbal PAL measures, as well as a receptive test of nonword learning. They used confusable verbal stimuli in cross-modal PAL tasks, suggesting that it may result in greater sensitivity to verbal learning than less confusable ones. The results showed no difference between good and poor readers in verbal-visual PAL, even with confusable verbal stimuli, while poor readers obtained consistently lower scores than good readers in the subsequent visual-verbal PAL phase. Interestingly, while verbal-visual PAL was equally achieved by poor and good readers, the former obtained lower scores on the receptive nonword learning measure (nonwords of the PAL task).

Finally, Litt et al. (2019) posited that the verbal output process of the PAL task could be related to reading via the phonological loop (Baddeley & Hitch, 1974; Hulme & Snowling, 1992). If this hypothesis were to be correct, the contribution of visual-verbal PAL would disappear once phonological short-term memory was controlled for. However, Windfuhr and Snowling (2001) demonstrated that the contribution of visual-verbal PAL remained significant when phonological short-term memory was controlled for (but see Huschka et al., 2021).

Intermediate Discussion

One way to investigate the role of the verbal output process in the relationship between PAL and reading is to compare the contribution of verbal-visual and visual-verbal PAL tasks to reading achievement.

The literature has shown mixed results, with some studies demonstrating that verbal-visual PAL contributes less or does not contribute to reading achievement at all compared to visual-verbal PAL (Aguiar & Brady, 1991; Kalashnikova & Burnham, 2016; Litt et al., 2013, 2019; Litt & Nation, 2014; Malone et al., 2019). Others have shown that verbal-visual PAL can be related to reading skills as much as visual-verbal PAL (Ellis & Large, 1987, 1988; Toffalini et al., 2019). It is thus impossible to conclude that verbal output processing fully accounts for the relationship between PAL and reading. Furthermore, verbal-visual PAL may simply be less sensitive to verbal learning than visual-verbal PAL, which would explain why it is often less associated with reading performance.

The study of Litt et al. (2019) aimed to address this issue by increasing the verbal demand for the verbal-visual PAL task. They still observed that poor readers performed more poorly on the visual-verbal PAL than good readers but that there was no significant difference between the groups for verbal-visual PAL. Importantly, they tested only 14 participants per group so the study had less than 80% power to detect effect size lower than d = 1.10. It is thus difficult to draw clear-cut conclusions from this single study. Moreover, poor readers obtained significantly lower scores on the learning measure of the nonwords used in the PAL task, although it was a receptive one. Such a pattern contradicts the hypothesis of a pure verbal output explanation for the relationship between visual-verbal PAL and reading and tends to confirm the role of verbal learning. The authors proposed that the nonword knowledge deficit might be a consequence of the verbal output deficit, since the verbal learning test was administered after the visual-verbal phase of the paradigm. They recommended that future researchers administer the nonword learning measure before verbal output measures.

Regarding the role of verbal output in reading achievement, Litt and colleagues referred to the observation made by Hulme and Snowling (1992), who suggested that a deficit in phonological output hinders the phonological loop (as described by Baddeley & Hitch, 1974) which is crucial for word synthesis during recoding. Interestingly, phonological memory is consistently impaired in poor readers (Melby-Lervåg & Lervåg, 2012; Peng et al., 2018; Swanson et al., 2009). However, this observation is not in line with the hypothesis that an output deficit accounts for the relationship between visual-verbal PAL and reading since visual-verbal PAL was found to contribute to reading even after controlling for phonological memory (Windfuhr & Snowling, 2001).

In conclusion, disentangling the role of verbal output from the role of verbal learning in the relationship between PAL and reading is a challenging task given the current evidence. There is a lack of substantial empirical data and theoretical background to support the existence of a specific and novel mechanism attributed to PAL verbal output in reading.

IV.2.3.6 Bidirectional Relationship Between Reading and the Cross-Modal PAL

The interactive relationship between reading and its predictors is well established (Landerl et al., 2019). We reviewed longitudinal studies examining the contribution of cross-modal PAL to reading achievement in the early stages of reading acquisition and before to determine to what extent the link between cross-modal PAL and reading in causal or interactive.

Results

We identified four longitudinal studies. In Norwegian and German, which have transparent orthographies, no contribution of cross-modal PAL was observed in various reading fluency measures (Huschka et al., 2021; Lervåg et al., 2009). In English, an opaque orthography, Singleton et al. (2000) also found no contribution of a verbal-visual PAL task to word reading six months later, measured in six-year-old children and controlling for various predictors. However, in Danish, another opaque orthography, Poulsen and Elbro (2018) found that visual-verbal PAL measured in preschool children predicted 2% of variance in word reading in G1 and 6% in word reading at G5, controlling for letter knowledge, phonological awareness and rapid automatized naming.

Intermediate Discussion

Overall, these studies suggest that the relationship between cross-modal PAL and reading skills are interactive as it seems more difficult to find a unique contribution of cross-modal PAL with reading when it is assessed before or at the very beginning of explicit instruction to reading. Note that none of the studies selected presents an optimal paradigm to answer the current question. The study of Huschka et al. (2021) and Lervåg et al. (2009) were conducted in a transparent orthography in which cross-modal PAL is less likely to be a contributor according to the verbal learning account (Elbro & de Jong, 2017). The results may thus be generalizable only to other transparent but not opaque orthographies. Moreover, all their reading measures had time constraints, whereas cross-modal PAL is more likely to be correlated with accuracy measures (Poulsen & Elbro, 2018). This choice was probably made because word reading is rapidly acquired in transparent orthographies (Seymour et al., 2003) and accuracy measures would likely have presented ceiling effects.

The study by Singleton et al. (2000) also suggested that cross-modal PAL does not contribute to reading. However, they used a verbal-visual PAL paradigm, which is usually less correlated with reading as discussed in the section about the verbal output process.

Finally, although Poulsen and Elbro (2018) found a long-term contribution of visual-verbal PAL to word reading, this effect was observed over certain key reading predictors but not all. Thus there is no evidence that cross-modal PAL predicts uniquely future reading achievement (cf. the subsequent section about the relation between PAL and other reading predictors).

IV.2.3.7 Is Cross-modal PAL-Reading Relationship Confounded with Principal Other Reading Predictors?

To determine whether the contribution of cross-modal PAL to reading is direct and not confounded with the other main reading predictors (including letter knowledge, phonological awareness, rapid automatized naming, phonological memory, vocabulary, and nonverbal abilities), we conducted a review of articles that reported multivariate correlational analyses.

Results

Most of the studies examined were concurrent and were conducted in English (Chow, 2014; Clayton et al., 2018; Hulme et al., 2007; Litt et al., 2013; Malone et al., 2019; Nilsen & Bourassa, 2008; Warmington & Hulme, 2012; Windfuhr & Snowling, 2001). One study was conducted in a transparent alphabetic script, the Chitonga language (Mourgues et al., 2016). Several studies were longitudinal including one in English (Singleton et al., 2000), two in Danish based on the same sample (Poulsen et al., 2017; Poulsen & Elbro, 2018)), one in German (Huschka et al., 2021) and one in Norwegian (Lervåg et al., 2009).

Only one study controlled for all reading predictors and nonverbal abilities simultaneously (Lervåg et al., 2009). It aimed to explain various reading skills including orthographic knowledge, text reading, nonword and single word decoding scores in children from Grades 2 and 3. The set of predictors was assessed at the beginning of the first and the second grades (letter knowledge, phonological awareness, rapid automatized naming, phonological memory, vocabulary and nonverbal abilities). Using Structural Equations Modeling, they found that the cross-modal PAL measure did not contribute significantly to any reading tasks.

Intermediate Discussion

The study of Lervåg et al. (2009) was the only one that examined the contribution of cross-modal PAL controlling for all the strongest reading predictors. The results indicated that the cross-modal PAL did not significantly contribute to reading tasks in a transparent orthography (Norwegian). As discussed above, this may not be generalizable to opaque orthographies. In addition, these findings may not extend to accuracy-based reading measures, as the tasks used were time-constrained.

IV.2.4. Implications for Future Studies

Further studies are needed to definitively determine the relevance of cross-modal PAL as a predictor of reading and its sub-processes in opaque orthographies, whereas it seems to be of less importance in transparent orthographies. The best approach appears to be conducting longitudinal studies in various scripts, assessing cross-modal PAL along with all potential confounding factors before formal assessment of reading. It seems essential to assess the different processes of PAL within the paradigm itself (see: Litt et al., 2019; H.-C. Wang et al., 2015; S. Wang & Allen, 2018) rather than comparing different tasks, which can introduce potential confounding factors. According to Litt et al. (2019), receptive measures should be taken before the productive ones, as they hypothesized that verbal output may degrade phonological representations. Finally, a wide range of reading measures should be included, encompassing at least nonword and word reading accuracy and fluency to determine which outcome would cross-modal be better related to, as in the study of Poulsen & Elbro (2018). Besides, new paradigms should be developed to directly address the hypothesis of a direct role of verbal learning in learning to read by means of training studies. This would have direct implications for teachers, speech therapists or educators.

IV.2.5. Limitations of This Systematic Review

This study focused on alphabetic scripts. Then, it is not generalizable to all scripts, in particular to Chinese script in which some research has been conducted (Chow, 2014; Georgiou et al., 2017; Ho, 2014; H. Li et al., 2009; C. Liu et al., 2020; C. Liu & Chung, 2022; Tseng et al., 2023; H.-C. Wang et al., 2015; S. Wang & Allen, 2018; Yang et al., 2023). Mechanisms involved in logographic scripts may be different. For example, Chow (2014) demonstrated that semantic-visual PAL uniquely contributes to character reading whereas verbal-visual PAL does not. In English, the pattern was reversed, with verbal-visual PAL uniquely contributing to word reading. Other research has shown that cross-modal learning may be important in logographic scripts (H.-C. Wang et al., 2015; S. Wang & Allen, 2018; but see: Yang et al., 2023).

It should be noted that a meta-analysis would not provide answers to the problems still outstanding after this systematic review. For example, the question of the unique contribution of multimodal PAL to opaque orthographies cannot be resolved, as no study to date has controlled for all the other main predictors. The few inconsistencies between studies examining the role of cross-modality cannot be resolved by meta-analysis either, because of the small number of studies and heterogeneous methodologies.

IV.2.6. Conclusion

To our knowledge, this is the first systematic review examining the mechanisms accounting for the relationship between cross-modal PAL abilities and reading in alphabetic scripts. The verbal learning processes seem to explain this relationship. However, no study to date has confirmed whether this relationship represents new and distinct mechanisms not captured by other main predictors of reading in opaque orthographies (letter knowledge, phonological awareness, rapid automatized naming, phonological memory, vocabulary, nonverbal abilities). In transparent orthographies, however, two longitudinal studies suggest that cross-modal PAL has no predictive power over other reading predictors, at least in time constraint measures of reading (Huschka et al., 2021; Lervåg et al., 2009). To draw solid conclusions on the value of continuing to use cross-modal PAL tasks in predicting reading achievement in opaque orthographies, longitudinal studies controlling for major factors and examining the various processes of PAL before the onset of formal reading instruction are now necessary.

Main results

- The relationship between visual-verbal PAL and decoding skills can be explained mainly by its verbal learning component.
- This relationship is bidirectional.
- It is not clear to what extent the causal relationship between visual-verbal PAL and decoding skills is not confounded with other reading predictors.
- This relationship may be stronger for opaque than for transparent orthographies.

IV.3. Examining Cross-modal and Verbal Learning in Word and Nonword Reading Skills in French Children

This study was conducted as part of the TANMALL project and is currently being published in the Journal of Educational Psychology (Bignon et al., in press). For simplicity's sake, the introduction has been summarized, along with certain elements of the methodology already mentioned in the TANMALL project presentation (section II, p.55).

This study carried on French Grade 1 and Grade 2 children. The first aim was to examine the unique contribution of visual-verbal PAL in French since most previous studies were conducted in opaque orthographies. Indeed, the transparency of French orthography is often considered as intermediate according to different classification methods (Borgwaldt et al., 2005; Schmalz et al., 2015; Seymour et al., 2003). Moreover, we have seen in the section V.5 (p.48) that cross-modal learning and verbal learning may be more involved in opaque orthographies. (e.g. Borgwaldt et al., 2005; Schmalz et al., 2015; Seymour et al., 2003).

Furthermore, visual-verbal PAL is correlated with all the other strongest cognitive and linguistic predictors such as nonverbal abilities, vocabulary, phonological awareness, rapid automatized naming and phonological short-term memory (e.g. de Jong et al., 2000; Ehm et al., 2019; Karipidis et al., 2017; Lervåg et al., 2009; Litt et al., 2013; Malone et al., 2019; Mayringer & Wimmer, 2000; Nielsen & Juul, 2016; Thomson & Goswami, 2010; Warmington & Hulme, 2012; Windfuhr & Snowling, 2001). From a purely statistical point of view, all these measures could therefore be confounding variables. The unique contribution of visual-verbal PAL should therefore be examined by taking all these predictors into account. However, hardly any research has controlled for all these variables simultaneously. Yet there is a doubt about the unique contribution of visual-verbal PAL. Note that we did not administer letter knowledge tasks. Since we recruited children from the middle of grade 1 to the end of grade 2, we expected to obtain a ceiling effect.

Second, we aimed at testing the contribution of each of these sub-components of visual-verbal PAL in word and nonword reading in French, namely, the cross-modal associative learning and verbal learning processes. To do so, we have created a new paradigm of visual-verbal PAL using intermediate tasks during the classical PAL paradigm. Visual-verbal PAL tasks are often divided into repeated learning blocks interspersed with testing blocks in which participants must name the different images of the pairs. An auditory recognition task and a designation task were added to each test block after the naming tests to capture online the learning of the verbal label and of the crossmodal associations, respectively. The auditory recognition test consisted in recognizing the verbal label of the paired associates among distractors chosen for their similarity to the targets (for a similar approach, see Litt et al., 2019). The designation test consisted in choosing the right picture associated with a given verbal label. All pictures of the pairs were displayed at the same time on a computer screen during this test (see method section for more details). One may argue that the designation phase also captured verbal learning since it was necessary to recognize the nonword to designate the right picture. We suggest, however, that the verbal demand for the designation task was lower than in the auditory recognition task, since participants did not have to identify the verbal label precisely. It was thus possible to complete the designation task despite poor verbal representations. Furthermore, it was possible to control the auditory recognition scores in the analyses to extract only the associative mechanism of the designation task (for a similar approach see Litt et al., 2019; H.-C. Wang et al., 2015; S. Wang & Allen, 2018).

IV.3.1. Method

IV.3.1.1 Participants

The participants were recruited within the framework of the TANMALL project. The initial sample comprised 256 children. Twenty-nine participants were excluded because of missing data or because they did not complete the tasks correctly (see the Data Diagnostic section).

The final sample consisted of 227 children (boys =110; girls = 117; mean age = 86.56 months, SD = 6.30 months, 1 missing value), 152 in Grade 1 and 75 in Grade 2. Parental questionnaires provided additional information. Sixty-two families reported that their child spoke a language other than French at home. Nineteen families reported that their child was attending a speech therapist during the study. Among these children, 13 were followed specifically for oral or written language difficulties. Participants were selected in 18 schools, including 6 from a priority education area (corresponding to 46 participants), and 27 classes. We also assessed the educational level of parents using the ISCED classification (OECD et al., 2015). The maximum level of education among parents was reported for each child. The average indicator of educational attainment was 5.94 (SD = 1.79; missing data = 27) which corresponds to short-cycle tertiary education or a bachelor's degree.

Data Collection

Data were mainly collected between February and July 2021 and 2022 in French elementary schools. The children were tested in their school by the authors or by trained experimenters. The tests lasted between an hour and an hour and a half, depending on the speed of the participants. When necessary, testing was divided into two sessions. The order of the tests was fixed and was set to alternate between easy and more difficult tests to maintain motivation. Participants thus completed the different tests in the following order: nonverbal abilities, vocabulary, paired-associate learning, rapid automatized naming, phonological awareness, nonword repetition, word and nonword reading.

IV.3.1.2 Measures

McDonald's ω reliability indicators were computed on participant data for all tasks except for rapid automatized naming, for which we computed the correlation between the two subtests. We used the scores of the following measures: word and nonword reading (respectively: $\omega = .91$; $\omega = .83$), nonverbal abilities ($\omega = .86$), phonological awareness ($\omega = .86$), rapid automatized naming ($r = .74$, $p < .001$), nonword repetition ($\omega = .65$), vocabulary ($\omega = .84$), the naming measure of visual-verbal PAL ($\omega_{\text{all trials}} = .90$; $\omega_{\text{mean scores}} = .75$), the auditory recognition measure of visual-verbal PAL ($\omega_{\text{all target trials}} = .83$; $\omega_{\text{mean scores on each target}} = .67$) and the designation measure of visual-verbal PAL ($\omega_{\text{all trials}} = .88$; $\omega_{\text{mean scores}} = .81$)[6]. We did not applied the flexible scoring in this section. A detailed description of the tasks can be found in the general method section of the TANMALL project (see the section "II.2. Measures", p. 63).

IV.3.1.3 Data Analyses

Descriptive and reliability analyses were conducted on JASP, version 0.17.3 (JASP Team, 2023). JASP uses R syntax and CRAN packages. Multilevel modeling were performed on R, version 4.2.2 (R Core Team, 2022) using the following packages: lme4, version 1.1-31 (Bates et al., 2015), lmerTest (Kuznetsova et al., 2017) and performance (Lüdecke et al., 2021). Data manipulation was facilitated using the dplyr package, version 1.1.1 (Wickham et al., 2023). Analysis of missing value was conducted using the naniar package, version 1.0.0 (Tierney & Cook, 2023).

6 Since the four items were repeated eight times across testing phases, reliability (ω) for each phase could be inflated. We thus computed two reliability indicator for each phase: (1) one on all trials of a given phase, considering that the items were all independent (e.g. the item 'piku' in the first block was considered different from the item 'piku' in other blocks in a given phase); (2) one on the mean scores of each item in a given phase across all blocks (i.e., the reliability calculation was performed on four recomputed items: the average scores on all blocks for each item).

IV.3.1.4 Data Diagnosis

Missing Data

Twenty-seven participants were excluded because of missing data. To test randomness of missing values across all the test measures, we use Little's test (Little, 1988) where the null hypothesis is that missing values are completely at random. Since the null hypothesis was not rejected, we can assume that the missing data are completely at random $\chi^2(123, 227) = 125$, $p = .43$. In other words, this suggests that the profile of the excluded children was not different from that of the included children.

Outliers

Examination of univariate and multivariate outliers was conducted following the guidelines of (Aguinis et al., 2013). Univariate outliers were detected to identify and rectify errors in the encoded data. We used the standard deviation cut-off of 2.24 SD following the simulations of Berger and Kiefer (2021). Two participants were excluded because they pressed the same button most of the time during the auditory recognition phase of the visual-verbal PAL task, indicating that they did not perform the task correctly. We have not excluded other univariate outliers because they do not necessarily impact the reliability of correlation analyses (for example, a participant may have very low values for both the dependent and predictor variables, which is relevant). We rather detect significant influential points using Cook's distance (Cook, 1977) for each model tested in this study. Following the guidelines of Aguinis et al. (2013), we decided to exclude participants in whom Cook's distance exceeded the following cut-off value computed using the F distribution, with df = $(k + 1, n - k - 1)$ and $\alpha = .50$, where 'k' represent the number of predictors and 'n' the number of participants. The computed cut-off was between 0.90 and 0.94 depending on the model. No significant influential point was detected in the various models computed.

IV.3.2. Results

The database is freely available at https://doi.org/10.57745/NGNCHN.

IV.3.2.1 Descriptive Statistics

The descriptive characteristics of each variable are presented in Table 36. Examiners observed that the visual-verbal PAL task was time-consuming (about 15 minutes, whereas each of the other tasks was completed in about five minutes) and tiring for the children. However, no floor effect was detected (with a criterion of one standard deviation below the mean). Separate analyses of target and distractor scores on the auditory recognition task indicated that the children performed the task correctly. A very low false alarm level was detected for the distractors (four on average for 32 distractors in total).

IV.3.2.2 Multilevel Analyses

The aims of this study were: (a) to determine whether visual-verbal PAL presents a unique contribution to word reading in French first and second grade children when controlling for the strongest reading predictors, and (b) to explore the role of cross-modal associative and verbal learning in its relationship with nonword and word reading scores.

All the variables in this study were significantly correlated, confirming the need to conduct multivariate analyses with word or nonword reading scores as dependent variables and reading predictors and visual-verbal PAL measures as independent variables (Table 37). The correlation between visual-verbal PAL (naming measure) and word reading skills was moderate. The correlation between visual-verbal PAL (naming measure) and other reading predictors was low to moderate.

Table 36. *Descriptive Results*

Variables (maximum possible score)	Mean (SD)	Min	Max	Skewness	Kurtosis
Nonverbal abilities (32)	20.82 (5.33)	4	32	-0.16	-0.47
Phonological Awareness (34)	26.62 (5.55)	3	34	-1.41	2.35
Rapid Automatized Naming (mean time in seconds)	32.85 (7.95)	18.50	79.00	1.78	6.24
Phonological Short-Term Memory (31)	26.65 (2.99)	16	31	-1.08	0.92
Vocabulary (50)	30.91 (6.41)	13	46	-0.39	0.09
PAL: Naming (32)	13.14 (7.43)	0	30	0.48	-0.69
Visual-Verbal PAL: Auditory Recognition (targets ; 32)	25.05 (5.16)	0	32	-1.32	2.94
Visual-Verbal PAL: Auditory Recognition (distractors; 32)	28.26 (3.76)	10	32	-2.56	8.29
Visual-Verbal PAL: Auditory Recognition (total; 64)	53.31 (7.13)	27	64	-1.42	2.59
Visual-Verbal PAL: designation (32)	20.51 (6.79)	4	32	-0.22	-0.86
Word Reading (48)	39.71 (7.22)	11	48	-1.23	1.43
Nonwords Reading (36)	26.81 (5.61)	9	36	-1.07	1.01

Reading improvement was highly dependent on the progress of the program, which depended on the choices made by the teachers. Children came from 27 classes (with independent teachers) that they shared with other participants. This condition may violate the assumption of independence of the data which is necessary in multiple regression analyses. To control for the potential effect of the teacher, we used multilevel analyses with ‘teacher’ as a random intercept (Peugh, 2010). The estimation method was REML and *t*-tests were based on Satterthwaite’s method.

Table 37. *Pearson correlations between performances on the various task (simple correlations above the diagonal, partial correlations controlling for grade below the diagonal)*

	1	2	3	4	5	6	7	8	9	10
1. Raven Matrices	—	.40	.26	.20**	.35	.27	.22**	.25	.40	.31
2. Phonological Awareness	.41	—	.28	.38	.31	.35	.30	.33	.52	.45
3. Rapid Automatized Naming (transformed)	.24	.30	—	.27	.14*	.27	0.14*	.29	.48	.50
4. Phonological Short-Term Memory	.20**	.38	.28	—	.22	.33	.21**	.27	.47	.38
5. Vocabulary	.36	.31	.15*	.22	—	.27	.23	.26	.34	.24
6. Visual-Verbal PAL: Naming	.26	.37	.23	.33	.28	—	.44	.71	.46	.35
7. Visual-Verbal PAL: Auditory Recognition (targets)	.21	.32	.11*	.21**	.23	.41	—	.34	.33	.24
8. Visual-Verbal PAL: designation	.24	.35	.27	.27	.26	.71	.33	—	.37	.24
9. Word Reading (transformed)	.39	.54	.46	.47	.34	.44	.30	.35	—	.73
10. Nonword Reading (transformed)	.30	.46	.49	.38	.24	.34	.23	.23	.73	—

Notes. All significant at *$p < .001$ except these marked with asterisks: * $p < .05$, ** $p < .01$,*

Graphical analyses of the word and nonword reading scores revealed high asymmetry. Additionally, graphical analyses of the multilevel models indicated that residuals deviated from normality and showed heteroscedasticity (see Supplementary Material S22, S23 and S24, respectively in the Appendices V, p. 278). Consequently, a transformation was applied to word and nonword reading scores to correct their distributions. We compared the histograms resulting from the various transformations described by Rummel (1988). The transformation that most closely resembled a normal distribution was achieved through the following procedure:

$$\frac{1}{2}\log\frac{\left(1+\dfrac{score}{maximumscore+1}\right)}{\left(1-\dfrac{score}{maximumscore+1}\right)}$$

After applying the transformations, a graphical check of the distribution of the word reading scores, the nonword reading scores, the residuals of each model, as well as the residuals versus the predicted value, showed that the distributions were greatly improved, as well as homoscedasticity (see Supplementary Material S22, S23 and S24, respectively, in the Appendices V, p. 278)).

For the sake of simplicity, multilevel analyses are shown as hierarchical regressions in Table 38 and 39. Complete models are available in the Supplemental Material. In step 1, we included all the variables that were supposed to mediate the contribution of visual-verbal PAL, namely: grade level, nonverbal intelligence, phonological awareness, rapid automatized naming, phonological short-term memory, and vocabulary. We also entered all interactions between grade level and the other predictors mentioned above. We then entered each measure of visual-verbal PAL in step 2 and its interaction with grade. Only significant interactions were retained in the models. We detected consistent interactions between grade level and rapid automatized naming as well as between grade level and vocabulary in all models explaining word reading scores. We also detected an interaction between grade level and vocabulary in the model explaining nonword reading scores. All other interactions were removed from the analyses as they were not significant. Tables 38 and 39 synthesize models explaining scores in word and nonword reading, respectively.

In step 1, all predictors (or their interactions with grades) contributed to word and nonword reading except nonverbal abilities. Further examinations of the interaction between grade and rapid automatized naming showed that rapid automatized naming played a significant role in Grade 1 but not Grade 2 in word reading. Further examination of the interactions between grade and vocabulary for both word and nonword reading showed the opposite pattern. Vocabulary played a significant role in grade 2 but not grade 1 (see Models 10, 14, 18 and 19 in the Supplemental Material in the Appendices V, p. 278).

Table 38. *Examination of the contribution of different measures of visual-verbal PAL to word reading.*

Step 1. Explain word reading by the main predictors (R^2 C = 53.61 ; R^2 M = 50.25%)					
Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Intercept	-0.10	0.08	11.09	-1.30	0.221
Grade	0.37	0.13	23.40	2.91	0.008
Nonverbal abilities	0.10	0.05	217.61	1.86	0.065
Phonological Awareness	0.28	0.06	207.53	4.99	<.001
Rapid Automatized Naming	0.31	0.06	216.85	4.82	<.001
Phonological Short-Term Memory	0.24	0.05	217.41	4.58	<.001
Vocabulary	0.01	0.06	217.39	0.22	0.825
Grade * Rapid Automatized Naming	-0.22	0.11	215.55	-2.13	0.034
Grade * Vocabulary	0.31	0.10	212.89	2.97	0.003
Random Effects	**Variance**	**Standard Deviation**			
Class (Intercept)	0.03	0.19			
Step 2. Examine the unique contribution of Visual-Verbal PAL: naming (R^2 C = 55.73% ; R^2 M = 52.05%)					
Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Visual-Verbal PAL: naming	0.17	0.05	213.11	3.15	0.002
Step 2. Examine the unique contribution of Visual-Verbal PAL: auditive recognition (R^2 C = 54.64% ; R^2 M = 51.20%)					
Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Visual-Verbal PAL: auditory recognition	0.11	0.05	205.53	2.12	0.035
Step 2. Examine the unique contribution of Visual-Verbal PAL: designation (R^2 C = 54.30% ; R^2 M = 50.32%)					
Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Visual-Verbal PAL: designation	0.08	0.05	205.40	1.55	0.124

Notes. R^2 C = R^2 conditional; R^2 M = R^2 marginal
Estimates are reported in the same way as for hierarchical regressions. Then, the estimates for step 1 are estimates only for the predictors entered in step 1. Estimates for all the final models are available in the supplementary material (S2. Model 1, S3. Model 2, S4. Model 3., S5. Model 4.).

Table 39. *Examination of the contribution of visual-verbal PAL to nonword reading.*

Step 1. Explain nonword reading by the main predictors (R^2 C = 41.28% ; R^2 M = 40.67%)					
Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Intercept	-0.02	0.07	13.75	-0.26	0.800
Grade	0.06	0.12	31.19	0.47	0.638
Nonverbal abilities	0.06	0.06	214.45	0.96	0.340
Phonological Awareness	0.25	0.06	216.17	3.98	<.001
Rapid Automatized Naming	0.33	0.06	211.06	5.65	<.001
Phonological Short-Term Memory	0.16	0.06	211.67	2.75	0.006
Vocabulary	-0.07	0.07	208.55	-0.96	0.339
Grade * Vocabulary	0.33	0.11	192.07	3.03	0.003
Random Effects	**Variance**	**Standard Deviation**			
Class (Intercept)	0.01	0.08			
Step 2. Examine the unique contribution of Visual-Verbal PAL: naming (R^2 C = 41.65% ; R^2 M = 41.13%)					
Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Visual-Verbal PAL: naming	0.09	0.06	217.95	1.48	0.140
Step 2. Examine the unique contribution of Visual-Verbal PAL: auditory recognition (R^2 C = 41.45%; R^2 M = 40.95%)					
Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Visual-Verbal PAL: auditory recognition	0.07	0.06	216.10	1.20	0.233
Step 2. Examine the unique contribution of Visual-Verbal PAL: designation (R^2 C = 41.17% ; R^2 M = 40.65%)					
Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Visual-Verbal PAL: designation	-0.03	0.06	215.16	-0.56	0.578

Notes. R^2 C = R^2 conditional; R^2 M = R^2 marginal
Estimates are reported in the same way as for hierarchical regressions. Then, the estimates for step 1 are estimates only for the predictors entered in step 1. Estimates for all the final models are available in the supplementary material (S6. Model 5, S7. Model 6, S8. Model 7., S9. Model 8.).

In step 2, we entered each visual-verbal PAL measures independently. For word reading scores, the naming and auditory recognition scores contributed significantly to the model above all other reading predictors (respectively: β = .17, t(213.11)= 3.15, p = .002 ; β = .11, t(205.53) = 2.12, p = .035). They added respectively around 2% and 1% additional explained variance to the models (the pattern for conditional and marginal R^2 was similar). For nonword reading, none of the visual-verbal PAL measures contributed significantly to the models above other predictors. When visual-verbal PAL measures were added to the different models, the significance of other predictors or interactions did not change.

IV.3.2.3 Follow-up Analyses

Although zero-order correlation between visual-verbal PAL (naming measure) and word reading was rather moderate, it accounted for only 2% additional variance to the model once all other predictors were controlled in the multilevel analysis. To examine which predictors contributed the most to visual-verbal PAL (naming measure) and therefore reduced its contribution to reading skills the most, another multilevel analysis was performed with visual-verbal PAL (naming measure) as the dependent variable. Grade and other reading predictors were defined as independent variables. A random intercept for teacher was added to the model. Results in Table 40 showed that visual-verbal PAL was significantly explained by phonological awareness (β = .20, t(216.62) = 2.92., p = .004), phonological short-term memory (β = .18, t(215.47) = 2.82., p = .005) and vocabulary (β = .15, t(212.78) = 2.32., p = .022). Interestingly, rapid automatized naming was not a significant contributor.

Table 40. *Examination of the correlates of visual-verbal PAL.*

Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Intercept	-0.17	0.08	15.03	-2.11	0.052
Grade	0.49	0.14	32.75	3.62	<.001
Nonverbal abilities	0.06	0.07	218.07	0.89	0.375
Phonological Awareness	0.20	0.07	216.62	2.92	0.004
Rapid Automatized Naming	0.08	0.06	216.59	1.29	0.199
Phonological Short-Term Memory	0.18	0.06	215.47	2.82	0.005
Vocabulary	0.15	0.06	212.78	2.32	0.022
Random Effects	**Variance**	**Standard Deviation**			
Class (Intercept)	0.01	0.11			
Residual	0.75	0.86			
Model fit	**AIC**	**BIC**	**R^2 C**	**R^2 M**	**ICC**
	617.31	648.13	27.28%	26.00%	0.02

Notes. R^2 C = R^2 conditionnal; R^2 M = R^2 marginal

IV.3.3. Discussion

As numerous studies on the contribution of the visuo-verbal PAL to reading acquisition have been conducted in opaque orthographies (e.g. Poulsen & Elbro, 2018; Warmington & Hulme, 2012; Windfuhr & Snowling, 2001), the present study focuses on French, whose orthography is intermediate in terms of transparency. First, we examined the unique contribution of visual-verbal PAL to reading in first and second grade children, when controlling for all the phonological predictors of word reading and vocabulary. Second, we studied the mechanisms that account for this relationship, i.e., cross-modal associative and verbal learning. Follow-up analyses gave an insight into the predictors which are most involved in visual-verbal PAL (naming measure).

IV.3.3.1 Does Visual-Verbal PAL Uniquely Contributes to Word Reading Above Other Phonological Reading Predictors and Vocabulary Level?

To determine whether visual-verbal PAL uniquely contributes to word reading in the first two grades, it is essential to control for any potential confounding factors, since it is correlated with nonverbal abilities and other reading predictors (phonological awareness, rapid automatized naming, phonological short-term memory and vocabulary; (e.g. see de Jong et al., 2000; Ehm et al., 2019; Karipidis et al., 2017; Lervåg et al., 2009; Litt et al., 2013; Malone et al., 2019; Mayringer & Wimmer, 2000; Nielsen & Juul, 2016; Poulsen et al., 2015; Poulsen & Elbro, 2018; Thomson & Goswami, 2010; Warmington & Hulme, 2012; Windfuhr & Snowling, 2001).

However, hardly any study controlled for all of them when the unique contribution of visual-verbal PAL was tested (but see Lervåg et al., 2009). In the present study, visual-verbal PAL (naming) was correlated with all of these measures. This confirms that they could be potential confounding factors and that they had to be controlled in our analyses. We then conducted a multilevel analysis with word and nonword reading as dependent variables. Despite controlling for all reading predictors, we found that visual-verbal PAL (naming measure) was a unique contributor to word reading scores in French first and second grade children. Its contribution was at the lower bound of those obtained in the literature, i.e. marginal and conditional R^2 increase were of 2% for word reading as in Poulsen and Elbro (2018), suggesting that visual-verbal PAL contributes weakly to early word reading skills in French. However, we now confirm for the first time that visual-verbal PAL could capture specific mechanisms that are not captured by any other reading predictors.

Interestingly, it did not contribute to nonword reading. The mechanisms explaining the link between visual-verbal PAL and word reading therefore seem to be related to lexical rather than sublexical processing (cf. subsequent sections for a discussion on the mechanisms involved in visual-verbal PAL). This result is similar to that obtained in previous studies (Litt et al., 2013; Windfuhr & Snowling, 2001), showing that the contribution of visual-verbal PAL was higher in word reading than in nonword reading. This might also be due to the lower reliability of the nonword reading measure (ω = .83) than that of word reading (ω = .91) and a lack of power since both word reading and nonword reading scores were strongly correlated (r = .73, p <.001).

The present study is the second examining the contribution of visual-verbal PAL conducted in a more transparent orthography than English. The other was conducted by Lervåg et al. (2009) in Norwegian with a longitudinal design. They found that visual-verbal PAL did not contribute to reading skills after controlling for all phonological predictors and both nonverbal and verbal abilities. Therefore, their study and ours do not lead to the same conclusion regarding the contribution of visual-verbal PAL.

This discrepancy may be due to the fact that Norwegian has a more transparent orthography compared to French (Seymour et al., 2003). Furthermore, it is worth noting that Lervåg et al. (2009) used time-constrained reading tasks, which are not directly comparable to our accuracy measures. Indeed, Poulsen and Elbro (2018) demonstrated (albeit in Danish, which has a more opaque orthography than Norwegian) that visual-verbal PAL contributed more to reading accuracy than to reading fluency or speed

IV.3.3.2 Which Mechanism Drives the Relationship Between Visual-Verbal PAL and Word Reading?

Our second objective was to investigate the contribution of the cross-modal associative and the verbal learning mechanisms in word and nonword reading. We operationalized these mechanisms by means of two additional measures taken during visual-verbal PAL: an auditory recognition measure and a designation measure.

Cross-modal Associative Learning Mechanism

The cross-modal associative learning mechanism was assessed by a picture designation measure in which participants learned nonwords and had to designate the corresponding pictures (for a similar methodology see Litt et al., 2019). Although visual-verbal PAL is usually expected to specifically assess this cross-modal mechanism (e.g. Chow, 2014; Clayton et al., 2020; Hulme et al., 2007; Warmington & Hulme, 2012; Windfuhr & Snowling, 2001), several studies have provided empirical results against such a view (Clayton et al., 2020; Elbro & Jensen, 2005; Litt et al., 2013; C. Liu et al., 2020; H.-C. Wang et al., 2017; Wass et al., 2019). The results of the present study are in line with the previous ones as the designation measure did not contribute uniquely to nonword or word reading. Despite the need to learn new associations to be able to read, cross-modal associative learning abilities do not account for interindividual differences in reading, at least in French.

Verbal Learning Mechanism

We evaluated the verbal learning mechanism with an auditory recognition task to assess whether the participants had learned the nonwords during the visual-verbal PAL task. As mentioned in the introduction, the role of the verbal learning mechanism in the relationship between visual-verbal

PAL and reading has received empirical support (Elbro & Jensen, 2005; Litt & Nation, 2014; Nielsen & Juul, 2016; Vellutino et al., 1995) and it has a theoretical basis (Elbro & de Jong, 2017).

The unique contribution of auditory recognition scores for word reading was low (only 1% of additional variance in the model) yet significant. The theoretical account proposed by Elbro and de Jong (2017) suggests that verbal learning is involved in orthographic learning via the learning of the 'spelling pronunciation' of complex graphemes or irregular words. Since French has a more consistent and predictable orthography than English (Borgwaldt et al., 2005; Schmalz et al., 2015; Seymour et al., 2003) and has fewer irregular words (Schmalz et al., 2015), verbal learning can be expected to be less decisive. However, French contains a few irregular words and verbal learning could also help to read words including contextual graphemes. As seen in the introduction, French contextual graphemes (e.g. the letter ‘g’) are read differently depending on the following vowels. For example, a ‘g’ followed by an ‘e’ or an ‘i’ is pronounced /ʒ/ while in other cases it is pronounced /g/. The word reading task used in the present study comprised 12 irregular words and 12 words with contextual graphemes (out of 48), which may have contributed to the relationship between visual-verbal PAL (naming measure) and reading. Since the regular words scores suffered from a ceiling effect, we were not able to compare the contribution of visual-verbal PAL (naming measure) in highly regular words and irregular words or words with contextual graphemes directly. It would thus be interesting to use a more sensitive measure in future studies (e.g. longer regular words with more complex syllable structures).

The Naming Measure

Until now, we have presented all the elements to understand the link between the classic visual-verbal PAL naming measure, and reading. The relationship between naming scores and reading cannot be accounted for by its cross-modal associative learning mechanism, as it was not involved in word and nonword reading in the present study. It may therefore be explained by the verbal learning mechanism. Interestingly, the naming measure explained a higher proportion of variance in reading than the auditory recognition measure (2% and 1%, respectively). Previous studies showed that verbal output drives, at least partially, the relationship between visual-verbal PAL and reading (Litt et al., 2013, 2019; Litt & Nation, 2014). One possible explanation is that verbal production (e.g. as in our naming task) may reflect verbal learning more sensitively than receptive measures (e.g. as in our auditory recognition task) in which slightly underspecified phonological representations do not necessarily impede task performance. Nevertheless, caution is warranted when comparing the difference between the proportion of variance explained by the naming measure and the auditory measure in the present study. The effect sizes were close, so their confidence intervals were likely to overlap.

IV.3.3.3 Follow-up Analyses on the Relationship Between Visual-verbal PAL and the Other Reading Predictors

As seen previously, visual-verbal PAL (naming measure) explains only 2% of additional variance in word reading in French, while it presents a rather moderate correlation with reading (almost as much as phonological awareness). Follow-up analyses aimed to explore which reading predictors were the most involved in paired associate learning and thus diminished its contribution to reading. A multilevel analysis indicated that phonological awareness, phonological short-term memory and vocabulary were the unique contributors of visual-verbal PAL.

Interestingly, rapid automatized naming was not a significant predictor of visual-verbal PAL. In fact, we have seen that they were not significantly correlated in the literature. Some authors suggested that both capture complementary abilities: while cross-modal PAL could capture the ability to create new associations in the memory (and, most of the time, new visual and verbal representations), rapid automatized naming could capture the efficiency of the link between these representations (Georgiou et al., 2017; Poulsen et al., 2015).

In summary, this analysis suggests that of the reading predictors examined in this section, the most important confounding variables in visual-verbal PAL are phonological awareness and phonological short-term memory. Vocabulary may be another confounding variable in opaque orthographies, such as English, in which it contributes more (Ricketts et al., 2007). Finally, the relationship between rapid automatized naming and visuo-verbal PAL was found to be highly inconsistent. We posit that it is more reasonable to control for it in the analyses, even though it might not be a substantial confounding variable.

IV.3.3.4 Limitations of the Present Study

The relationship between verbal learning and word reading skills may be bidirectional. Reading acquisition improves phonological processing (Cheung et al., 2001; Cheung & Chen, 2004; Landerl et al., 2019; Morais et al., 1979), which may in turn improve visual-verbal PAL abilities (de Jong et al., 2000). Complementary analyses showed that visual-verbal PAL contributes uniquely to word reading, when controlling for nonword reading in addition to the other predictors (see Model 20 in the Supplemental Material, in the Appendices V, p. 278). This suggests that the relationship between visual-verbal PAL and French word reading is not entirely due to the refinement of phonological representations during decoding development. A longitudinal study should examine this point more precisely in future studies.

IV.3.3.5 Generalizability

This study was conducted in an alphabetic orthography. However, writing systems vary according to: (1) mapping principles, i.e., types of written units connected to spoken units such as phonemes, syllables, morphemes, whole words; (2) graphemes number and complexity. Despite universal principles, each writing system has its own demands (Verhoeven & Perfetti, 2022). The results presented in this paper and in past literature on visual-verbal PAL may thus not apply to other writing systems (e.g. see studies on PAL in logographic orthographies: Georgiou et al., 2017; Ho, 2014; and a direct comparison between English and Cantonese: Chow, 2014).

Moreover, this study was conducted on first and second grade children. We did not detect any interaction between grade and visual-verbal PAL in the models designed to explain success in word and nonword reading. This suggests that the contribution of PAL is not substantially moderated by grade, although we should remain cautious as our sample was not designed to detect the effect of interaction terms (Brysbaert, 2019). Complementary analyses on Grade 1 children (N = 152) provided the same pattern of results (see Supplemental Material, Models 11, 12 and 13 in the Appendices V, p. 278). This suggests that the results of the present study reflect learning processes which are proper, at least, to Grade 1 children. Studies on children in higher grades may provide different results since word reading procedures or strategies change over time (see for example the longitudinal study of Poulsen and Elbro (2018) suggesting that PAL explain more variance in higher grades).

Finally, visual-verbal PAL often consists in repeated learning and naming phases (e.g. Warmington & Hulme, 2012). Our paradigm was quite different as we tested learning three times in each block (naming, auditory recognition and naming tasks). This could have had two effects: (1) to improve verbal learning because the children were exposed to verbal labels several times during the auditory recognition and naming tasks; (2) to reduce success in the naming task because the blocks of trials were spaced farther apart than in the conventional tasks. However, as our aim was to compare the contribution of each test score to reading and not to compare success in each type of test, this should not have affected our results.

IV.3.4. Conclusion

This study has shown that visual-verbal paired associate learning is a weak but significant correlate of word reading in French, which has a more transparent orthography than English, after controlling for all the strongest cognitive and linguistic predictors of reading. We also examined two mechanisms: cross-modal associative learning and verbal learning. Our data support the verbal account of Litt et al. (2013) and indicate that verbal learning abilities are at the core of the relation between visual-verbal PAL and reading. While the role of verbal learning has been considered more important for the purpose of irregular word reading (and probably words encompassing contextual graphemes in French) than regular word reading (Elbro & de Jong, 2017) it would be interesting to compare its contribution in reading both types of words in further studies. Experimental studies with specific training on learning the orthographic pronunciation of irregular words and words encompassing contextual graphemes could provide causal evidence of these mechanisms and help to develop applications in educational settings.

Main results

- Visual-verbal PAL has a unique contribution to decoding skills in French over the other main reading predictors and nonword reading skills.
- This contribution is more likely to be due to its verbal learning component.
- It was not possible to examine verbal learning more deeply in simple (with a regular orthography and no contextual graphemes) and complex word reading (regular word with contextual graphemes or irregular words).

IV.4. Examining Cross-modal and Verbal Learning in Simple and Complex Word Reading Skills in French Children

IV.4.1. Introduction

We have seen that visual-verbal PAL is an explanatory factor for word reading in first- and second-grade French children. This relationship can probably be explained by the 'verbal learning' component. Theoretically, this component is supposed to support the reading of complex words, i.e. words whose grapheme-phoneme conversions may be ambiguous such as irregular words or words with contextual graphemes (Elbro & de Jong, 2017). We should therefore observe a greater contribution from verbal learning in the scores for complex words than for simple words (perfect regular words without contextual graphemes).

However, in the previous study, it was not possible to compare the contribution of verbal learning in simple and complex words as the reading scores for simple words showed ceiling scores. In addition, some words in the regular word lists of the EVALEC test included contextual graphemes. Therefore, the primary aim of this new study was to improve the sensitivity of the reading measures to ensure that the contribution of verbal learning in simple and complex words was comparable, as well as to scrupulously respect the use or non-use of contextual graphemes in the different reading lists. To do so, we increased the number of items in the various tasks and asked the children to read as fast as possible, timing them to increase the difficulty of the tasks and provoke the appearance of errors. We took advantage of this to calculate fluency scores, i.e. the number of words correctly read in a given time. Fluency measures consider both accuracy and speed. So, if the accuracy measure could not distinguish the children from each other, they would at least be differentiated by reading speed. Note that this approach represented a real gamble given that Poulsen and Elbro (2018) showed that visual-verbal PAL may be less well associated with reading speed than with accuracy.

We took the opportunity of this new data collection to achieve the following secondary objectives:

(1) We again examined the cross-modal component of visual-verbal PAL by comparing the contribution of a verbal-verbal PAL and a visual-verbal PAL to decoding skills, drawing on studies by Hulme et al. (2007) or Litt et al. (2013). Verbal-verbal PAL tasks involve learning pairs of nonwords rather than pairs of images and nonwords. The mapping modality is therefore unimodal. As in visual-verbal PAL, participants are exposed to different pairs and then are asked to complete naming tasks. Unlike the visual-verbal PAL task, the naming tasks are based on verbal rather than visual stimuli. In other words, rather than asking children to name images, they are asked to find the word associated with the nonword presented to them (also called the 'response'). If the cross-modal component is important in explaining the relationship between visual-verbal PAL and reading, then verbal-verbal PAL should contribute less to reading scores. Alternatively, if verbal learning primarily explains the relationship between visual-verbal PAL, then we should expect verbal-verbal PAL to be a good contributor to reading scores too. As verbal-verbal PAL is often less successful, we felt it was important to reduce the number of items in both tasks to 3. We counterbalanced responses between participants (i.e., words learned and requested during naming tasks). We also counterbalanced the order of presentation of the tasks (some participants performed the visual-verbal PAL in the morning and others in the afternoon, and vice versa).

(2) we attempted to capture verbal learning with a verbal output measure in addition to the auditory recognition measure. Indeed, verbal output measures are better related to reading success than receptive one (Litt et al., 2019; Litt & Nation, 2014). To this end, we took naming measures with phonological cues during the visual-verbal and verbal-verbal PAL naming tasks. Phonological

cues consisted in presenting the first sound of the response nonword after a few seconds of stimulus presentation, even if the child had already answered. By presenting the first sound of the nonword, we wished to lift the constraint on cross-modal learning and hoped that the child would pronounce the expected nonword if he or she had learned it. We therefore expected the score for naming with a cue to be more predictive of reading success than either auditory recognition or the spontaneous naming score (i.e. the score corresponding to responses given before production of the phonemic cue).

IV.4.2. Method

IV.4.2.1 Participants

Participants were recruited through the T'PALCAP project (in French: 'Étude de la relation entre les composants des Tâches d'apprentissage de Paires Associées visuo-verbales et la réussite en Lecture de mots : Cross-modalité, Apprentissage verbal ou Production verbale ?'; reviewed by the ethic committee of the university of Lille, reference: 2022-642-S110). The initial sample consisted of 203 children according to the sample estimation carried out in the TANMALL project (see section II.1.2, p.56). Fourteen participants were excluded because of missing data on the variable of interest or because they did not complete the tasks correctly (see the Data Diagnostic section).

The final sample consisted of 186 grade 1 children (boys = 85; girls = 101; mean age = 82.11 months, SD = 3.79 months). Parental questionnaires provided additional information. Sixteen families reported that their child spoke a language other than French at home. Nineteen families reported that their child was attending a speech therapist during the study. Among these children, 13 were followed specifically for oral or written language difficulties.

Data Collection

Data were mainly collected between March and July 2023 in 15 French elementary schools at the Lille Academy in France. The children were tested in their school by the authors or by trained experimenters. The testing lasted around an hour and a half. They were divided into two sessions, one in the morning and one in the afternoon. The order of the tests was fixed (except for the paired associate learning tasks as described below) and was set to alternate between easy and more difficult tests to maintain motivation. Half of the participants performed the visual-verbal PAL task in the first session, and the other half performed the verbal-verbal PAL task. In the first session, participants performed the nonverbal abilities test, one of the PAL tests, nonword repetition and vocabulary. In the second session, they performed one of the PAL tasks, rapid automatized naming, phonological awareness, and reading tasks.

IV.4.2.2 Measures

Some measures were the same as in the TANMALL project : nonverbal abilities, phonological awareness, rapid automatized naming, nonword repetition. For a detailed description see the section “II.2. Measures”, p. 63).

The reading and visual-verbal PAL tasks were modified and a verbal-verbal PAL task was added to the protocol.

Word Reading

We created four lists of 24 words of increasing difficulty: (1) highly consistent words without digraphs and (2) highly consistent words with digraphs, both corresponding to 'simple words'; (3) words with contextual graphemes and (4) irregular words, both corresponding to 'complex words'. The lists were matched as closely as possible according to the following criteria: number of sounds, number of letters, number of oral syllables, number of written syllables, bigram frequency, and lexical frequency. Details are given in Table 41.

The following procedure was designed to obtain both fluency and accuracy scores directly for each list to minimize testing time and difficulty for the children. Each list was presented as a column on an A4 sheet of paper. Participants were asked to read each list as quickly as possible and were timed. They were stopped after 60 seconds unless they had not read the first 15 words of each list. In this case, the timer was stopped, the last word before 60 seconds was identified by the investigators, and the children were asked to read up to the fifteenth word. We chose to limit the accuracy measures to 15 words per list, as this was a good compromise for having enough items for simple and complex words (30 for each) and limiting the test duration for poor readers.

Table 41. *Characteristics of Word and Nonword Lists.*

	Accuracy (30 items per list)						Fluency (48 items per list)					
	S	*L*	*SyllOr*	*SyllEc*	*Big*	*FqLex*	*S*	*L*	*SyllOr*	*SyllEc*	*Big*	*FqLex*
Simple words	3.8	4.73	1.33	1.87	7725.05	134.34	4.48	5.58	1.67	2.21	7686.67	103.59
Complex words	3.73	4.77	1.57	1.87	6238.53	115.52	4.29	5.6	1.77	2.17	7042.58	107.61
All words	3.77	4.75	1.45	1.87	6981.79	124.93	4.4	5.59	1.72	2.19	7322.25	105.52
All nonwords	3.73	4.73	1.40	2.00	6766.33	_	4.38	5.57	1.67	2.28	7159.26	_

Note. L = mean number of letters, S = mean number of sounds, SyllOr = mean number of oral syllables, SyllEc = mean number of written syllables, Big = mean token bigram frequency, FqLex = mean word frequency
All values were reported from the database Manulex (Peereman et al., 2007). We considered grade 1 values.

Accuracy was defined as the number of words read correctly in the first 15 words of each list. The total accuracy score was the mean score across all lists (α = 0.94). The 'simple word accuracy score' was the mean of the first two lists (highly consistent words without digraphs, highly consistent words with digraphs; α = 0.87), and the 'complex word accuracy score' was the mean of the next two lists (words with contextual graphemes, irregular words; α = 0.90). Fluency was defined as the number of words read correctly within 60 seconds. If the 24 words were read before the end of the 60 seconds, we simply calculated the number of words read correctly over the reading time. Reliability was estimated by examining the correlations between the lists (see Table 42). The total fluency score was the mean score across all lists ($.84 < r < .91$, $p < .001$). The 'simple word fluency score' was the mean of the first two lists (highly consistent words without digraphs, highly consistent words with digraphs, r = .91, p <.001) and the 'complex word fluency score' was the mean of the next two lists (words with contextual graphemes, irregular words, r = .90, p <.001).

Nonword Reading

We created three lists of 24 nonwords of increasing difficulty were presented: (1) highly consistent words without digraphs, (2) highly consistent words with digraphs and (3) words with contextual graphemes. The lists were matched as closely as possible to each other and lists of word reading according to the following criteria: number of sounds, number of letters, number of oral syllables, number of written syllables and bigram frequency. Details are provided in the Table 41.

The testing and scoring procedures were exactly the same as for the word reading task. We calculated the total accuracy score by averaging the mean accuracy scores of the three lists (α = .86). The total fluency score was the mean fluency score of the three lists ($.80 < r < .85$, p <.001).

Table 42. *Correlation between reading lists.*

	1	2	3	4	5	6	7	8
1. Word reading fluency 1	_	.91	.89	.86	.98	.90	.83	.78
2. Word reading fluency 2	.91	_	.91	.84	.98	.90	.84	.81
3. Word reading fluency 3	.89	.91	_	.90	.92	.98	.75	.72
4. Word reading fluency 4	.86	.84	.90	_	.87	.97	.69	.63
5. Word reading fluency 1 and 2	.98	.98	.92	.87	_	.92	.86	.82
6. Word reading fluency 3 and 4	.90	.90	.98	.97	.92	_	.74	.70
7. Nonword reading fluency 1	.83	.84	.75	.69	.86	.74	_	.85
8. Nonword reading fluency 2	.78	.81	.72	.63	.82	.70	.85	_
9. Nonword reading fluency 3	.84	.85	.83	.75	.86	.82	.84	.80

Note. All correlations were significant at p <.001.

Paired Associate Learning Tasks

Participants performed two paired associative learning tasks. A visual-verbal task and a verbal-verbal task. In each task, they had to learn three pairs of stimuli and responses. The **stimuli** in the pairs were either pictures of imaginary animals (in the case of the **visual**-verbal PAL) or nonwords (in the case of the **verbal**-verbal PAL: /kɛ̃s/, /gɛd/, /nuʃ/). Verbal responses were two sets of CVC nonwords: (1) /vɔ̃p/, /saʁ/, /ʒøm/ and (2) /fãb/, /zit/, /ʃol/. The two sets were counterbalanced across participants and tasks. In version 1 of the PAL paradigms, the set 1 was associated with the pictures of imaginary animals, while the set 2 was associated with the nonword stimuli. Version 2 was reversed. The set 1 was associated with the nonword stimuli, while the set 2 was associated with the pictures of the imaginary animals. The following sections describe each paradigm in detail.

Visual-Verbal PAL

The children were told that they were going to learn the names of some funny animals. The task consisted of three phases repeated ten times (ten blocks): a learning phase, a naming phase, and an auditory recognition phase (see Figure 16 for an illustration).

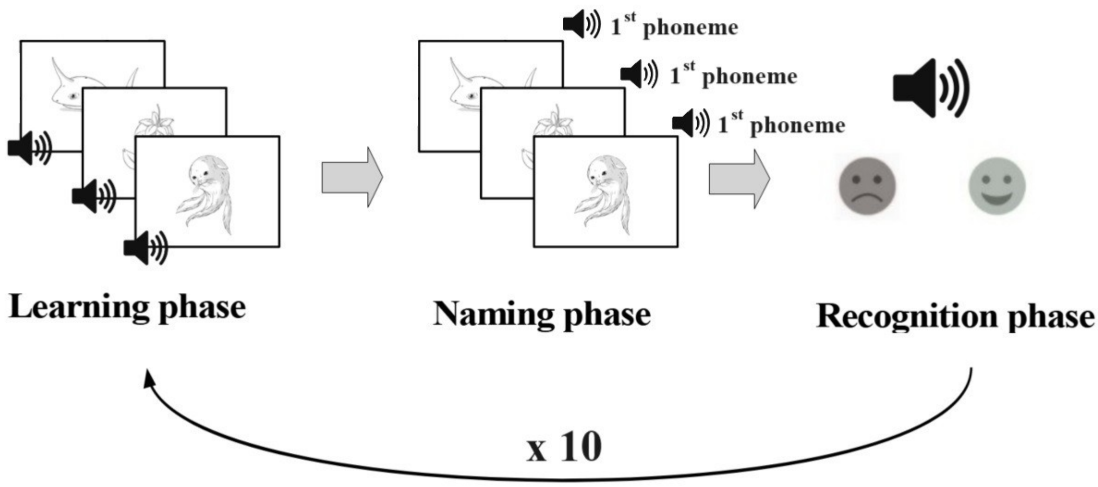
Learning Phase. Pictures appeared sequentially on the screen. The names were presented simultaneously and orally by the computer twice and had to be repeated by the children only the first time. No feedback was given. The order of presentation of the pairs was counterbalanced across participants but varied across blocks. No scores were calculated in these phases.

Naming Phase. Each picture appeared on the screen and had to be named by the participants. No feedback was provided. After five seconds, the first phoneme of the target nonword was presented. However, children were explicitly asked to respond as quickly as possible, and to try to give answers before and after the presentation of the first phoneme of the response word. The order of the presentation of the pairs was fixed across participants but varied across blocks. Two scores were calculated: (1) the “spontaneous naming score” corresponded to the total correct naming, before the first phoneme was provided, across blocks ($\alpha_{\text{version 1}} = .91$; $\alpha_{\text{version 2}} = .85$) ; (2) the “cued naming score” corresponded to the total number of correct naming, after the first phoneme was provided, across blocks ($\alpha_{\text{version 1}} = .90$; $\alpha_{\text{version 2}} = .83$). In each case, the maximum possible score was of 30. Note that if the children repeated the same error half the time during the learning phase (e.g.

pronouncing /ʒøn/ instead of /ʒøm/), we considered them to have named the picture correctly if they made the same 'error' during the naming phase.

Auditory Recognition Phase. In each block, the three target nonwords were presented among three distractors, that varied across blocks. The order of the presentation of the targets and distractors was fixed across participants but varied across blocks. The main rule for creating the distractors was to use the same sounds as those used in all targets (e.g. /sɔ̃p/ was created with the sounds of the targets /vɔ̃p/ and /saʁ/). Children responded by pressing a green key for targets or a red key for distractors on the keyboard. Scores corresponded to the sum of correct recognition of the targets and corrrect rejection of distractors ($\alpha_{\text{version 1}}$ = .86; $\alpha_{\text{version 2}}$ = .82).

Figure 16. *Illustration of the visual-verbal PAL paradigm.*



Verbal-Verbal PAL

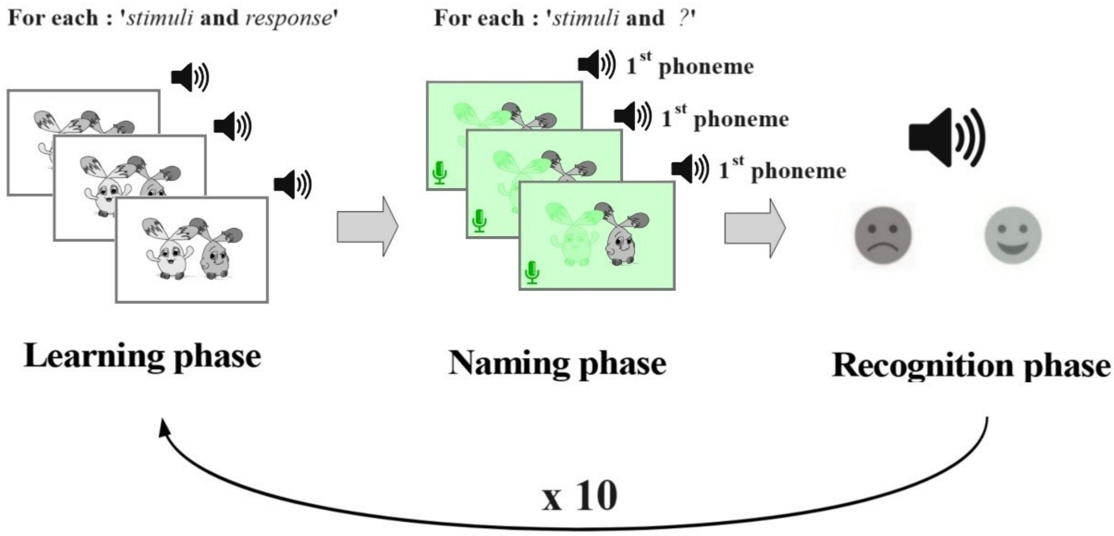
The children were told that they would learn the names of several alien brothers. The task was highly similar to the visual-verbal PAL paradigm. It consisted of three phases repeated ten times (ten blocks): a learning phase, a naming phase and an auditory recognition phase (see Figure 17 for an illustration).

Learning Phase. The pairs of aliens were presented to the children sequentially, with each pair presented as follows. First, the pairs of nonwords were presented. For example, '/nuʃ/ and /zit/'. Next, the first noun was presented and the participant was asked to complete with the second noun in the pair: for example, '/nuʃ/ and ?'. Finally, regardless of the accuracy of the response, both names were repeated: for example, '/nuʃ/ and /zit/'. No feedback was given. The order of presentation of the pairs was the same for all participants, but varied from block to block. No scores were calculated during these phases.

Naming Phase. Each first name of the pairs were presented as the following: e.g. '/nuʃ/ and ?'. The children were asked to complete the pairs by pronouncing the second name. No feedback was provided. After five seconds, the first phoneme of the target nonword was provided. The order of the presentation of the pairs was fixed across participants but varied across blocks. As in visual-verbal PAL, two scores were computed. (1) the 'spontaneous naming score' corresponded to the total number of correct naming before the first phoneme was presented, across blocks ($\alpha_{version\ 1}$ = .83; $\alpha_{version\ 2}$ = .87) ; (2) the "cued naming score" corresponded to the total number of correct naming, after the first phoneme was presented, across blocks ($\alpha_{version\ 1}$ = .85; $\alpha_{version\ 2}$ = .88). In each case, the maximum possible score is of 30. Again, if the children repeated the same error half the time during the learning phase (e.g. pronouncing /ʒøn/ instead of /ʒøm/), we considered them to have named the picture correctly if they made the same 'error' during the naming phase.

Auditory Recognition Phase. In each block, the three target nonwords were presented among three distractors that varied across blocks. The order of the presentation of the targets and distractors was fixed across participants but varied across blocks. The main rule for creating the distractors was to use the same sounds as that used in the targets. Children responded by pressing a green key for targets or a red key for distractors on the keyboard. Scores corresponded to the sum of good recognition of the targets and good rejection of distractors ($\alpha_{version\ 1}$ = .83; $\alpha_{version\ 2}$ = .87).

Figure 17. *Illustration of the verbal-verbal PAL paradigm.*



IV.4.2.3 Data Analyzes

All analyses were performed on R, version 4.2.2 (R Core Team, 2022) using the following packages: 'dplyr' for data manipulation, version 1.1.1 (Wickham et al., 2023) 'moments' for kurtosis and skewness values, version 0.14.1 (Kzmsta & Novomestky, 2015), 'ltm' for reliability analyses, version 1.2-0 (Rizopoulos, 2022), 'naniar' for missing values analyses, version 1.0.0 (Tierney & Cook, 2023), 'Hmisc' for simple correlations, version 4.7-2 (Harrell & Dupont, 2024), 'boot.pval' for bootstrap regression analyses, version 0.5 (Thulin, 2023).

IV.4.2.4 Data Diagnosis

Missing Data

We examined missing data on the social position indicator, nonverbal abilities, phonological awareness, rapid automatized naming, nonword repetition, vocabulary, visual-verbal PAL, verbal-verbal PAL, word and nonword reading scores. Fourteen participants were excluded because of missing data. The Little's test (Little, 1988) was used to test the randomness of missing values on all test measures. The null hypothesis was rejected, meaning that missing data were not completely at random, $\chi^2(123, 203) = 173.95$, $p < .001$. In other words, this suggests that the profile of the excluded children was different from that of the included children. The investigators' notes suggest that eight excluded participants had great difficulty completing tasks or staying focused. Two participants had missing data for technical reasons. No information is available for the remaining four participants. This should not have a major impact on the results, given the low number of missing data in the whole sample.

Outliers

Examination of univariate and multivariate outliers was performed following the guidelines of Aguinis et al. (2013). Univariate outliers were detected to identify and correct errors in the coded data. We used the standard deviation cut-off of 2.24 SD, following the simulations of Berger and Kiefer (2021). Three participants were excluded because they pressed the same button most of the time during the auditory recognition phase of the visual-verbal PAL task, indicating that they did not perform the task correctly. We chose not to exclude other univariate outliers because they do not necessarily impact the reliability of correlational analyses (for example, a participant may have very low values for both the dependent and predictor variables, which is relevant). We thus chose to detect significant influential points (or 'multivariate outliers') with standardized beta coefficients (DFBETAS) and excluded them. We excluded participants with DFBETAS higher or lower than 3 SD from the mean DFBETAS in each variable (for more details see Appendix IV). Traditionally, outliers are excluded prior to analysis. However, using the DFBETAS procedure implies that regression analyses have already been carried out (because we need the slope estimates). In addition, the outliers detected may differ from one model to another. We have therefore chosen to present the models estimated with and without outlier exclusion and to specify the number of outliers detected.

IV.4.2.5 Multiple Regression Analyses

Multiple linear regression analyses were used to model the relationship between the different factors identified and reading achievement. The p-values of the beta coefficients were estimated using a nonparametric bootstrap, which allowed us to dispense with the assumptions of normality and homoscedasticity of the residuals (Fox & Weisberg, 2002). We conducted analyses with 5000 bootstraps.

IV.4.3. Results

IV.4.3.1 Descriptive Statistics

The descriptive characteristics of each variable are shown in Table 43. The scores for simple words are better than those for complex words. Then, the naming scores were higher for visual-verbal PAL than for verbal-verbal PAL. The phonemic cues were moderately helpful. The difference between the scores with and without the phonemic cue was between three and four over 30 for both PAL paradigms. Interestingly, children obtained similar auditory recognition scores in both visual-verbal and verbal-verbal PAL. Finally, we did not find ceiling or floor effect for any variable.

IV.4.3.2 Simple Correlations

Correlations between predictors are shown in the Table 44. Correlations between predictors and reading measures were shown in the Table 45. All reading predictors are correlated with each other and with all reading measures. The social position indicator, age, and number of months in first grade had little or no correlation with the other predictors and reading scores. However, they were included in the regression models as a precaution.

Table 43. *Descriptive statistics*

Variable	Mean (SD)	min-max	Skewness	Kurtosis
Social Position Indicator	112.34 (10.31)	77.3-122.54	-0.87	3.33
Number of month of grade 1	8.24 (1.28)	6.12-10.03	-0.29	1.59
Age in months	82.11 (3.79)	72–97	0.11	3.28
Nonverbal abilities (max = 32)	19.99 (4.89)	6–32	-0.18	2.7
Phonological awareness (max = 34)	25.53 (5.93)	2–34	-1.1	3.93
Rapid automatized naming	33.48 (6.82)	21–71.5	1.52	7.8
Nonword repetition (max = 31)	25.69 (3.21)	15–31	-0.8	3.27
Vocabulary (max = 50)	29.42 (6.17)	5–45	-0.64	3.86
Visual-verbal PAL (naming; max = 30)	12.95 (6.57)	0–28	0.27	2.32
Visual-verbal PAL (naming cued; max = 30)	16.35 (6.24)	1–29	0.04	2.3
Visual-verbal PAL (auditory recognition; max = 60)	46.97 (7.27)	25–59	-0.68	3.15
Verbal-verbal PAL (naming; max = 30)	7.03 (5.06)	0-20	0.41	2.22
Verbal-verbal PAL (naming cued; max = 30)	11.27 (6.02)	0-27	0.14	2.43
Verbal-verbal PAL (auditory recognition; max = 60)	46.04 (7.79)	23-60	-0.66	3
Total word reading accuracy[a] (max = 15)	10.32 (2.91)	2.25-15	-0.56	2.5
Total word reading fluency[b]	0.33 (0.24)	0.04-1.37	1.62	6.13
Simple word reading accuracy (max = 15)	12.12 (2.63)	2-15	-1.18	4.08
Complex word reading accuracy (max = 15)	8.51 (3.49)	1.5-15	-0.24	2.08
Simple word reading fluency[a]	0.40 (0.25)	0.05-1.32	1.12	4.12
Complex word reading fluency[a]	0.26 (0.24)	0.01-1.43	2.26	9.18
Total nonword reading accuracy (max = 15)	9.82 (2.49)	3.67-14.33	-0.48	2.63
Total nonword reading fluency[a]	0.25 (0.12)	0.04-0.72	1.03	4.6

[a] number of words correctly read per list (on the first 15 words in each list)
[b] number of words correctly read per second, per list

Table 44. *Simple correlations between predictors.*

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. IPS	_	-.16*	-.04	.10	.14*	-.18*	.16*	.32***	.20**	.16*	.12	.09	.06
2. Number of months of grade 1	-.16*	_	.26***	.01	-.06	.04	-.03	-.05	-.07	.00	-.03	-.09	-.06
3. Age in months	-.04	.26***	_	.04	-.07	-.16*	-.21**	-.01	-.06	-.13	-.04	-.05	-.07
4. Nonverbal abilities	.10	.01	.04	_	.29***	-.13	.15*	.32***	.27***	.22**	.29***	.12	.24**
5. Phonological awareness	.14*	-.06	-.07	.29***	_	-.34***	.39***	.36***	.20**	.22**	.24***	.21**	.18*
6. Rapid automatized naming	-.18*	.04	-.16*	-.13	-.34***	_	-.13	-.25***	-.16*	-.10	-.07	-.12	-.10
7. Nonword repetition	.16*	-.03	-.21**	.15*	.39***	-.13	_	.34***	.19**	.22**	.26***	.25***	.26***
8. Vocabulary	.32***	-.05	-.01	.32***	.36***	-.25***	.34***	_	.26***	.25***	.36***	.18*	.14
9. Visual-verbal PAL (naming)	.20**	-.07	-.06	.27***	.20**	-.16*	.19**	.26***	_	.88***	.56***	.46***	.51***
10. Visual-verbal PAL (naming cued)	.16*	.00	-.13	.22**	.22**	-.10	.22**	.25***	.88***	_	.59***	.41***	.50***
11. Visual-verbal PAL (auditory recognition)	.12	-.03	-.04	.29***	.24***	-.07	.26***	.36***	.56***	.59***	_	.39***	.44***
12. Verbal-verbal PAL (naming)	.09	-.09	-.05	.12	.21**	-.12	.25***	.18*	.46***	.41***	.39***	_	.81***
13. Verbal-verbal PAL (naming cued)	.06	-.06	-.07	.24**	.18*	-.10	.26***	.14	.51***	.50***	.44***	.81***	_
14. Verbal-verbal PAL (auditory recognition)	.16*	-.12	.01	.20**	.13	-.12	.19**	.26***	.27***	.28***	.49***	.35***	.45***

Table 45. *Simple correlation between reading outcomes and predictors.*

	Word reading accuracy	Word reading fluency	Simple word reading accuracy	Complex word reading accuracy	Simple word reading fluency	Complex word reading fluency
IPS	.06	.16*	0.06	0.06	0.17*	0.14
Number of month of grade 1	.07	.07	0	0.11	0.03	0.11
Age in months	.15*	.13	0.09	0.18*	0.13	0.11
Nonverbal abilities	.42***	.39***	0.35***	0.44***	0.40***	0.37***
Phonological awareness	.50***	.34***	0.51***	0.45***	0.36***	0.31***
Rapid automatized naming	-.47***	-.46***	-0.44***	-0.46***	-0.49***	-0.40***
Nonword repetition	.25***	.26***	0.26***	0.22**	0.26***	0.25***
Vocabulary	.23**	.27***	0.18*	0.25***	0.26***	0.27***
Visual-verbal PAL (naming)	.32***	.38***	0.29***	0.31***	0.39***	0.36***
Visual-verbal PAL (naming cued)	.28***	.34***	0.26***	0.27***	0.34***	0.32***
Visual-verbal PAL (auditory recognition)	.36***	.36***	0.32***	0.36***	0.36***	0.35***
Verbal-verbal PAL (naming)	.20**	.30***	0.21**	0.17*	0.29***	0.29***
Verbal-verbal PAL (naming cued)	.23**	.33***	0.24**	0.21**	0.34***	0.31***
Verbal-verbal PAL (auditory recognition)	.18*	.22**	0.18*	0.17*	0.22**	0.22**

IV.4.3.3 Regression Analyses

We first tested the contribution of PAL measures to accuracy and fluency measures of word and nonword reading without distinguishing between simple and complex words. The model for the whole word and nonword scores (accuracy and fluency, without distinguishing simple and complex words) were reported in Tables 46 and 47, respectively. We reproduce the results obtained in the previous chapter. The naming measure of the visual-verbal PAL contributed to nonword reading accuracy and fluency. It also contributed to both word accuracy and fluency. To test whether the relationship with word reading scores was not mediated by the relationship with nonword reading scores, we tested the contribution of the naming measure of visual-verbal PAL to word reading scores while controlling for nonword reading scores. The contribution of the naming measure of visual-verbal PAL remained significant. Besides, the naming measure of verbal-verbal PAL contributed to word reading fluency scores, even after controlling for nonword reading fluency scores. However, it did not contribute to accuracy measures or to nonword reading scores.

To test more directly the verbal learning component of the different PAL measures, we used cued naming measures corresponding to the number of correct naming when children were given the first sound of each response. When the cued naming scores were entered into the models explaining the word reading scores, they eliminated the contribution of the simple naming measure. The verbal-verbal cued naming measure contributed more than the simple naming measure to word reading fluency scores. It also contributed significantly to nonword reading accuracy and fluency scores, whereas the simple naming measure was not a significant contributor. To test the verbal learning component of PAL, we also used auditory recognition tasks of the nonword responses. The auditory recognition score of verbal-verbal PAL contributed to the word and nonword reading accuracy and fluency scores over the visual-verbal PAL naming scores. However, the verbal-verbal PAL auditory recognition score only contributed to nonword reading accuracy.

Table 46. *Contribution of PAL tasks to Word Reading Skills.*

	Word reading accuracy						**Word reading fluency**					
	β	***p***	***ΔR^2***	***β***	***p***	***ΔR^2***	***β***	***p***	***ΔR^2***	***β***	***p***	***ΔR^2***
Step 1	R^2_{adj} = 44.10			R^2_{adj} = 55.38 E = 15			R^2_{adj} = 33.73			R^2_{adj} = 43.63 E = 15		
(Intercept)	0.00	.998		-0.04	.451		0	.921		-0.14	.005	
IPS	-0.06	.214	0.06	-0.11	.023	0.79	0.03	.555	-0.26	0.03	.526	-0.25
Age in months	0.12	.072	1.06	0.09	.124	0.41	0.1	.203	0.5	0.1	.051	0.83
Nonverbal abilities	0.30	.000	7.59	0.38	.000	13.74	0.3	.000	7.56	0.27	.000	9.58
Phonological awareness	0.31	.002	6.65	0.25	.001	3.74	0.08	.251	0.04	0.08	.113	0.23
Rapid automatized naming	-0.33	.000	9.00	-0.39	.000	12.62	-0.35	.000	10.14	-0.38	.000	15.23
Nonword repetition	0.10	.101	0.53	0.10	.072	0.51	0.16	.006	1.64	0.13	.003	1.68
Vocabulary	-0.08	.342	0.11	-0.01	.861	-0.26	-0.01	.979	-0.37	0.03	.590	-0.28
Step 2	R^2_{adj} = 46.31			R^2_{adj} = 58.34 E = 18			R^2_{adj} = 38.21			R^2_{adj} = 46.96 E = 17		
Visual-verbal PAL (naming)	0.17	.005	2.21	0.15	.003	1.8	0.23	.001	4.48	0.19	.001	5.11
Step 2	R^2_{adj} = 46.07			R^2_{adj} = 57.40 E = 19			R^2_{adj} = 38.13			R^2_{adj} = 51.66 E = 20		
Visual-verbal PAL (naming)	0.12	.319	0.03	0.07	.497	-0.16	0.14	.248	0.08	0.17	.058	0.60
Visual-verbal PAL (naming cued)	0.05	.665	-0.24	0.12	.256	0.03	0.11	.298	-0.08	0.08	.299	-0.10
Step 2	R^2_{adj} = 48.59			R^2_{adj} = 59.04 E = 16			R^2_{adj} = 39.39			R^2_{adj} = 48.82 E = 18		
Visual-verbal PAL (naming)	0.07	.246	0.06	0.09	.157	0.24	0.16	.019	1.36	0.12	.039	1.36
Visual-verbal PAL (recognition)	0.20	.003	2.28	0.17	.003	1.60	0.16	.010	1.19	0.12	.010	1.38
Step 2	R^2_{adj} = 71.98			R^2_{adj} = 80.75 E = 16			R^2_{adj} = 75.47			R^2_{adj} = 86.39 E = 11		
Nonword reading accuracy	0.67	.000	25.67	0.66	.000	28.93	_	_	_	_	_	_
Nonword reading fluency	_	_	_	_	_	_	0.80	.000	37.27	0.79	.000	43.34
Visual-verbal PAL (naming)	0.06	.104	0.19	0.09	.003	0.69	0.09	.034	0.58	0.07	.003	0.54
Step 2	R^2_{adj} = 44.14			R^2_{adj} = 56.30 E = 15			R^2_{adj} = 36.48			R^2_{adj} = 46.62 E = 13		
Verbal-verbal PAL (naming)	0.06	.274	0.04	0.09	.072	0.46	0.18	.004	2.75	0.15	.005	2.85
Step 2	R^2_{adj} = 44.36			R^2_{adj} = 57.42 E = 17			R^2_{adj} = 36.88			R^2_{adj} = 45.64 E = 15		
Verbal-verbal PAL (naming)	_	_	_	_	_	_	0.06	.576	-0.23	-0.02	.799	-0.32
Verbal-verbal PAL (naming cued)	0.08	.152	0.26	0.06	.161	0.14	0.15	.136	0.40	0.18	.012	1.63
Step 2	R^2_{adj} = 44.14			R^2_{adj} = 56.30 E = 17			R^2_{adj} = 34.03			R^2_{adj} = 44.79 E = 17		
Verbal-verbal PAL (recognition)	0.06	.280	0.03	0.03	.507	-0.17	0.09	.194	0.3	0.03	.546	-0.24
Step 2							R^2_{adj} = 75.76			R^2_{adj} = 85.97 E = 13		
Nonword reading fluency	_	_	_	_	_	_	0.81	.000	39.28	0.80	.000	46.36
Verbal-verbal PAL (naming)	_	_	_	_	_	_	0.10	.018	0.86	0.06	.020	0.44

Note. R^2_{adj} = R^2 adjusted; E = number of participants excluded based on their DFBETAS.

Table 47. *Contribution of PAL Tasks to Nonword Reading Skills.*

	Nonword reading accuracy						**Nonword reading fluency**					
	β	***p***	***ΔR²***	***β***	***p***	***ΔR²***	***β***	***p***	***ΔR²***	***β***	***p***	***ΔR²***
Step 1	R^2_{adj} = 42.65			R^2_{adj} = E = 17			R^2_{adj} = 39.61			R^2_{adj} = 48.50 E = 15		
(Intercept)	0.00	.982		0.02	.679		0.00	.943		-0.08	.093	
IPS	-0.07	.199	0.10	-0.03	.594	-0.24	0.02	.644	-0.29	0.04	.338	-0.14
Age in months	0.03	.671	-0.27	0.05	.434	-0.07	0.10	.134	0.60	0.12	.031	0.99
Nonverbal abilities	0.24	.001	4.90	0.27	.000	7.41	0.22	.001	3.92	0.22	.000	4.85
Phonological awareness	0.34	.001	8.03	0.26	.000	4.28	0.15	.019	1.29	0.11	.065	0.45
Rapid automatized naming	-0.34	.000	9.52	-0.44	.000	15.38	-0.44	.000	15.79	-0.53	.000	22.96
Nonword repetition	0.05	.404	-0.16	0.03	.497	-0.21	0.12	.032	0.71	0.12	.011	1.04
Vocabulary	-0.04	.626	-0.21	0.01	.857	-0.31	0.00	.995	-0.34	0.05	.355	-0.12
Step 2	R^2_{adj} = 42.25			R^2_{adj} = 51.87 E = 17			R^2_{adj} = 42.04			R^2_{adj} = 55.34 E = 21		
Visual-verbal PAL (naming)	0.16	.014	1.86	0.14	.008	1.79	0.18	.002	2.43	0.17	.000	3.07
Step 2	R^2_{adj} = 41.95			R^2_{adj} = 52.48 E = 17			R^2_{adj} = 41.79			R^2_{adj} = 52.71 E = 18		
Visual-verbal PAL (naming)	0.13	.377	0.03	0.10	.336	-0.07	0.12	.284	0.02	0.14	.155	0.22
Visual-verbal PAL (naming cued)	0.03	.779	-0.30	0.05	.670	-0.25	0.06	.582	-0.25	0.06	.455	-0.19
Step 2	R^2_{adj} = 45.87			R^2_{adj} = 59.07 E = 19			R^2_{adj} = 43.87			R^2_{adj} = 54.86 E = 18		
Visual-verbal PAL (naming)	0.04	.588	-0.21	-0.01	.909	-0.26	0.09	.216	0.20	0.10	.087	0.60
Visual-verbal PAL (recognition)	0.25	.001	3.62	0.32	.000	6.69	0.18	.009	1.83	0.15	.003	1.43
Step 2	R^2_{adj} = 40.13			R^2_{adj} = 48.00 E = 16			R^2_{adj} = 40.15			R^2_{adj} = 50.37 E = 17		
Verbal-verbal PAL (naming)	0.03	.681	-0.27	0.02	.685	-0.27	0.10	.119	0.54	0.06	.196	0.16
Step 2	R^2_{adj} = 40.26			R^2_{adj} = 49.83 E = 17			R^2_{adj} = 40.21			R^2_{adj} = 51.17 E = 18		
Verbal-verbal PAL (naming cued)	0.05	.004	-0.14	0.06	.231	0.10	0.02	.096	0.60	0.02	.048	0.65
Step 2	R^2_{adj} = 41.48			R^2_{adj} = 52.48 E = 17			R^2_{adj} = 39.69			R^2_{adj} = 49.55 E = 16		
Verbal-verbal PAL (recognition)	0.12	.052	1.09	0.16	.003	2.09	0.07	.325	0.08	0.03	.478	-0.20

Note. R^2_{adj} = R^2 adjusted; E = number of participants excluded based on their DFBETAS.

The main aim of this experiment was to determine if the contribution of verbal learning was specific to complex words reading. The Table 48 shows the contribution of the various measures of PAL to simple word reading. The pattern of results was identical than this presented above for total word reading scores. The Table 49 shows the contribution of various measures of PAL in complex word reading scores, controlling for simple word reading scores. No verbal learning measure contributes to complex word reading above simple word reading except the naming measures of visual-verbal PAL.

Table 48. *Hierarchical regression comparing the contribution of various PAL measures on simple word reading outcomes.*

	Simple word reading accuracy						**Simple word reading fluency**					
	β	***p***	***ΔR²***	***β***	***p***	***ΔR²***	***β***	***p***	***ΔR²***	***β***	***p***	***ΔR²***
Step 1	R^2_{adj} = 38.71			R^2_{adj} = 51.23 E = 16			R^2_{adj} = 37.31			R^2_{adj} = 43.90 E = 15		
(Intercept)	0	.979		0.04	.448		0.00	.951		-0.12	.012	
IPS	-0.05	.401	-0.12	-0.06	.171	0.09	0.05	.368	-0.13	0.04	.364	-0.13
Age in months	0.08	.275	0.2	0.12	.011	1.14	0.10	.189	0.52	0.10	.069	0.84
Nonverbal abilities	0.23	.001	4.5	0.24	.000	6.49	0.31	.000	7.96	0.25	.000	6.62
Phonological awareness	0.36	.001	8.85	0.23	.003	3.5	0.09	.208	0.18	0.08	.128	0.20
Rapid automatized naming	-0.3	.000	7.51	-0.38	.000	14.29	-0.39	.000	12.38	-0.45	.000	18.21
Nonword repetition	0.11	.113	0.59	0.16	.004	2.12	0.16	.005	1.71	0.13	.005	1.49
Vocabulary	-0.12	.171	0.71	-0.04	.511	-0.15	-0.04	.643	-0.24	0.03	.607	-0.29
Step 2	R^2_{adj} = 40.50			R^2_{adj} = 52.28 E = 17			R^2_{adj} = 41.88			R^2_{adj} = 52.51 E = 18		
Visual-verbal PAL (naming)	0.15	.014	1.79	0.15	.005	2.04	0.23	.000	4.58	0.23	.000	6.16
Step 2	R^2_{adj} = 40.16			R^2_{adj} = 53.41 E = 19			R^2_{adj} = 41.53			R^2_{adj} = 51.31 E = 16		
Visual-verbal PAL (naming cued)	0.14	.024	1.45	0.14	.006	1.76	0.22	.001	4.22	0.23	.000	5.59
Step 2	R^2_{adj} = 42.1			R^2_{adj} = 54.48 E = 20			R^2_{adj} = 41.79			R^2_{adj} = 49.56 E = 15		
Visual-verbal PAL (recognition)	0.21	.000	3.4	0.18	.001	3	0.24	.000	4.48	0.22	.000	5.51
Step 2	R^2_{adj} = 38.97			R^2_{adj} = 51.03 E = 16			R^2_{adj} = 39.74			R^2_{adj} = 47.20 E = 14		
Verbal-verbal PAL (naming)	0.08	.194	0.26	0.03	.491	-0.2	0.17	.006	2.44	0.16	.002	2.78
Step 2	R^2_{adj} = 39.20			R^2_{adj} = 51.11 E = 16			R^2_{adj} = 40.90			R^2_{adj} = 46.89 E = 16		
Verbal-verbal PAL (naming cued)	0.1	.093	0.49	0.04	.395	-0.12	0.21	.001	3.59	0.21	.000	5.25
Step 2	R^2_{adj} = 38.91			R^2_{adj} = 54.34 E = 21			R^2_{adj} = 37.55			R^2_{adj} = 45.54 E = 18		
Verbal-verbal PAL (recognition)	0.08	.177	0.2	0.05	.272	0.03	0.08	.205	0.25	0.05	.301	-0.06

Note. R^2_{adj} = R^2 $_{adj}$usted; E = number of participants excluded based on their DFBETAS.

Table 49. *Hierarchical regression comparing the contribution of various PAL measures on complex word reading outcomes controlling for simple word reading outcomes.*

	Complex word reading accuracy						Complex word reading fluency					
	β	***p***	***ΔR²***	***β***	***p***	***ΔR²***	***β***	***p***	***ΔR²***	***β***	***p***	***ΔR²***
Step 1	R^2_{adj} = 68.51			R^2_{adj} = 74.86 E = 17			R^2_{adj} = 84.88			R^2_{adj} = 89.09 E = 12		
(Intercept)	0.00	.935		0.01	.887		0	.940		-0.05	.006	
IPS	-0.04	.440	-0.06	-0.04	.374	-0.05	-0.03	.302	-0.01	-0.03	.109	0.08
Age in months	0.09	.035	0.64	0.08	.079	0.45	0	.997	-0.09	0	.976	-0.07
Nonverbal abilities	0.17	.001	2.08	0.20	.000	3.32	-0.02	.663	-0.07	0.02	.306	-0.02
Phonological awareness	0.01	.811	-0.17	0.02	.560	-0.12	-0.02	.433	-0.05	-0.01	.733	-0.06
Rapid automatized naming	-0.12	.015	0.90	-0.11	.028	0.65	0.07	.011	0.26	0.05	.009	0.28
Nonword repetition	0.02	.716	-0.15	0.01	.847	-0.16	0	.968	-0.09	0	.919	-0.07
Vocabulary	0.04	.365	-0.04	0.08	.056	0.26	0.06	.027	0.21	0.06	.003	0.36
Simple word reading accuracy	0.67	.000	27.27	0.65	.000	24.19	_	_	_	_	_	_
Simple word reading fluency	_	_	_	_	_	_	0.96	.000	57.55	0.82	.000	54.62
Step 2	R^2_{adj} = 68.66			R^2_{adj} = 75.02 E = 20			R^2_{adj} = 84.79			R^2_{adj} = 89.10 E = 12		
Visual-verbal PAL (naming)	0.06	.128	0.16	0.08	.019	0.55	0.00	.857	-0.08	-0.01	.278	0.00
Step 2	R^2_{adj} = 68.53			R^2_{adj} = 75.45 E = 22			R^2_{adj} = 84.73			R^2_{adj} = 89.51 E = 15		
Visual-verbal PAL (naming cued)	0.06	.106	0.19	0.09	.007	0.69	0.00	.920	-0.09	0.00	.358	-0.02
Step 2	R^2_{adj} = 69.16			R^2_{adj} = 77.33 E = 22			R^2_{adj} = 84.79			R^2_{adj} = 89.06 E = 12		
Visual-verbal PAL (recognition)	0.10	.032	0.65	0.07	.095	0.25	0.00	.796	-0.08	0.00	.386	-0.03
Step 2	R^2_{adj} = 68.34			R^2_{adj} = 74.43 E = 18			R^2_{adj} = 84.85			R^2_{adj} = 89.56 E = 12		
Verbal-verbal PAL (naming)	-0.01	.814	-0.17	0.02	.661	-0.13	0.03	.502	-0.03	-0.01	.750	-0.06
Step 2	R^2_{adj} = 68.33			R^2_{adj} = 75.79 E = 21			R^2_{adj} = 84.80			R^2_{adj} = 89.44 E = 13		
Verbal-verbal PAL (naming cued)	0.00	.962	-0.18	0.04	.262	0.01	-0.01	.798	-0.08	-0.04	0.07	0.13
Step 2	R^2_{adj} = 68.33			R^2_{adj} = 76.30 E = 23			R^2_{adj} = 84.80			R^2_{adj} = 89.26 E = 14		
Verbal-verbal PAL (recognition)	-0.01	.810	-0.17	0.00	.970	-0.15	0.01	.658	-0.07	0.00	.888	-0.07

Note. R^2_{adj} = R^2 adjusted; E = number of participants excluded based on their DFBETAS.

IV.4.4. Discussion

The purpose of this study was to better understand the contribution of visual-verbal PAL to word reading skills in beginning French readers. More specifically, we focused on the role of its verbal learning component in simple and complex word reading. By complex word reading, we meant irregular words or words with contextual graphemes that may require the support of verbal learning to be read, in line with the framework of Elbro and de Jong (2017). We studied verbal learning by means of a cued naming score and an auditory recognition score obtained thanks to the PAL paradigms. Thus, we hypothesized that verbal learning would contribute more to complex word reading than to simple word reading. Since simple word reading suffered from a ceiling effect in our previous experiment, we used fluency measures that should differentiate children even if they had a good level of accuracy. This was to prevent differences in sensitivity between readings from distorting the comparison. In addition, we also administered a verbal-verbal PAL task to examine in a different way than in our previous study the role of cross-modal learning in the relationship between visual-verbal PAL and decoding skills. Given that verbal learning was considered to be central to this relationship, we did not expect there to be a difference between the contribution of verbal-verbal PAL and visual-verbal PAL in reading scores.

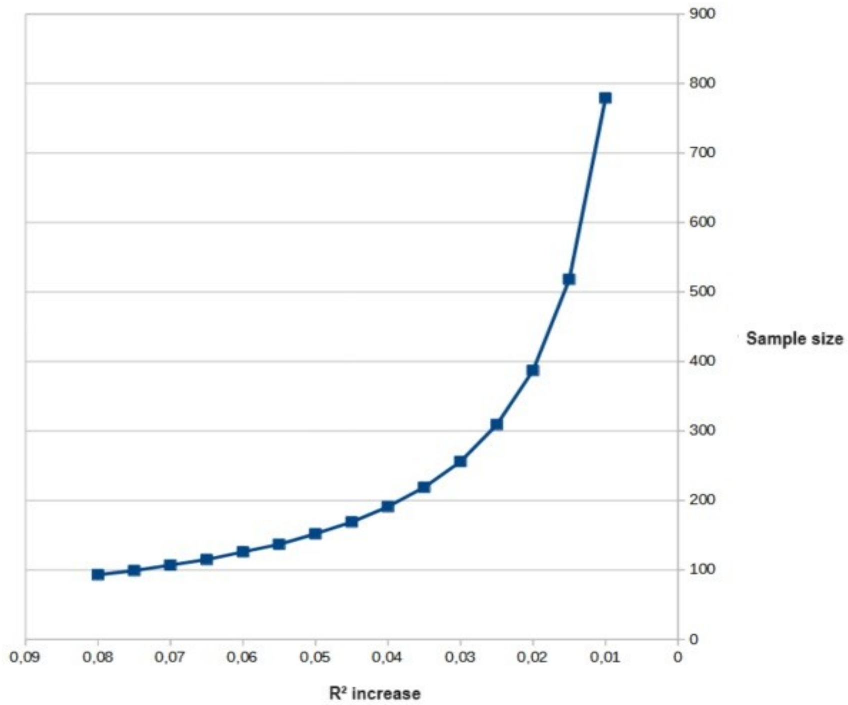
IV.4.4.1 The Contributions of Visual-verbal and Verbal-verbal Scores to Word and Nonword reading Scores

We first attempted to replicate the results obtained in the previous chapter to confirm whether the verbal learning component of visual-verbal PAL contributed to word reading scores. Indeed, visual-verbal PAL was a significant contributor to reading ability over and above nonverbal abilities, phonological awareness, rapid automatized naming, phonological short-term memory, and vocabulary. Both specific verbal learning measures (the cued naming and auditory recognition measures) contributed to word reading. Note that this contribution was not mediated by nonword reading scores. Thus, we suggest that visual-verbal PAL has a specific relationship with word reading. This seems to be mainly due to its verbal learning component. However, additional results cast doubt on this latter conclusion.

Interestingly, verbal-verbal PAL (naming score) contributed to reading fluency scores over nonword reading scores. However, it did not contribute to reading accuracy scores. This is quite unexpected since verbal-verbal PAL was found to correlate with word reading skills as well as or better than visual-verbal PAL in previous studies (Clayton et al., 2018; Litt et al., 2013; H.-C. Wang et al., 2017; Wass et al., 2019; but see Hulme et al., 2007). Even more troubling, the auditory recognition score on the verbal-verbal PAL task, unlike the auditory recognition score on the visual-verbal PAL task, did not contribute to any reading outcome, even though they were designed to test exactly the same verbal learning mechanisms.

We could interpret these results in two ways. First, on a statistical basis, we hypothesized that differences in the contribution of visual-verbal and verbal-verbal PAL naming scores was due to the fact that the sensitivity of the verbal-verbal PAL naming score may be weaker than that of the visual-verbal PAL task. Indeed, verbal-verbal PAL naming scores presented almost a floor effect (the mean was equal to the standard deviation and the distribution was skewed to the right). However, this explanation cannot apply to the cued naming or auditory recognition scores of the verbal-verbal PAL because their distributions were much more symmetrical. Another statistical explanation is that power was limited despite the large number of participants. In fact, power is not ‘absolute’. It depends on the targeted effect size. The Figure 18 shows the number of participants needed to detect different R^2 increases with 80% power. We can see that we had enough power to detect an R^2 increase of 4%. In the literature, the contribution of visual-verbal PAL to word reading was between 2% and 6% (Poulsen & Elbro, 2018; Windfuhr & Snowling, 2001), which means that we had just enough power. Ideally, we should have recruited more participants than estimated, as the effect size might have been overestimated in the literature. Indeed, if the actual effect size is less than that reported in the literature, it is possible that the pattern of effects was incomplete because our power was overestimated (Brysbaert, 2019).

Figure 18. *Sample size estimation in function of expected R^2 increase.*



Second, on a theoretical basis, the difference between verbal learning in verbal-verbal PAL and visual-verbal PAL depends on the modality of the mapping in both tasks, which raises several questions: To what extent does the modality of mapping influence verbal learning of the response in cross-modal PAL? Why should auditory recognition of the verbal response be influenced by the modality of mapping? Does this mean that cross-modality is important to explain the link between visual-verbal PAL and word reading? The latter account would imply that cross-modality has a sufficiently strong effect on auditory recognition to have an indirect contribution to word reading. In the following, we offer some suggestions for future research.

To minimize testing time, we chose to measure verbal and cross-modal learning with alternating phases of exposure, naming, and auditory recognition. However, this procedure did not allow us to conclude the absence of a role for cross-modality in verbal learning in visual-verbal PAL because nonwords were systematically presented with pictures. We suggest that in further studies, nonwords should be learned before cross-modal or unimodal learning (see Litt & Nation, 2014; H.-C. Wang et al., 2015; S. Wang & Allen, 2018). Interestingly, Litt and Nation (2014) showed that differences in visual-verbal PAL between good and poor readers disappeared when verbal learning of responses was controlled for in the analyses. They measured verbal learning prior to the binding conditions. To do this, they presented all the nonwords sequentially and then asked the children to recall them immediately without corrective feedback. This procedure was repeated several times. The total number of correct recalls constituted the verbal learning score. Importantly, nonwords were not presented with pictures in this phase, so we cannot assume that verbal learning was influenced by cross-modality. Further studies could adopt a similar paradigm for visual-verbal and verbal-verbal PAL with additional precautions such as using a large sample size, controlling for various reading predictors, controlling for nonword reading skills to determine the specific variance in word reading skills and, ideally, in longitudinal design to prevent from the possible causal influence of reading skills on verbal learning.

Note that these results, however, did not reject the hypotheses that verbal learning may, at least partially, explain the relationship between visual-verbal PAL and reading. Indeed, the naming measures of verbal-verbal PAL contributed to word reading fluency. In addition, the cued naming score contributed above the naming score in word reading fluency.

IV.4.4.2 Contribution of Verbal Learning to Complex Word Reading Scores

Following Elbro and de Jong (2017) framework, we hypothesized that verbal learning would contribute more to complex word reading than to simple word reading. The results are equivocal.

The naming and cued naming scores of the visual-verbal PAL contributed significantly to complex word reading accuracy, but not to complex word reading fluency, over simple word measures. However, neither the auditory recognition score of visual-verbal PAL contributes to complex word reading scores, nor do verbal-verbal PAL scores over the simple word reading scores. There are at least two possible explanations for this.

First, the effect may be marginal or nonexistent in French. As argued in previous chapters, reading may explain the relationship between verbal learning and word reading scores. Indeed, French has a more transparent orthography than English (e.g. Schmalz et al., 2015; Seymour et al., 2003). Children then have fewer opportunities to consciously develop strategies that involve learning the 'spelling pronunciation' of irregular words (assuming this can be considered a 'strategy' rather than an automatic mechanism, which is debatable). It should also be noted that the evidence for the importance of 'orthographic pronunciation' in decoding is, as far as we know, all indirect. Elbro and de Jong (2017) presented three indirect arguments: first, 'spelling pronunciation' learning is analogous to dialect learning, which is easy for humans; second, adults consciously rely on 'spelling pronunciation' to spell words; and third, 'spelling pronunciation' is learned automatically, even if it is not trained. In addition, research citing the article of Elbro and de Jong (2017) have essentially carried on 'Set for Variability', i.e., the ability to retrieve the phonological representation of a word based on a degraded phonological form (e.g. see A. Edwards et al., 2020; Savage et al., 2018; Steacy et al., 2023). According to Steacy et al. (2023), 'Set for Variability' has often been operationalized with tasks that require participants to infer the correct phonological representation of a word from its orally presented 'spelling pronunciation' (but see Elbro et al., 2012). Consequently, the distinction between the role of learning 'spelling pronunciation' and the 'Set for Variability' ability is difficult to disentangle. Direct evidence for the support of 'spelling pronunciation' learning for word reading can be provided by training studies. Participants could be trained to read new irregular words by having them orally associate their 'spelling pronunciation' with the correct one. The performance can be compared to a control group that learns irregular words using other teaching strategies (e.g. look and say or 'Set for Variability').

Secondly, the fact that we detected no specific effect of verbal learning on the reading of complex words compared to the reading of simple words may simply mean that verbal learning is just as important for simple words as for complex words. In French, when we pronounce a consonant in isolation, we often associate it with a vowel as an [ə] or even an [œ] (e.g. the letter ’m' might sound like [mœ]). Then, when children are taught to associate an ’m' with an 'a', we might hypothesize that they learn a 'spelling pronunciation' as [məa] as an alternative to the correct syllable [ma]. Thus, verbal learning may also be important at the sublexical level, even for highly regular grapheme-to-phoneme conversions. Further studies could directly test this hypothesis by explicitly teaching kindergarten children this type of ‘syllabic spelling pronunciation’ associated with target oral syllables. Reading improvement could be compared with that of a control group in which the ‘spelling pronunciation’ is never pronounced by the experimenter.

In conclusion, although this study has defied our expectations, it has at least allowed us to clarify how cross-modal and verbal components can be tested in future studies, and to suggest research perspectives on the link between 'spelling pronunciation' learning, phonological recoding, and complex word reading.

Main results

- This study confirms the role of verbal learning in the decoding skills of first-grade French students.
- No specific contribution of verbal learning was detected for complex word reading.
- A causal relationship from verbal learning should to be tested with a longitudinal or a training design.
- Contrary to our expectations, the cross-modal component of the task might partly explain the relationship between visual-verbal PAL

IV.5. Conclusion of the Second Axis

Visual-verbal PAL is a correlate of word reading skills but the potential mechanisms accounting for this relationship are numerous. We take stock of the evidence in the literature for each of them thanks to a systematic review. More precisely, we found that the relationship between visual-verbal PAL and reading could not be accounted for by general associative learning processing. More likely, cross-modal associative learning processing could be a part of the explanation (Hulme et al., 2007). Theoretically, it would reflect letter to sound or written word to oral word mappings. However, we posited that orthographic learning processing may not be summarized as just 'cross-modal' learning processing. Orthographic representations cannot be considered as 'photographs' of written words but rather as abstract representations (e.g. Dehaene et al., 2005). Cross-modal PAL may not reflect such abstract higher-level mechanisms. Litt and colleagues (Litt et al., 2013; Litt & Nation, 2014) rather suggest that the relationship with word reading is due to the verbal learning component and, to some extent, verbal output. Indeed, visual-verbal PAL achievement involved verbal learning of responses. Verbal learning may support word reading skills via the learning of 'spelling pronunciation' of words with ambiguous grapheme to phoneme correspondences (Elbro &

de Jong, 2017). We argued that the role of the verbal output hypothesis was difficult to disentangle from the verbal learning hypothesis. Higher correlations between productive verbal learning measures than receptive verbal learning measures may be simply due to higher sensitivity of verbal output measures.

Though the verbal learning hypothesis obtained the best theoretical and empirical support, some doubt remained about its unique contribution to word reading since no study has controlled for other main predictors of reading skills. Moreover, it remains unclear if the causal relationship was from verbal learning to reading skills or the reverse. First, reading acquisition may improve phonological awareness (Cheung et al., 2001; Cheung & Chen, 2004; Morais et al., 1979) which in turn may improve verbal learning abilities (de Jong et al., 2000). Second, orthographic representations (e.g. letters or syllables) may be activated when a word is presented orally and constitute a cue for retrieving the accurate phonological form in naming tasks. Research has shown that orthographic cues enhance verbal learning (Baron et al., 2018; Colenbrander et al., 2019), and that orthographic representations are automatically activated when participants are exposed to new words (Wegener et al., 2018).

Our second study aimed to examine the contribution of visual-verbal PAL in French Grade 1 and 2 children over the main reading predictors (phonological awareness, rapid automatized naming, phonological short-term memory, vocabulary). To determine if the relationship was specific to word reading and was not just accounted by the development of ‘phonological awareness’ or ‘orthographic representations’ as suggested above, we tested its contribution over nonword reading scores. Indeed, visual-verbal PAL has a specific contribution to word reading score, over the main predictors and nonword reading scores. This suggest that a causal relationship exists from visual-verbal PAL to word reading though this must be confirmed by longitudinal studies. Moreover we tested the specific contribution of cross-modal associative learning and verbal learning. We found a contribution of verbal learning but not of cross-modal learning.

The role of verbal learning is thought to be mediated by the learning of 'spelling pronunciation' of words with ambiguous grapheme to phoneme conversions such as irregular or words with contextual graphemes (‘complex words reading’ in the following). Thus, verbal learning should have a specific contribution to complex word reading, over simple word reading (word highly regular grapheme to phoneme conversion). It was not possible to test this hypothesis in the present study since simple word reading scores suffer from a ceiling effect. We thus conducted a last experiment on grade 1 children. Our results did not confirm our expectations unequivocally. Only some verbal learning measures were correlated with complex word reading scores over simple word reading scores. At least two explanations may account for this result: (1) verbal learning is not a causal factor of reading development, at least in French and the causal relationship is rather from reading skills to verbal learning. This may not be the case since we have that visual-verbal PAL scores still contribute to words reading scores once nonword scores were controlled in the analyses though this must be confirmed by further longitudinal studies. (2) On the contrary, verbal learning may be a causal factor of recoding skills in general (at the sublexical and the lexical level). This account should be tested directly thanks to training studies with kindergarten children.

We also examined the role of cross-modality in the relationship between visual-verbal PAL and reading by comparing the contribution of visual-verbal (cross-modal) and verbal-verbal (unimodal) PAL scores to reading outcomes. Interestingly, visual-verbal PAL measures contributed more strongly to word reading scores than verbal-verbal PAL measures, even those that we considered to be purely focused on verbal learning. These results contradict these of the previous one because they suggest that cross-modality has a role in the relationship between visual-verbal PAL and decoding skills without contradicting the importance of the verbal learning component. To definitively disentangle the role of cross-modality and verbal learning, we have provided some suggestions for further studies:

- Further research should compare the contribution of visual-verbal PAL and verbal-verbal PAL paradigms preceded by verbal learning of the responses independent of the stimuli, to completely distinguish verbal learning from binding learning (either cross-modal or unimodal).
- They should control for the main predictors of reading (i.e., letter knowledge if the study begins before formal reading learning, phonological awareness, rapid automatized naming, phonological short-term memory, vocabulary).
- They should favor a longitudinal design to measure PAL prior to formal reading instruction and be able to infer a causal relationship between visual-verbal PAL (more specifically, verbal learning) and word reading.
- They should include a large number of participants and, if possible, a number greater than that needed to reproduce the results obtained in the literature in order to avoid finding an incomplete pattern of results (see Brysbaert, 2019).

Part 3. General Discussion

The strategic aim of this research was to lay the foundations for the development of screening tools to identify early EANA children at risk of reading failure. We defined **EANA children** as **'French as additional language learners newly schooled in France'**. We focused on primary school ages children. Moreover, we focused on **decoding skills** defined as **'the ability to find the correct phonological form of a written word out of context'** and operationalized thanks to nonword and word reading tasks. In this general discussion, we summarized the main results of this research. We refer readers to the discussions of each chapter for further details on avenues for future work. We ended this discussion by a reflection on the relevance (or not) to conduct additional research on visual-verbal PAL in French and EANA children.

I. Heterogeneity of EANA Children's Decoding Skills

In the first experimental part we compared decoding scores of EANA children and French children matched on duration of attendance at primary school. Whereas past literature suggested that additional language learners present similar decoding performance than native children (Geva et al., 2019; Melby-Lervåg & Lervåg, 2014) we found that EANA children lagged behind French children and that their scores were very heterogeneous.

To account for this heterogeneity we examined a set of contextual factors. We observed that children who had started to learn to read before arriving in France obtained higher scores than others. Moreover, children who were exposed to a Latin orthography before arriving in France obtained higher scores than others. Unexpectedly, children arrived during the first grade obtained lower scores than older children although they benefit from an explicit and intensive instruction to reading. We hypothesized that older children benefit from higher experience in reading in their first language than younger children. They also presented higher cognitive abilities and may be more motivated. The fact that children have been schooled or not prior to the arrival in France made no contribution to decoding scores above the fact that they had started to learn to read. Children who spoke Indo-European languages obtained similar scores than others suggesting that this criteria was not relevant to determine if a child is at risk or not to have difficulties to learn to read in French. Finally, we did not observe differences between children who were exposed to alphabetic systems or non-alphabetic systems (i.e. logographic, abjad, abugida) probably because the non-alphabetic were 'quasi-alphabetic systems'. We compared the decoding scores of a subsample of EANA children who benefit from the most favorable factors in our results to French children and showed that they still lagged behind French children. Additional research is necessary to better understand the contextual factors that may be responsible for this gap between EANA and French children on decoding skills.

II. Cognitive-Linguistic Predictors of Decoding Skills in EANA Children

We examined the strongest cognitive-linguistic predictors of reading skills: phonological awareness, rapid automatized naming, phonological short-term memory and vocabulary. We also examined the contribution of a visual-verbal paired associate learning task since previous literature has demonstrated that it contributes uniquely to decoding skills (e.g. Poulsen & Elbro, 2018; Warmington & Hulme, 2012) and because it would not be biased by the phonological distance between languages and the amount of exposure to French. Given the large number of contextual factors that may account for reading achievement, we wondered if these predictors would predict decoding skills as well in EANA children than French children. Our results demonstrated that they explained a large amount of variance in decoding scores in EANA children, including visual-verbal paired associate learning, suggesting that screening tools may be created thanks to these measures to identify children at risk of reading failure.

III. The Difficulty of Creating Homogeneous Reference Groups to Standardize Cognitive-Linguistic Predictors

We have highlighted certain biases that can alter the accuracy of second language assessment and limit the creation of adequate standards for determining whether an EANA's performance is below 'norm' or not. First, the assessments may be biased by the phonological distance between languages leading to inaccurate pronunciation of certain sounds (e.g. Ingvalson et al., 2014) and transcription errors, especially for vowels (Stoel-Gammon, 2001). Second, the assessment may be biased by the language demand of the tasks which may lead to confusion between the competencies targeted and the amount of exposure to French. Thus, we used a flexible scoring for vowel substitutions which was shown to be more favorable to EANA scores than for French scores without altering the sensibility of the different tasks nor the internal consistency. We also used a nonword repetition tasks with quasi-universal properties and applied the same principle to the original visual-verbal PAL that we created for this study. Despite these efforts, EANA children obtained lower scores at all predictors except nonverbal abilities and nonword repetition controlling for age, duration of attendance at primary school. We showed that these differences disappeared once reading scores were controlled in the analyses suggesting that they were due to the bidirectional relationship between cognitive-linguistic predictors and reading skills. We concluded that **universal norms can be constituted for phonological awareness, rapid automatized naming and visual-verbal PAL provided that EANA children had the same amount of exposure to reading instruction in an alphabetic or quasi-alphabetic orthography**. Note that rapid automatized naming may not be used until several months or years of exposure to French since it relies on linguistic knowledge although items are selected if they are very familiar to children (Geva et al., 2000). **When little is known about past schooling or about the amount of reading instruction children had benefited before arriving in France, it may be possible to use**

nonverbal abilities and nonword repetition tasks. Indeed, they were the only tasks for which universal norms may be created although they were not shown or thought to be specific unique predictors of decoding skills and they already explained together 33% of variance in decoding skills.

IV. Visual-Verbal Paired Associate Learning

We examined the contribution of visual-verbal PAL to reading skills because it was shown to be a unique contributor of decoding skills in past literature (e.g. Litt et al., 2013; Poulsen & Elbro, 2018; Warmington & Hulme, 2012; Windfuhr & Snowling, 2001) and because it is well suited for a second language assessment. First, it does not rely on previous linguistic knowledge because it is a learning tasks. This approach has been already tested in the field of oral language assessment in which learning tasks used as part of 'dynamic assessment' were shown to be a good alternative to static assessment relying on linguistic knowledge for children with diverse cultural and linguistic background (Camilleri & Botting, 2013; Hasson et al., 2013; Kapantzoglou et al., 2012; Matrat et al., 2022; Orellana et al., 2019; Peña, 2000; Petersen et al., 2020). Second, it was possible to create items with universal typological properties (simple syllables and universal phonemes) because verbal responses were nonwords. Finally, we hoped that universal norms could be created for all children (either monolingual, bilingual or EANA).

Most of the previous studies examining the contribution of visual-verbal PAL were conducted in opaque orthographies (e.g. in Danish: Poulsen & Elbro, 2018; in English: Warmington & Hulme, 2012). Thus, is was important to determine if these results held in French which has more transparent orthography (e.g. Borgwaldt et al., 2005; Schmalz et al., 2015; Seymour et al., 2003). Indeed, we demonstrated that visual-verbal PAL was a significant contributor of decoding skills in French and EANA children over other reading predictors and nonverbal abilities. The unique contribution was very low in French children for reading accuracy measures, however, contrary to previous literature (Poulsen & Elbro, 2018), it was higher in fluency scores. We posited that this may be due to higher sensibility of fluency scores to decoding skills in French children since accuracy develops at a fast rate during the first year of primary school (Sprenger-Charolles et al., 2005). In EANA children, the unique contribution was rather high. It explained around 4 to 7% of variance explained over other predictors. Thus our results confirm that using a visual-verbal PAL task in combination with other reading predictors may improve detection of EANA children at risk of reading failure.

Nevertheless, our results have also shown that it was not possible to create universal norms for visual-verbal PAL as expected. EANA children performed less well than French children when controlling for nonverbal abilities, age, the social position indicator of school and the duration of attendance at primary school. This difference disappeared once decoding sills were controlled in the analyses suggesting at least that universal norms may be used for children who benefit from the same amount of reading instruction in alphabetic or quasi alphabetic orthographies.

Despite these promising results, the mechanisms accounting for this relationship are not clear. We conducted a systematic review to make the state of the evidence for the various mechanisms explaining this relationship. Overall, the role verbal learning component of the task (learning nonwords) obtained consistent empirical (e.g. Litt et al., 2013, 2019; Litt & Nation, 2014) and theoretical support (Elbro & de Jong, 2017). However, the crossmodal learning mechanism (learning the association between a visual stimulus and a verbal response) obtained inconsistent support. We tested these components thanks to an original paradigm of visual-verbal PAL. Our results suggest that the verbal learning in the main explanation of the relationship between visual-verbal PAL and decoding skills in French. However, we were not able to conclude on the role of cross-modal learning. Although verbal learning was thought to be involved in reading complex words (irregular words or words with contextual graphemes; Elbro & de Jong, 2017) our results have suggested that verbal learning did not contribute specifically to complex word reading. We hypothesized that verbal learning may have a causal role in both simple and complex words reading or that the causal relationship was reversed (decoding skills predicting verbal learning), through the development of phonological awareness for example (e.g. de Jong et al., 2000).

We stressed that the only way to definitively conclude on a causal relationship between visual-verbal PAL and more specifically its verbal learning component and reading in French was to conduct a longitudinal study, controlling for all other reading predictors. This raises the question of feasibility. While we targeted 4% of additional variance explained by visual-verbal PAL based on previous literature, we often observe smaller effect sizes in our samples (around 1 and 2%) for word accuracy scores, although contributions were higher for fluency scores (around 5%). The effect size could be much smaller in longitudinal designs due to the influence of many contextual factors across time, suggesting that larger sample sizes should be used. In our view, it is worth investigating the longitudinal contribution of visual-verbal PAL in EANA children, given that effect sizes were higher ($r = .52$, $<.001$ and $4\% < \Delta R^2 < 7\%$) and the good properties of this task for additional language learners. However, we might have reached the limit of what we can do, or at least what is reasonable to do, for French children.

V. Conclusion

This research aimed at laying the foundation for the creation of tools designed to identify early French as additional language learners newly schooled in France (EANA) at risk of reading failure. We identified some contextual and cognitive-linguistic correlates of decoding skills with a particular focus on visual-verbal paired associate learning (PAL). Cognitive-linguistic predictors predicted a large amount of variance in decoding skills in EANA children confirming the relevance of creating tools to identify early children at risk of reading failure. We underlined the importance of taking into account typological distance between first languages and French and potential biases due to linguistic knowledge. We examined the predictive role of visual-verbal PAL in French and EANA children, precisely because it did not rely on linguistic knowledge and because it was possible to create items with universal properties. Although it presented a good unique contribution to decoding skills in EANA children, the mechanisms accounting for this relationship are not well elucidated. Critically, it is still unsure that it is a causal contributor of decoding skills though results are promising, especially for EANA children. We provided avenues for future work both for creating standardized tools for identifying EANA children with reading difficulties and to better understand the mechanisms involved in visual-verbal PAL.

Personal note

As the strategic issue of this research was the creation of screening tools, we asked ourselves how such screening could be implemented in the reception of EANA children. In the following sections, we describe the path taken by EANA children from their arrival in France to their actual schooling. Then we describe the initial assessments carried out by UPE2A teachers. Finally, we ask why screening for reading difficulties is a priority, and how such screening could be implemented in practice.

I. From the Arrival in France to School

The procedures differ according to the age of the EANA children for enrolling in the school. We summarize in the two following points the results of the EVASCOL investigation (Armagnague & Rigoni, 2018, chapter 3).

I.1. For Children of Elementary School Age

Parents register their children at the town hall. The mayor's office then assigns the children to a school. The school organizes an assessment of the children's French reading, writing and mathematics skills in their first language(s) with a UPE2A teacher or an examiner from the 'academic centers for the education of EANA children and children from itinerant and traveling families' (CASNAV). The purpose of the evaluation is to determine which class the children will attend and the level of support they will receive from the UPE2A. Parents are sometimes present during the evaluation. Rarely, traducers mediate communication between children, families and examiners.

I.2. For Children of Secondary School Age

The first step is to contact the CASNAV or an 'information and orientation center' (CIO), which initiates the administrative procedures. The children then meet with a psychologist to discuss their schooling before arriving in France, their migration history and their aspirations. Finally, the

CASNAV or CIO organizes an evaluation of the child's academic skills and French language skills. The administrative information and the assessment are sent to the academic authorities who decide on the schools to which the children will be assigned.

I.3. Content and Aim of the Assessments

The examiners fill in a liaison form, indicating the child's country of origin, the languages spoken, whether the child attended school before arriving in France, and a summary of the oral, written and mathematical assessments. This liaison form enables the UPE2A teachers, the class teachers and CASNAV to communicate easily on the child's profile, to determine the class level in which the child will be integrated and the support he or she will need in the unit for newcomer children.

The assessments are divided into two areas: language skills (French and first language) and mathematical skills. French language skills are assessed according to the 'Common European Framework of Reference for Languages' (CEFR; Europarat, 2020). Assessment tools seem to vary from district to district. They focus on comprehension and expression in both oral and written modalities. Reading comprehension skills can then be assessed thanks to an extensive set of tools published by the CANOPÉ network in 24 languages (Valiau, 2021). They consist of reading short passages and answering written questions. There are different versions for children from grade 1 to 9. Regarding mathematical skills, the CANOPÉ network has published language-free assessments (Missir, 2021), which mainly target knowledge of Arabic numerals and operation resolution. More detailed tools are also available in 24 languages for children from grade 1 to 9 (Missir, 2021).

Overall, these tests were designed to determine what the children know or can do in French and in their first language(s). Although they provide crucial information to determine the class level at which they can be integrated and to inform the teacher's interventions in the units for newcomer children, they were not designed to test cognitive abilities or to identify children most at risk of future reading difficulties.

The measures examined in the present study (phonological awareness, rapid automatized naming, phonological short-term memory and visual-verbal PAL) may offer additional insight on the potential of the children to learn to read in French, providing that the professionals use appropriate norms for the appropriate children.

II. Implementing screening for at-risk children (or from a PhD student's dreams to real life)

While it is crucial to screen EANA children as early as possible for the risk of future reading difficulties, the ways in which such screening might be implemented raise a number of questions: Why focus on reading skills ? Who will do the screening? Where? When?

II.1.1. Why Focusing on Reading Skills ?

Because reading is at the core of academic learning (the so-called 'learning to read and reading to learn'). Thus, preventing reading failure is preventing academic failure. Moreover, reading is a strong support for oral language learning like vocabulary learning on the phonological and the semantic dimensions (Colenbrander et al., 2019). In fact, the flow of spoken language is rapid and spoken words only give the listener one chance to identify them, whereas written words can be read as many times as necessary. In addition, oral flow is continuous whereas written words are clearly segmented in relation to other words in the sentence, but also intrinsically; i.e. phonological units are clearly identifiable by graphemes, at least when the relationship between the units is consistent. Indeed, research has shown that non-native phonological contrasts or non-native consonant clusters are easier to learn when the written forms of the words are presented (Hayes-Harb & Barrios, 2021). Thus, improving the reading skills of children with EANA by any means improves their chances of improving their oral language skills.

To be more nuanced, the identification of early children presenting a language disorder may also benefit the children and should be done simultaneously. Fortunately, although dos Santos and Ferré (2018) nonword repetition task was not a unique predictor of reading ability, it may at least be a sensitive tool for identifying early children at risk of presenting an oral language disorder (Ortiz, 2021). We have seen that this is the only task for which it is possible to establish universal norms (see the section III.5, p. 114). The use of parental questionnaires such as PABIQ (Tuller, 2015) or ALDEQ (Paradis et al., 2010) may be also be a good way to identify children with language disorders (Abutbul-Oz & Armon-Lotem, 2022), although it may be much more time-consuming than the nonword repetition tasks.

II.1.2. Where, When and Who ?

School can be seen as the main place where children in difficulty are identified and families are referred to the right services (C. R. Jørgensen et al., 2020). Teachers can use their experience to identify children with significant difficulties in relation to other children in the class. However, the teacher's subjective judgment cannot replace an objective assessment using standardized tools. Moreover, relying on teachers alone means waiting for difficulties to emerge before responding, which is commonly referred to as 'waiting for failure' (e.g. Al Otaiba et al., 2014). Children may therefore accumulate learning delays before they are identified. Note that this delay can be exacerbated by the difficulty of getting an appointment with a speech and language therapist. Families call many professionals and often wait several months before getting an appointment.

Nevertheless, as children and parents are familiar with school, it is relevant to do there this screening. Moreover, it would not be specific to EANA children, as such screenings already exist for French children at the age of 6. So who can take on this screening?

(1) UPE2A teachers. They are in direct contact with EANA children and could administer these tests if they were trained to do so. The screening tests could be administered as part of other assessments. However, the discussions we had with some of them revealed at least two types of reluctance.

First, some teachers do not feel legitimate in administering this type of test, considering that it is the role of health professionals and not educational professionals. They should certainly be trained in the basic principles of administering psychometric tests: to follow instructions scrupulously, not to intervene or help the child when they are not supposed to, to administer the tests in conditions that encourage the child's concentration, not to administer them several times in a row in order to avoid retest effects, and so on. Theoretically, they should be made aware of the mechanisms targeted by the tests, but it does not seem necessary for them to understand all the details. By analogy, not everyone has a deep understanding of how COVID's self-tests work. However, we have all (or almost all) understood the value of these tests and have managed to use them.

The second difficulty lies in the time that UPE2A teachers could devote to these assessments. Such a screening, if carried out with the tools used in this study, could take about one hour in addition to the existing assessments. In some regions, less than 20% of children benefit from French language support (whether in a UPE2A or not; Brun, 2023). It is particularly difficult to organize UPE2A support in rural areas. Moreover, the minimum number of hours is not always respected (Cour des comptes, 2023). In this sense, giving UPE2A teachers an additional task (identifying children at risk of reading difficulties) could possibly reduce their teaching time.

Note that the assessments conducted by UPE2A teachers can be stressful for children (Armagnague & Rigoni, 2018). If a screening is added to the existing assessment, it should be designed in such a way that it does not add to the children's anxiety or alter the teacher-child relationship. It may be reasonable to wait a few weeks before screening children, to give them time to adapt to the school environment, get to know their teachers better and become more confident.

(2) **National Education Psychologists, Nurses and Doctors**. All of these professionals are

involved in the identification of children at risk for disabilities in school. In principle, school doctors or nurses should meet children at the age of 6 to carry out a general health check, including the identification of language and learning difficulties. However, a recent parliamentary report revealed that these screenings are not carried out systematically. What's more, school health care suffers from a shortage of staff because the professions are unattractive (Reda, 2023). In short, their participation in the screening of EANA may be possible, provided that the number of professionals increases.

(3) **Speech and Language Therapists**. In an ideal world, speech therapists should do this screening because they are specially trained. Unfortunately, there is nothing structurally organized to make speech and language therapists intervene in schools in France. Moreover, French speech and language therapists (through their representative unions: 'Fédération Nationale des Orthophonistes') are reluctant to intervene in schools, arguing that it could be unfair competition for other speech and language therapists or undermine the patient's right to choose their therapist (Benchimol & Rives, 2019). It can also be argued that intervention in schools reduces the connection with families. However, this situation is marginal among French-speaking speech-language pathologists. In Switzerland, Belgium and Quebec, speech and language therapists can work in schools. Note that in Quebec there is a specific status for speech therapists working in schools (Paquette et al., 2023). In the specific case of children with EANA, this would allow them to see a speech therapist at an early stage and avoid the family having to call several professionals and wait months for an appointment.

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Appendices

I. Languages Spoken by Bilingual and EANA Children in the TANMALL project.

French bilingual children	
Languages	**Number of speakers**
Arabic	34
English	14
German	5
Spanish	4
Italian	3
Russian	3
Berbere	2
Diakhanke	2
Kurdish	2
Lituanian	2
Pulaar	2
Wolof	2
Albanian	1
Chinese	1
Greek	1
Khmer	1
Malagasy	1
Manjak	1
Nepali	1
Persian	1
Romanian	1
Swedish	1
Taki Taki	1
Tamil	1
Czech	1
Turkish	1
Visaya	1

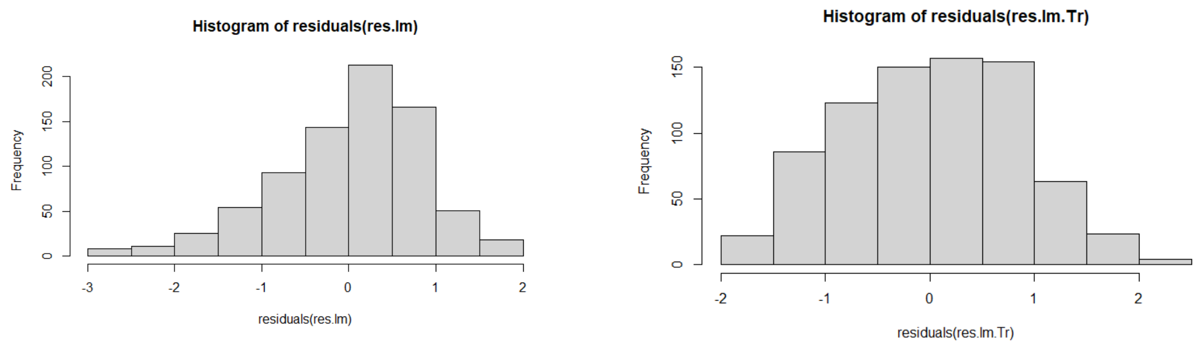
EANA children			
Languages	**Number of speakers**	**Languages (continued)**	**Number of speakers (continued)**
Arabic	44	Diakhanke	2
English	31	Indonesian	2
Russian	12	Kabyle	2
Turkish	12	Mauritanian	2
Spanish	11	Urdu	2
Italian	10	Ful	2
Ukrainian	10	Romani	2
Georgian	7	Czech	2
Pachto	7	German	1
Kinyarwanda	6	Armenian	1
Persian	6	Chinese	1
Portuguese	6	Greek	1
Romanian	5	Japanese	1
Soninke	5	Lingala	1
Albanian	4	Malian	1
Tigrinya	4	Malinke	1
Amharic	3	Mandingo	1
Comorian	3	Moldavian	1
Eritrean Language	3	Mongolian	1
Hindi	3	Pulaar 2	1
Kurdish	3	Somali	1
Serbian	3	Sudanese	1
Syrian	3	Swedish	1
Afaan Oromoo	2	Swahili	1
Bambara	2	Tagalog	1
Bengali	2	Tamil	1
Berber	2	Tibetan	1
Bulgarian	2	Wolof	1
Sinhalese	2		

II. Data Preparation for ANOVA analysis of the section III.3

We examined the assumptions underlying the use of ANOVA. First, we examined the distribution of the residuals by performing multiple regression analyses with the same factors. They were slightly asymmetrical (Figure A.a).

Figure A. *Distribution of the ANOVA residuals before and after transforming the dependent variable.*

a) Before transformation	b) After transformation



Second, we used a Levene's test to check for homogeneity of variance. Unfortunately, the variances were significantly higher in EANA children than in other groups (word reading: $F(2,388) = 45.10$, $p < .001$; nonword reading: $F(2,388) = 27.35$, $p < .001$; see the Table A.a). The covariances were also heterogeneous (Box's M test = 171.97, $p < .001$).

Table A. *Standard deviation of the dependent variables comparison and Levene's test before and after transforming the dependent variables.*

Task	Group	Standard Deviation	df1	df2	*F*	*p*
		a) Before transformation				
	EANA	1.14	2	388	45.10	<.001
Nonword reading	Monolingual	0.61				
	Bilingual	0.54				
	EANA	1.13	2	388	27.35	<.001
Word reading	Monolingual	0.54				
	Bilingual	0.51				
		b) After transformation				
	EANA	0.93	2	388	1.11	.45
Nonword reading	Monolingual	0.85				
	Bilingual	0.87				
	EANA	0.90	2	388	2.92	.043
Word reading	Monolingual	0.75				
	Bilingual	0.72				

For all these reasons, we applied a transformation on our dependent variable. The best way (compared to the classical one 'log', 'square root', 'quadratic') was the Yeo-Johnson (Yeo & Johnson, 2000) implemented in the powerTransform function of the R car package (Komsta & Novomestky, 2015). Basically, it determines the best transformation to maximize the normality of the residuals.

Thanks to the transformation, the distribution of the residuals was more symmetric (Figure A.b), the homogeneity of the variance was greatly improved (see the Table A.b) and the covariances were more homogeneous (i.e. less significant; note that this test is known to be highly sensitive with a high number of participants): Box's M test = 6.85 p = .032.

III. Procedure for determining whether an EANA child has been exposed to an alphabetic or Latin writing before arriving in France

If children started learning to read before arriving in France, we took into account the exact writing system(s) in which they started learning to read, if this information was available. If at least one of them was alphabetic, we considered the child to have been exposed to an alphabetic system. If one of them was Latin, we considered the child to have been exposed to a Latin system.

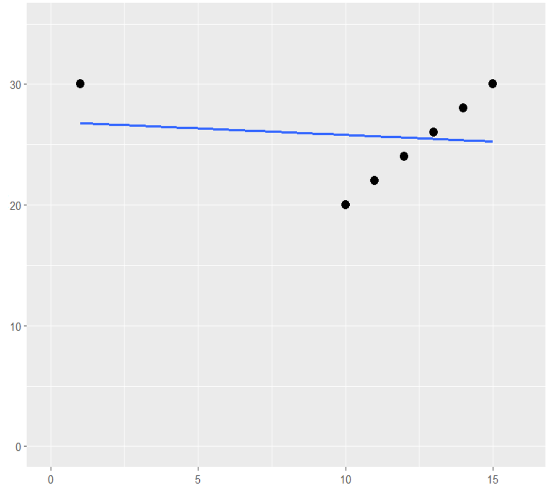
If the children had not started learning to read before arriving in France, or if the families did not indicate the languages in which the children had started learning to read, we considered the writing systems of all the languages spoken by the children other than French as an approximation. If at least one of them was alphabetic, we considered the child to have been exposed to an alphabetic system. If one of them was Latin, we considered that the child to have been exposed to a Latin system.

If information on the writing system was missing for one of the languages spoken or one of the languages in which the child started to learn to read, we focused on the information available in the other languages. If no information was available, we indicated 'not available'.

These choices were motivated by the need to limit the number of missing data. In addition, taking into account the writing systems of languages spoken by children who have not yet started learning to read is justified by the fact that children are likely to have already familiarized themselves with written characters through books, advertisements, newspapers, messages written on mobile phones, etc.

IV. Identifying multivariate outlier thanks to DFBETA

Figure A. *One influential point.*



DFBETA is the difference between the beta coefficient of a variable and the beta coefficient of the same variable when a participant is removed from the analyses. Calculating DFBETA for all participants can help identify influential points. For example, in Figure A, one point looks very different from the others (on the left). It appears to have a large impact on the regression slope.

The figure B represents the DFBETAs for all the participants of figure A. We observe that when we remove the seventh participant, the slope changes from 0 to 2! Therefore, it is relevant to remove this participant from the analyses. Note that the DFBETA is the difference between raw slopes with and without a participant, while DFBETA<u>S</u> is the difference between standardized slopes.

Figure B. *DFBETA*

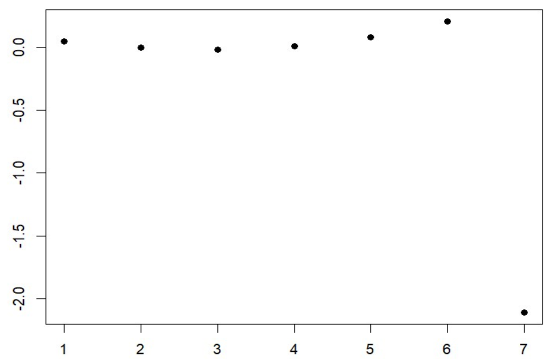
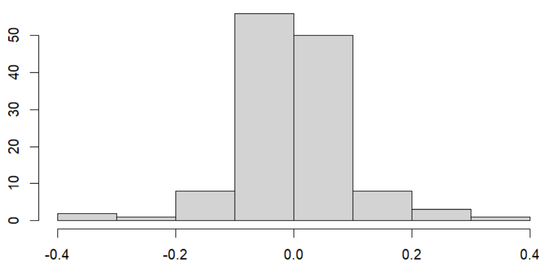


Figure C. *Example of distribution of DFBETAS.*

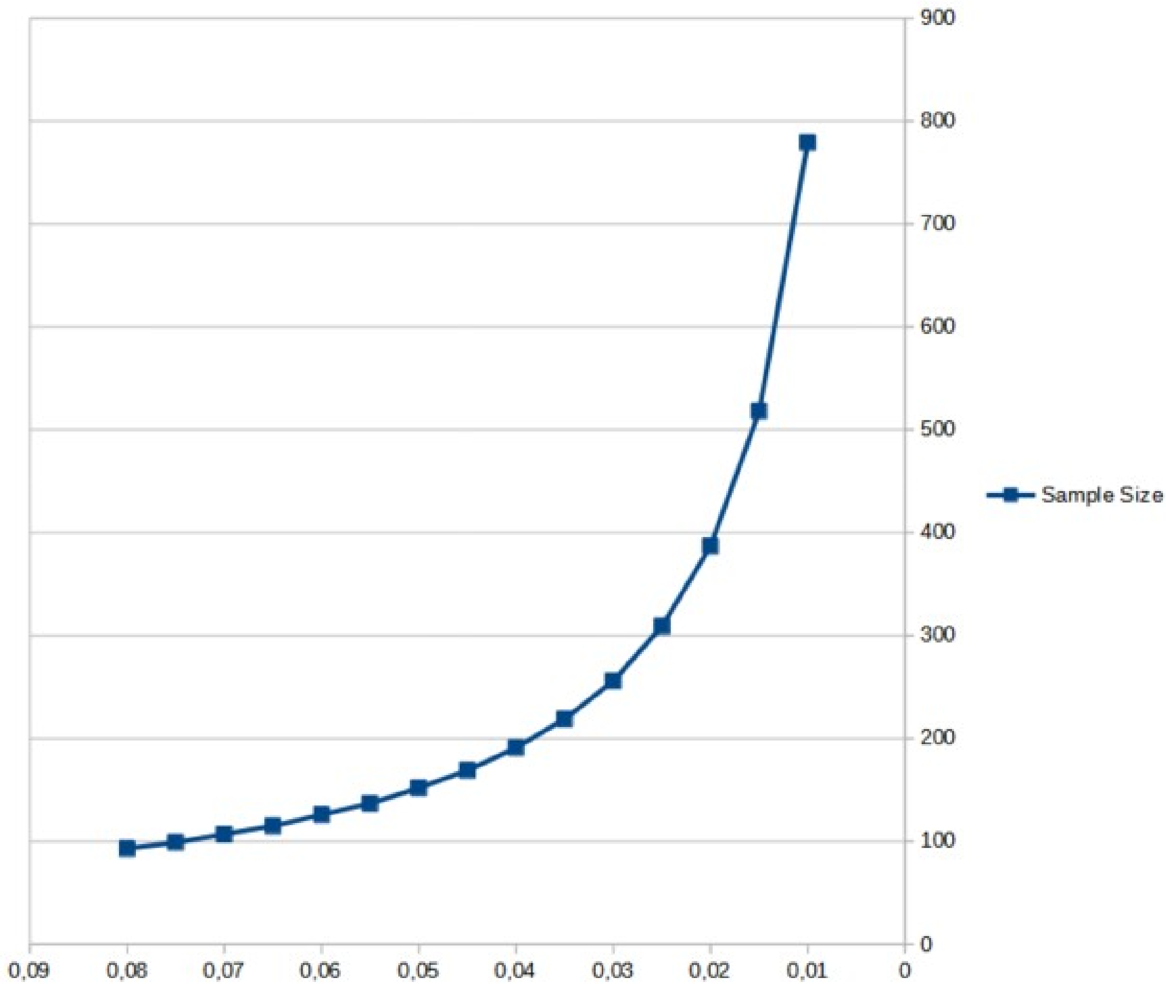


In our research, we performed multiple regression analyses. Since the slope of one predictor influences the slope of other predictors, we decided to identify extreme DFBETAS for all variables in our models. Aguinis et al. (2013) suggested that DFBETAS greater than $2/\sqrt{n}$, in absolute value were extreme. This cut-off resulted in the exclusion of many participants (about 20% of our sample). Since the distribution of DFBETAS is rather symmetric (see Figure C), we decided to use the standard deviation to determine a cut-off. Using a cut-off of 3 SD seemed relevant as it generally led to the exclusion of fewer participants.

V. Supplemental Material of Bignon et al. (Currently being published)

S1. *Sample Size Estimation Based on Effect Sizes in the Literature.*

ΔR²	Estimated Sample Size	Reference
.02	387	(Poulsen & Elbro, 2018; Windfuhr & Snowling, 2001)
.03	256	(Windfuhr & Snowling, 2001)
.04	191	
.05	152	
.06	126	(Poulsen & Elbro, 2018)



S2. Model 1. *Dependent variable: Word Reading*

Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Intercept	-0.10	0.08	11.09	-1.30	0.221
Grade	0.37	0.13	23.40	2.91	0.008
Non-Verbal IQ	0.10	0.05	217.61	1.86	0.065
Phonological Awareness	0.28	0.06	207.53	4.99	<.001
Rapid Automatized Naming	0.31	0.06	216.85	4.82	<.001
Phonological Short-Term Memory	0.24	0.05	217.41	4.58	<.001
Vocabulary	0.01	0.06	217.39	0.22	0.825
Grade * Rapid Automatized Naming	-0.22	0.11	215.55	-2.13	0.034
Grade * Vocabulary	0.31	0.10	212.89	2.97	0.003
Random Effects	**Variance**	**Standard Deviation**			
Teacher (Intercept)	0.03	0.19			
Residuals	0.47	0.69			
Model fit	**AIC**	**BIC**	**R^2 C**	**R^2 M**	**ICC**
	531.96	569.64	53.61%	50.25%	0.07

Notes. R^2 C = R^2 conditionnal; R^2 M = R^2 marginal

S3. Model 2. *Dependent variable: Word Reading; examination of the contribution of the visual-verbal PAL naming measure.*

Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Intercept	-0.07	0.08	11.57	-0.91	0.379
Grade	0.29	0.13	25.38	2.28	0.031
Non-Verbal IQ	0.09	0.05	215.80	1.73	0.085
Phonological Awareness	0.24	0.06	206.36	4.41	<.001
Rapid Automatized Naming	0.31	0.06	216.72	4.88	<.001
Phonological Short-Term Memory	0.21	0.05	216.98	4.05	<.001
Vocabulary	-0.01	0.06	216.35	-0.13	0.894
Visual-Verbal PAL: naming	0.17	0.05	213.11	3.15	0.002
Grade * Rapid Automatized Naming	-0.25	0.10	213.40	-2.46	0.015
Grade * Vocabulary	0.29	0.10	212.90	2.86	0.005
Random Effects	**Variance**	**Standard Deviation**			
Teacher (Intercept)	0.04	0.19			
Residuals	0.45	0.67			
Model fit	**AIC**	**BIC**	**R^2 C**	**R^2 M**	**ICC**
	528.24	569.34	55.73%	52.05%	0.08

Notes. R^2 C = R^2 conditionnal; R^2 M = R^2 marginal; without transformation, the effect of grade and its interaction with vocabulary disappear.

S4. Model 3. *Dependent variable: Word Reading; examination of the contribution of the visual-verbal PAL auditory recognition measure.*

Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Intercept	-0.09	0.08	10.98	-1.12	0.288
Grade	0.33	0.13	24.12	2.60	0.016
Non-Verbal IQ	0.09	0.05	216.38	1.73	0.084
Phonological Awareness	0.25	0.06	203.66	4.53	<.001
Rapid Automatized Naming	0.32	0.06	216.10	4.98	<.001
Phonological Short-Term Memory	0.23	0.05	216.59	4.40	<.001
Vocabulary	0.00	0.06	216.80	-0.03	0.979
Visual-Verbal PAL: auditory recognition	0.11	0.05	205.53	2.12	0.035
Grade * Rapid Automatized Naming	-0.24	0.10	214.11	-2.30	0.022
Grade * Vocabulary	0.32	0.10	212.56	3.10	0.002
Random Effects	**Variance**	**Standard Deviation**			
Teacher (Intercept)	0.04	0.19			
Residual	0.47	0.68			
Model fit	**AIC**	**BIC**	**R^2 C**	**R^2 M**	**ICC**
	533.64	574.74	54.64%	51.20%	0.07

Notes. R^2 C = R^2 conditionnal; R^2 M = R^2 marginal

S5. Model 4. *Dependent variable: Word Reading; examination of the contribution of the visual-verbal PAL designation measure.*

Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Intercept	-0.09	0.08	11.32	-1.16	0.270
Grade	0.35	0.13	23.64	2.71	0.012
Non-Verbal IQ	0.10	0.05	215.67	1.78	0.077
Phonological Awareness	0.26	0.06	204.81	4.69	<.001
Rapid Automatized Naming	0.30	0.06	216.62	4.63	<.001
Phonological Short-Term Memory	0.23	0.05	216.91	4.41	<.001
Vocabulary	0.00	0.06	216.90	0.04	0.966
Visual-Verbal PAL: designation	0.08	0.05	205.40	1.55	0.124
Grade * Rapid Automatized Naming	-0.23	0.10	212.97	-2.19	0.030
Grade * Vocabulary	0.30	0.10	212.97	2.88	0.004
Random Effects	**Variance**	**Standard Deviation**			
Teacher (Intercept)	0.04	0.20			
Residual	0.47	0.68			
Model fit	**AIC**	**BIC**	**R^2 C**	**R^2 M**	**ICC**
	535.70	576.80	54.30%	50.32%	0.08

Notes. R^2 C = R^2 conditionnal; R^2 M = R^2 marginal

S6. Model 5. *Dependent variable: Nonword Reading*

Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Intercept	-0.02	0.07	13.75	-0.26	0.800
Grade	0.06	0.12	31.19	0.47	0.638
Non-Verbal IQ	0.06	0.06	214.45	0.96	0.340
Phonological Awareness	0.25	0.06	216.17	3.98	<.001
Rapid Automatized Naming	0.33	0.06	211.06	5.65	<.001
Phonological Short-Term Memory	0.16	0.06	211.67	2.75	0.006
Vocabulary	-0.07	0.07	208.55	-0.96	0.339
Grade * Vocabulary	0.33	0.11	192.07	3.03	0.003
Random Effects	**Variance**	**Standard Deviation**			
Teacher (Intercept)	0.01	0.08			
Residual	0.60	0.78			
Model fit	**AIC**	**BIC**	**R² C**	**R² M**	**ICC**
	571.78	606.03	41.28%	40.67%	0.01

Notes. R^2 C = R^2 conditionnal; R^2 M = R^2 marginal

S7. Model 6. *Dependent variable: Nonword Reading; examination of the contribution of the visual-verbal PAL naming measure.*

Fixed Effects	Estimate	Standard Error	*df*	*t*	*p*
Intercept	0.00	0.07	14.07	-0.04	0.969
Grade	0.01	0.12	35.54	0.10	0.920
Non-Verbal IQ	0.05	0.06	213.56	0.87	0.384
Phonological Awareness	0.23	0.06	215.38	3.63	<.001
Rapid Automatized Naming	0.32	0.06	208.27	5.55	<.001
Phonological Short-Term Memory	0.14	0.06	211.01	2.43	0.016
Vocabulary	-0.07	0.07	203.44	-1.09	0.279
Visual-Verbal PAL: naming	0.09	0.06	217.95	1.48	0.140
Grade * Vocabulary	0.32	0.11	191.64	2.93	0.004
Random Effects	**Variance**	**Standard Deviation**			
Teacher (Intercept)	0.01	0.07			
Residual	0.60	0.77			
Model fit	**AIC**	**BIC**	**R^2 C**	**R^2 M**	**ICC**
	575.37	613.05	41.65%	41.13%	0.01

Notes. R^2 C = R^2 conditionnal; R^2 M = R^2 marginal

S8. Model 7. *Dependent variable: Nonword Reading; examination of the contribution of the visual-verbal PAL auditory recognition measure.*

Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Intercept	-0.01	0.07	13.97	-0.12	0.904
Grade	0.03	0.12	34.25	0.24	0.810
Non-Verbal IQ	0.05	0.06	213.13	0.88	0.379
Phonological Awareness	0.23	0.06	214.01	3.66	<.001
Rapid Automatized Naming	0.33	0.06	208.81	5.68	<.001
Phonological Short-Term Memory	0.15	0.06	210.03	2.62	0.009
Vocabulary	-0.08	0.07	207.83	-1.10	0.274
Visual-Verbal PAL: auditory recognition	0.07	0.06	216.10	1.20	0.233
Grade * Vocabulary	0.34	0.11	190.53	3.09	0.002
Random Effects	**Variance**	**Standard Deviation**			
Teacher (Intercept)	0.01	0.07			
Residual	0.60	0.78			
Model fit	**AIC**	**BIC**	**R² C**	**R² M**	**ICC**
	576.27	613.94	41.45%	40.95%	0.01

Notes. R^2 C = R^2 conditionnal; R^2 M = R^2 marginal

S9. Model 8. *Dependent variable: Nonword Reading; examination of the contribution of the visual-verbal PAL designation measure.*

Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Intercept	-0.02	0.07	13.56	-0.30	0.769
Grade	0.06	0.12	31.54	0.54	0.590
Non-Verbal IQ	0.06	0.06	213.37	0.98	0.327
Phonological Awareness	0.25	0.06	214.83	4.00	<.001
Rapid Automatized Naming	0.33	0.06	205.65	5.67	<.001
Phonological Short-Term Memory	0.16	0.06	210.22	2.79	0.006
Vocabulary	-0.06	0.07	206.20	-0.90	0.369
Visual-Verbal PAL: designation	-0.03	0.06	215.16	-0.56	0.578
Grade * Vocabulary	0.34	0.11	190.29	3.05	0.003
Random Effects	**Variance**	**Standard Deviation**			
Teacher (Intercept)	0.01	0.07			
Residual	0.60	0.78			
Model fit	**AIC**	**BIC**	**R² C**	**R² M**	**ICC**
	577.34	615.01	41.17%	40.65%	0.01

Notes. R^2 C = R^2 conditionnal; R^2 M = R^2 marginal

S10. Model 9. *Examination of the correlates of visual-verbal PAL.*

Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Intercept	-0.17	0.08	15.03	-2.11	0.052
Grade	0.49	0.14	32.75	3.62	<.001
Non-Verbal IQ	0.06	0.07	218.07	0.89	0.375
Phonological Awareness	0.20	0.07	216.62	2.92	0.004
Rapid Automatized Naming	0.08	0.06	216.59	1.29	0.199
Phonological Short-Term Memory	0.18	0.06	215.47	2.82	0.005
Vocabulary	0.15	0.06	212.78	2.32	0.022
Random Effects	**Variance**	**Standard Deviation**			
Teacher (Intercept)	0.01	0.11			
Residual	0.75	0.86			
Model fit	**AIC**	**BIC**	**R^2 C**	**R^2 M**	**ICC**
	617.31	648.13	27.28%	26.00%	0.02

Notes. R^2 C = R^2 conditionnal; R^2 M = R^2 marginal

S11. Model 10. *Dependent variable: word reading; sample: the 152 grade 1 children.*

Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Intercept	-0.01	0.07	9.38	-0.07	0.945
Non-Verbal IQ	0.05	0.07	143.70	0.73	0.468
Phonological Awareness	0.29	0.07	142.16	4.03	<.001
Rapid Automatized Naming	0.32	0.07	141.15	4.74	<.001
Phonological Short-Term Memory	0.25	0.07	145.92	3.62	<.001
Vocabulary	0.03	0.07	143.92	0.48	0.629
Random Effects	**Variance**	**Standard Deviation**			
Teacher (Intercept)	0.02	0.14			
Residual	0.59	0.77			
Model fit	**AIC**	**BIC**	**R^2 C**	**R^2 M**	**ICC**
	385.91	410.10	42.27%	40.37%	0.03

Notes. R^2 C = R^2 conditionnal; R^2 M = R^2 marginal

S12. Model 11. *Dependent variable: word reading; sample: the 152 grade 1 children; examination of the contribution of the visual-verbal PAL naming measure.*

Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Intercept	-0.01	0.08	8.91	-0.08	0.94
Non-Verbal IQ	0.04	0.07	143.93	0.62	0.54
Phonological Awareness	0.25	0.07	139.57	3.54	<.001
Rapid Automatized Naming	0.32	0.07	142.56	4.79	<.001
Phonological Short-Term Memory	0.21	0.07	144.88	3.02	0.00
Vocabulary	0.01	0.07	142.73	0.21	0.84
Visual-Verbal PAL: naming	0.15	0.07	144.60	2.10	0.04
Random Effects	**Variance**	**Standard Deviation**			
Teacher (Intercept)	0.03	0.16			
Residual	0.57	0.75			
Model fit	**AIC**	**BIC**	**R^2 C**	**R^2 M**	**ICC**
	387.08	414.29	44.29%	41.74%	0.04

Notes. R^2 C = R^2 conditionnal; R^2 M = R^2 marginal

S13. Model 12. *Dependent variable: word reading; sample: the 152 grade 1 children; examination of the contribution of the visual-verbal PAL auditory recognition measure.*

Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Intercept	-0.01	0.07	9.34	-0.08	0.94
Non-Verbal IQ	0.04	0.07	142.59	0.57	0.57
Phonological Awareness	0.26	0.07	140.79	3.71	.001
Rapid Automatized Naming	0.33	0.07	139.23	4.92	.001
Phonological Short-Term Memory	0.23	0.07	144.93	3.48	.001
Vocabulary	0.02	0.07	143.38	0.23	0.82
Visual-Verbal PAL: auditory recognition	0.13	0.07	142.93	2.05	0.04
Random Effects	**Variance**	**Standard Deviation**			
Teacher (Intercept)	0.02	0.13			
Residual	0.58	0.76			
Model fit	**AIC**	**BIC**	**R^2 C**	**R^2 M**	**ICC**
	387.36	414.57	43.69%	41.97%	0.03

Notes. R^2 C = R^2 conditionnal; R^2 M = R^2 marginal

S14. Model 13. *Dependent variable: word reading; sample: the 152 grade 1 children; examination of the contribution of the visual-verbal PAL designation measure.*

Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Intercept	0.00	0.08	9.10	-0.06	0.95
Non-Verbal IQ	0.05	0.07	143.77	0.65	0.52
Phonological Awareness	0.27	0.07	139.35	3.73	<.001
Rapid Automatized Naming	0.31	0.07	141.24	4.58	<.001
Phonological Short-Term Memory	0.23	0.07	144.96	3.31	0.00
Vocabulary	0.02	0.07	143.64	0.31	0.75
Visual-Verbal PAL: designation	0.09	0.07	141.11	1.33	0.19
Random Effects	**Variance**	**Standard Deviation**			
Teacher (Intercept)	0.03	0.16			
Residual	0.58	0.76			
Model fit	**AIC**	**BIC**	**R^2 C**	**R^2 M**	**ICC**
	389.69	416.90	43.18%	40.68%	0.04

Notes. R^2 C = R^2 conditionnal; R^2 M = R^2 marginal

S15. Model 14. *Dependent variable: nonword reading; sample: the 152 grade 1 children.*

Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Intercept	0.00	0.07	146.00	0.00	1.000
Non-Verbal IQ	-0.04	0.07	146.00	-0.50	0.618
Phonological Awareness	0.30	0.08	146.00	4.04	<.001
Rapid Automatized Naming	0.34	0.07	146.00	4.89	<.001
Phonological Short-Term Memory	0.21	0.07	146.00	2.92	0.004
Vocabulary	-0.06	0.07	146.00	-0.89	0.377
Random Effects	**Variance**	**Standard Deviation**			
Teacher (Intercept)	0.00	0.00			
Residual	0.66	0.81			
Model fit	**AIC**	**BIC**	**R^2 C**	**R^2 M**	**ICC**
	399.74	423.93	NA	35.23%	NA

Notes. R^2 C = R^2 conditionnal; R^2 M = R^2 marginal; fit was singular because the variance of the random intercept was equal to zero. Then, R^2 conditionnal and ICC were not provided.

S16. Model 15. *Dependent variable: nonword reading; sample: the 152 grade 1 children; examination of the contribution of the visual-verbal PAL naming measure.*

Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Intercept	0.00	0.07	145.00	0.00	1.00
Non-Verbal IQ	-0.04	0.07	145.00	-0.51	0.61
Phonological Awareness	0.30	0.08	145.00	3.86	<.001
Rapid Automatized Naming	0.35	0.07	145.00	4.88	<.001
Phonological Short-Term Memory	0.20	0.07	145.00	2.72	0.01
Vocabulary	-0.06	0.07	145.00	-0.91	0.36
Visual-Verbal PAL: naming	0.03	0.07	145.00	0.35	0.73
Random Effects	**Variance**	**Standard Deviation**			
Teacher (Intercept)	0.00	0.00			
Residual	0.67	0.82			
Model fit	**AIC**	**BIC**	**R^2 C**	**R^2 M**	**ICC**
	404.99	432.20	NA	35.12%	NA

Notes. R^2 C = R^2 conditionnal; R^2 M = R^2 marginal; fit was singular because the variance of the random intercept was equal to zero. Then, R^2 conditionnal and ICC were not provided.

S17. Model 16. *Dependent variable: nonword reading; sample: the 152 grade 1 children; examination of the contribution of the visual-verbal PAL auditory recognition measure.*

Fixed Effects	Estimate	Standard Error	*df*	*t*	*p*
Intercept	0.00	0.07	145.00	0.00	1.00
Non-Verbal IQ	-0.04	0.07	145.00	-0.58	0.56
Phonological Awareness	0.29	0.08	145.00	3.84	<.001
Rapid Automatized Naming	0.35	0.07	145.00	4.94	<.001
Phonological Short-Term Memory	0.20	0.07	145.00	2.83	0.01
Vocabulary	-0.07	0.07	145.00	-1.01	0.32
Visual-Verbal PAL: auditory recognition	0.07	0.07	145.00	0.98	0.33
Random Effects	**Variance**	**Standard Deviation**			
Teacher (Intercept)	0.00	0.00			
Residual	0.66	0.81			
Model fit	**AIC**	**BIC**	**R^2 C**	**R^2 M**	**ICC**
	404.27	431.48	NA	35.48%	NA

Notes. R^2 C = R^2 conditionnal; R^2 M = R^2 marginal; fit was singular because the variance of the random intercept was equal to zero. Then, R^2 conditionnal and ICC were not provided.

S18. Model 17. *Dependent variable: nonword reading; sample: the 152 grade 1 children; examination of the contribution of the visual-verbal PAL designation measure.*

Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Intercept	0.00	0.07	145.00	0.00	1.00
Non-Verbal IQ	-0.03	0.07	145.00	-0.44	0.66
Phonological Awareness	0.32	0.08	145.00	4.24	0.00
Rapid Automatized Naming	0.35	0.07	145.00	5.00	0.00
Phonological Short-Term Memory	0.23	0.07	145.00	3.16	0.00
Vocabulary	-0.05	0.07	145.00	-0.75	0.45
Visual-Verbal PAL: designation	-0.10	0.07	145.00	-1.38	0.17
Random Effects	**Variance**	**Standard Deviation**			
Teacher (Intercept)	0.00	0.00			
Residual	0.66	0.81			
Model fit	**AIC**	**BIC**	**R^2 C**	**R^2 M**	**ICC**
	403.26	430.47	NA	35.88%	NA

Notes. R^2 C = R^2 conditionnal; R^2 M = R^2 marginal; fit was singular because the variance of the random intercept was equal to zero. Then, R^2 conditionnal and ICC were not provided.

S19. Model 18. *Dependent variable: word reading; sample: the 75 grade 2 children.*

Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Intercept	0.01	0.12	9.20	0.04	0.965
Non-Verbal IQ	0.21	0.08	61.09	2.44	0.018
Phonological Awareness	0.28	0.09	59.81	3.16	0.003
Rapid Automatized Naming	0.06	0.07	57.34	0.77	0.447
Phonological Short-Term Memory	0.25	0.09	66.78	2.90	0.005
Vocabulary	0.22	0.09	67.16	2.39	0.020
Random Effects	**Variance**	**Standard Deviation**			
Teacher (Intercept)	0.12	0.35			
Residual	0.30	0.54			
Model fit	**AIC**	**BIC**	**R^2 C**	**R^2 M**	**ICC**
	165.54	184.08	0.69	0.57	0.00

Notes. R^2 C = R^2 conditionnal; R^2 M = R^2 marginal

S20. Model 19. *Dependent variable: nonword reading; sample: the 75 grade 2 children.*

Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Intercept	-0.03	0.10	7.11	-0.36	0.730
Non-Verbal IQ	0.26	0.10	66.30	2.62	0.011
Phonological Awareness	0.12	0.10	65.48	1.15	0.255
Rapid Automatized Naming	0.25	0.09	62.04	2.88	0.005
Phonological Short-Term Memory	0.13	0.10	67.03	1.31	0.194
Vocabulary	0.27	0.10	66.62	2.64	0.010
Random Effects	**Variance**	**Standard Deviation**			
Teacher (Intercept)	0.04	0.20			
Residual	0.43	0.66			
Model fit	**AIC**	**BIC**	**R^2 C**	**R^2 M**	**ICC**
	183.15	201.69	0.58	0.54	0.08

Notes. R^2 C = R^2 conditionnal; R^2 M = R^2 marginal

S21. Model 20. *Examination of the contribution of visual-verbal PAL (naming) to word reading after taking into account nonword reading and other factors predictive of reading.*

Fixed Effects	**Estimate**	**Standard Error**	***df***	***t***	***p***
Intercept	-0.07	0.06	9.57	-1.15	0.28
Grade	0.28	0.10	22.26	2.66	0.01
Nonword reading	0.46	0.05	213.57	8.83	<.001
Non-Verbal IQ	0.07	0.05	215.99	1.50	0.13
Phonological Awareness	0.14	0.05	207.73	2.81	0.01
Rapid Automatized Naming	0.14	0.06	212.32	2.47	0.01
Phonological Short-Term Memory	0.14	0.05	212.26	3.06	0.00
Vocabulary	0.03	0.05	211.09	0.63	0.53
Visual-verbal PAL: naming	0.13	0.05	213.90	2.69	0.01
Grade * Rapid Automatized Naming	-0.19	0.09	215.07	-2.13	0.03
Grade * Vocabulary	0.14	0.09	209.96	1.54	0.13
Random Effects	**Variance**	**Standard Deviation**			
Teacher (Intercept)	0.02	0.13			
Residual	0.34	0.58			
Model fit	**AIC**	**BIC**	**R^2 C**	**R^2 M**	**ICC**
	467.65	512.17	66.39%	64.67%	0.05

Notes. R^2 C = R^2 conditionnal; R^2 M = R^2 marginal

S22. *Comparison of the distributions of word reading and nonword reading scores without and with transformation.*

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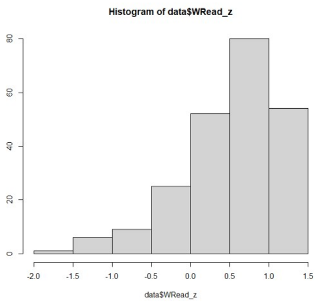
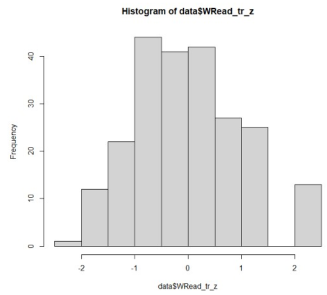
<tr><td>Word Reading Histograms</td><td>
</td><td>
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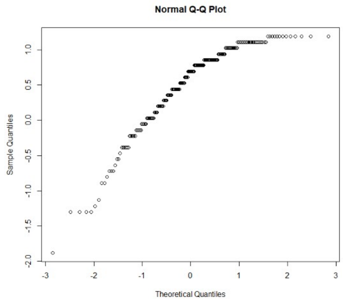
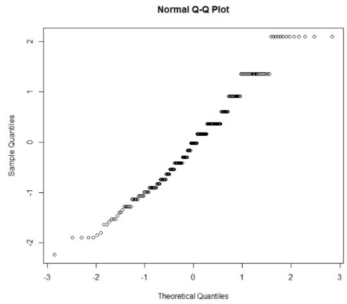
<tr><td>Word Reading QQ-plots</td><td>
</td><td>
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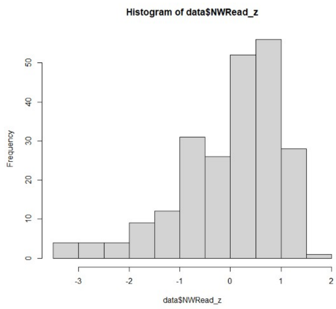
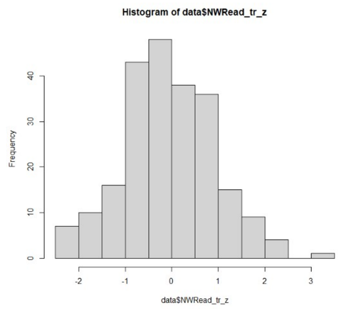
<tr><td>Nonword Reading Histograms</td><td>
</td><td>
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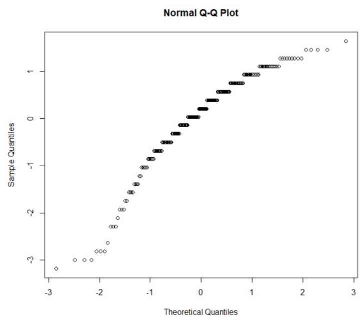
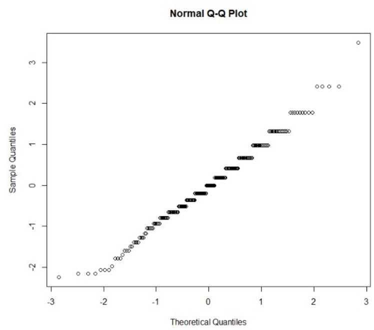
<tr><td>Nonword Reading QQ-plots</td><td>
</td><td>
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S23. *Quantile-Quantile Plots and Residuals vs. Predicted Plots with and without Transformation of Dependent Variables.*

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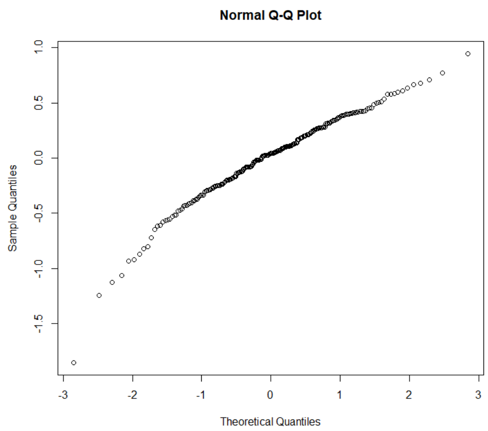
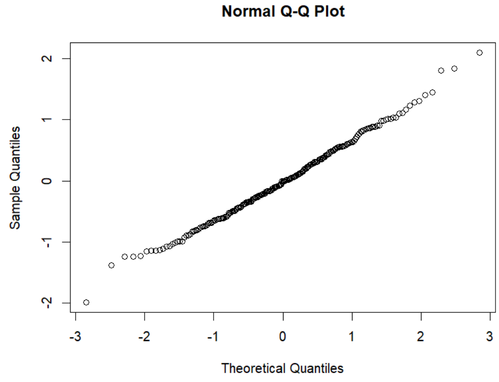
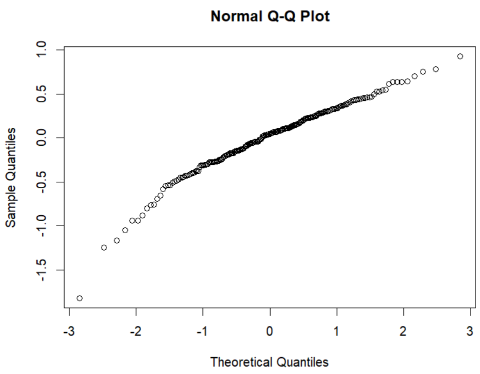
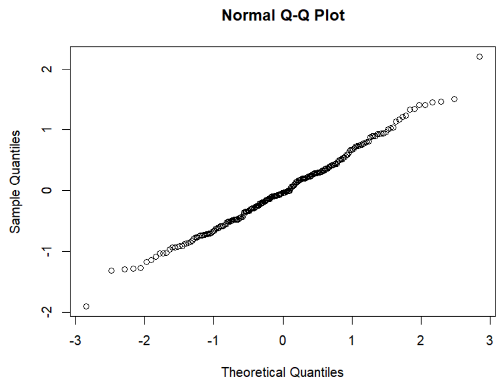
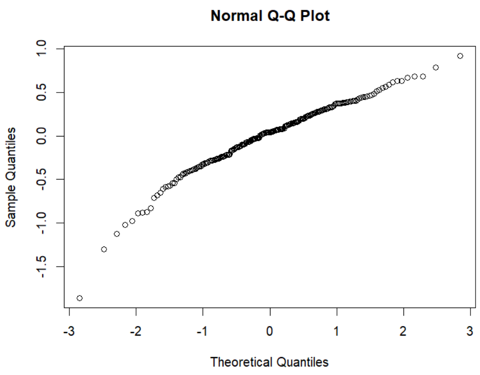
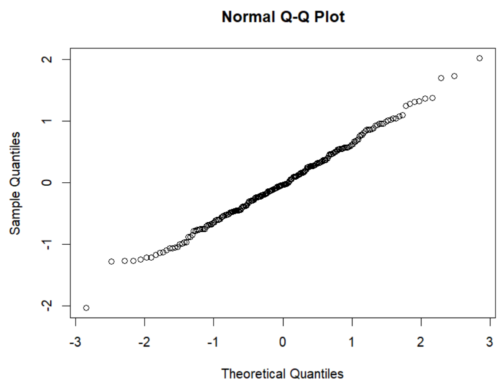
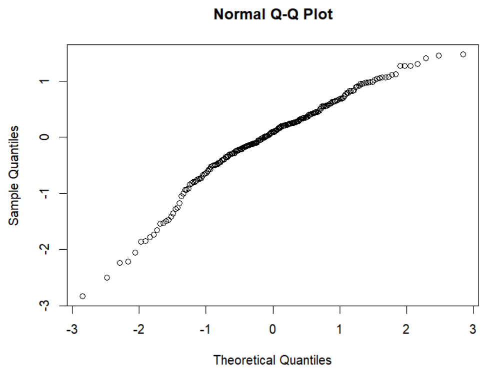
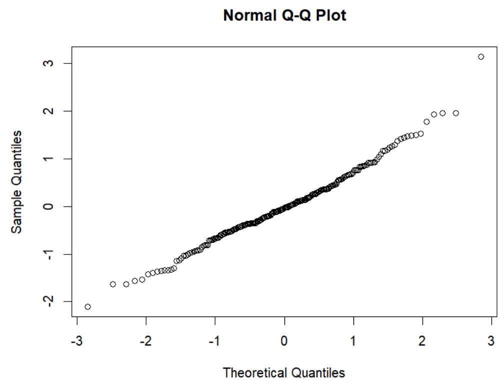
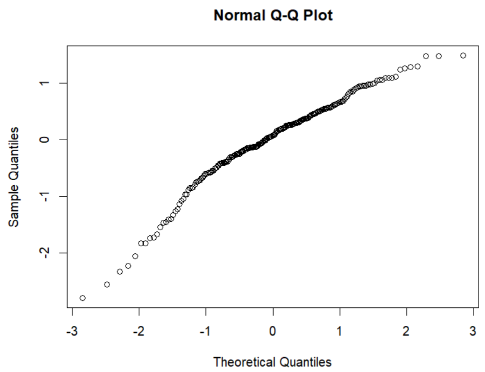
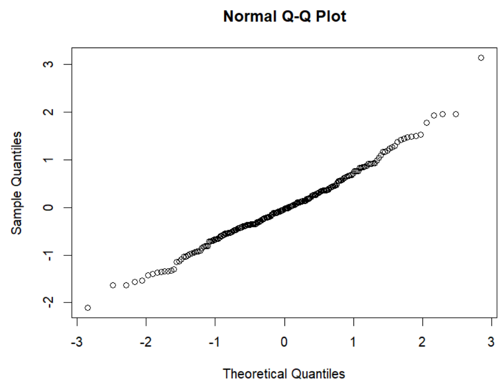
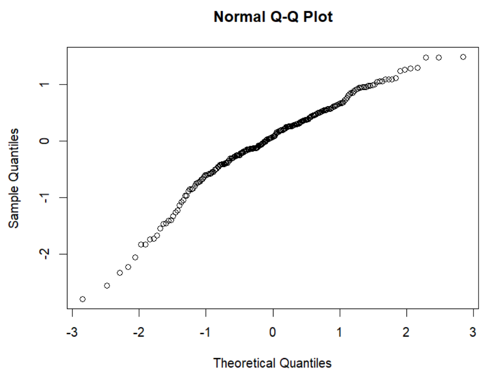
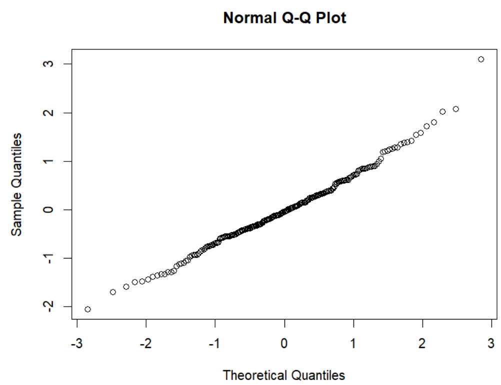
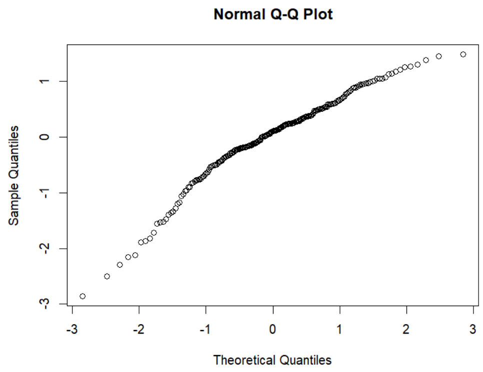
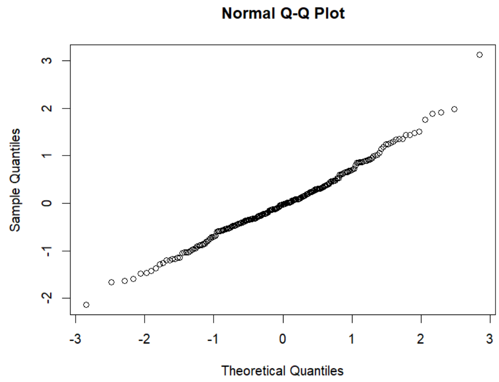
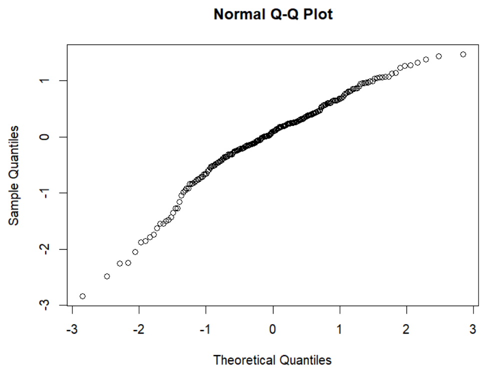
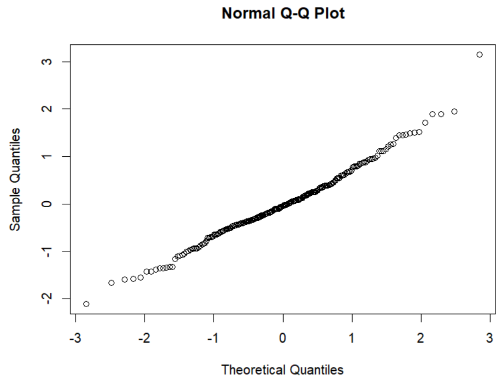
Model 1		
Model 2		
Model 3		

Model 4		
Model 5		
Model 6		

Model 7		
Model 8		

S24. *Residuals vs. Predicted Plots without and with Transformation of Dependent Variables.*

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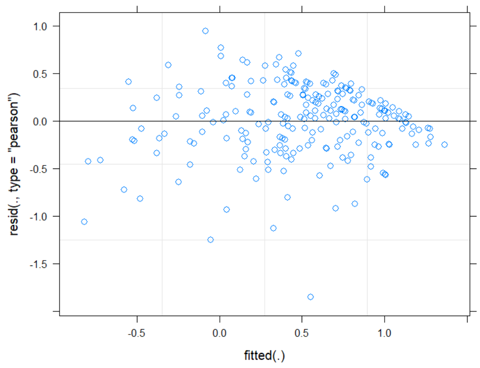
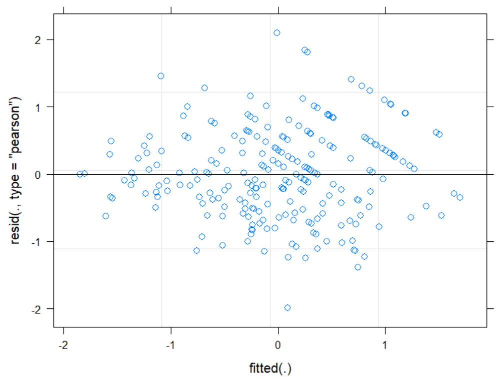
<tr><td>Model 1</td><td>
</td><td>
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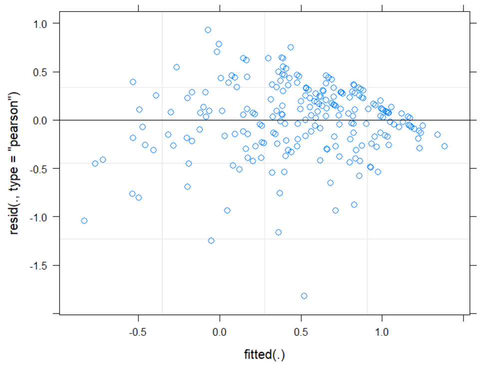
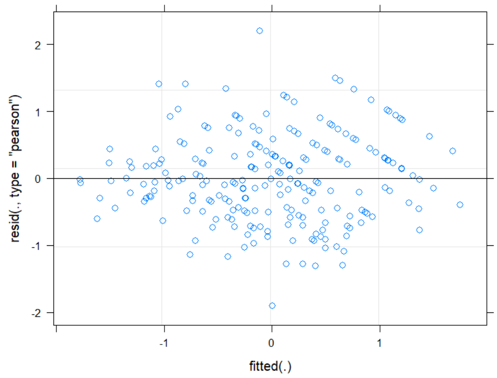
<tr><td>Model 2</td><td>
</td><td>
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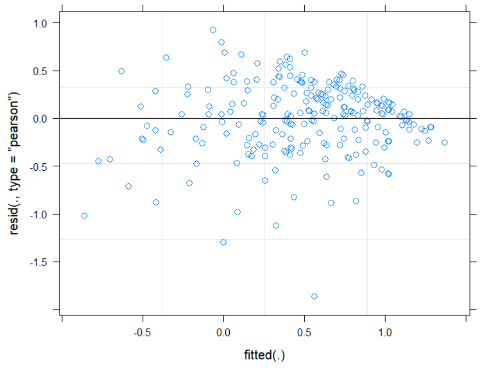
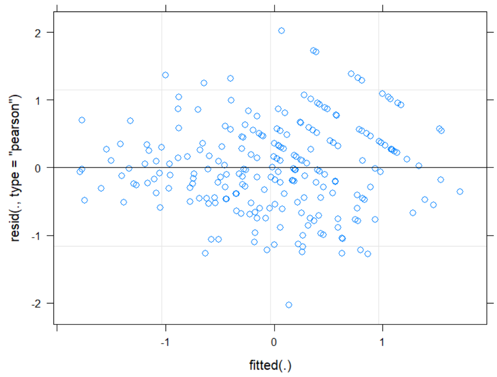
<tr><td>Model 3</td><td>
</td><td>
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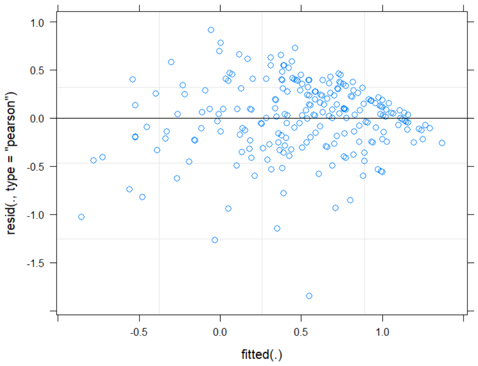
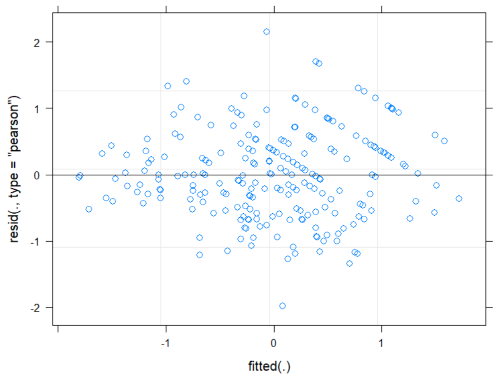
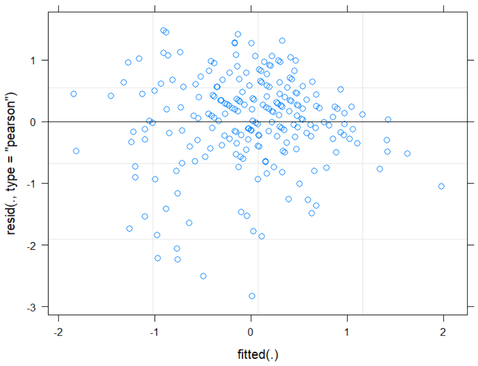
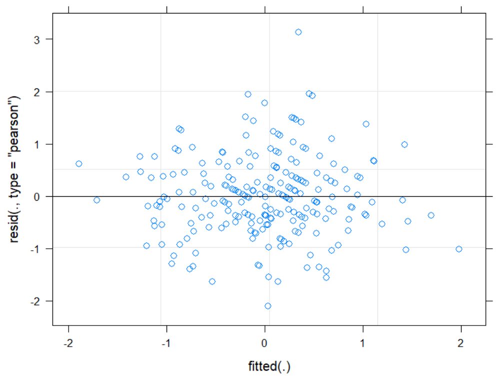
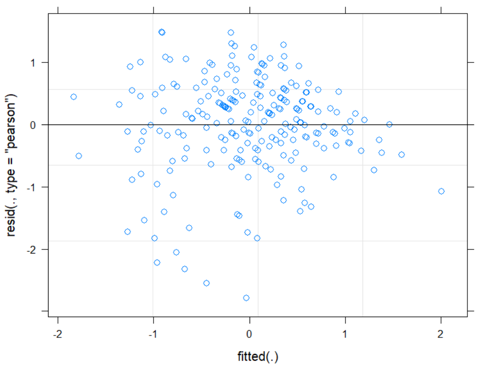
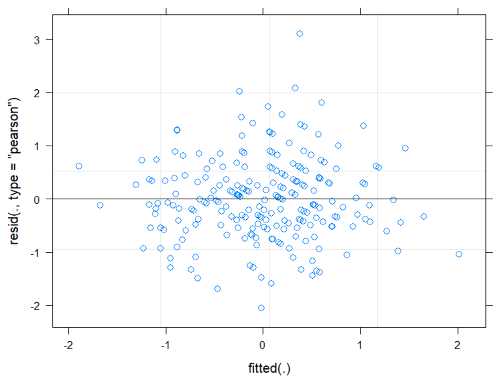
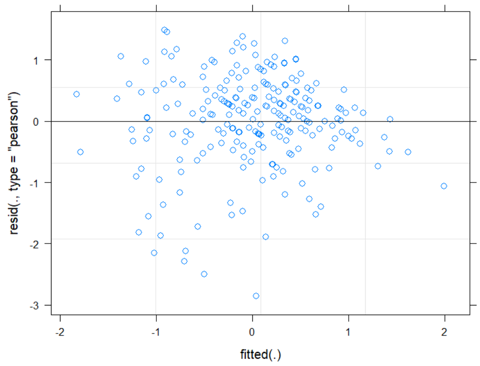
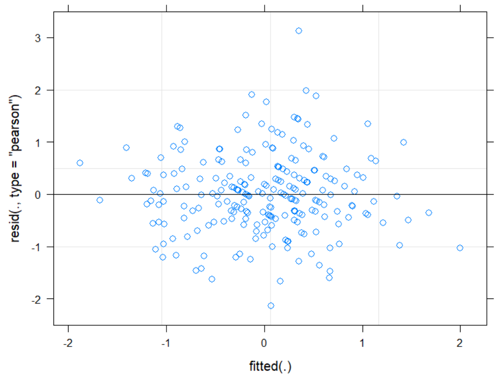
Model 4		
Model 5		
Model 6		

Model 7		
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