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Ana Júlia Moreira
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Dynamics of perception and aesthetics in interaction with the environment: The case of car exterior design

Composition du jury :

Pr. Thierry Baccino	Président du jury, Université Paris 8
Pr. Yann Coello	Directeur de thèse, Université de Lille
Dr. Laurent Sparrow	Co-encadrant de thèse, Université de Lille
Mme. Nathalie Le Hir	Co-encadrant de thèse, Renault
Mme. Stéphanie Baron	Examinatrice, Renault
Pr. Jean Lorenceau	Rapporteur, Paris-Université
Pr. Daniel Mestre	Rapporteur, Aix-Marseille Université

SCALab UMR CNRS 9193
Université de Lille
Rue du Barreau
BP60149
59653 Villeneuve d'Ascq
Tél. 03 20 41 71 21

“There is surely no department of life without its aesthetic aspects.”

Berlyne, 1972

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Résumé

Afin d'innover ou améliorer un produit, il est essentiel de comprendre comment les consommateurs le perçoivent et le vivent. De nombreuses études portant sur l'expérience du consommateur ont déjà été réalisées mais, en général, elles s'appuient sur des mesures subjectives. Dans cette thèse, nous proposons et nous testons l'utilisation des différents indicateurs objectifs, afin de mieux comprendre les processus cognitifs (attentionnels, perceptifs) et affectifs (psychophysiologiques) impliqués dans l'expérience du consommateur vis-à-vis le design extérieur des voitures.

Dans l'*étude 1*, afin de prouver l'existence d'une capture attentionnelle liée au design des voitures, une tâche *dot probe* a été utilisée en faisant varier le niveau d'innovation et la forme du design. Les résultats montrent un avantage attentionnel pour les designs plus familiers et les formes hautes. Dans l'*étude 2,* nous avons testé la présence de réactions affectives spécifiques vis-à-vis les différents designs, en examinant aussi la saillance et l'exploration visuelles. Dans une tâche d'exploration visuelle libre de voitures, deux types de catégorisations ont été pris en compte : une catégorisation basée sur la forme et une catégorisation propre à l'entreprise Renault. Les formes basses et les formes courbes ont été préférées et ont provoqué une fréquence cardiaque plus élevée. Les formes basses et angulaires ont suscité un traitement de type *bottom-up* (*i.e. stimulus-driven*). L'importance du logo a également été confirmée. Dans l'*étude 3*, afin d'explorer l'impact potentiel de la taille des stimuli sur l'expérience du consommateur, des images de voitures à une échelle quasi-réelle ont été présentées dans une tâche d'exploration visuelle libre. Aucune différence n'a été constatée sur les indicateurs électrodermaux ou cardiaques. Les formes courbes (*vs.* angulaires) ont provoqué une plus grande dilatation pupillaire. Les formes hautes et les formes angulaires ont été plus susceptibles aux influences *top-down* (*i.e. goal-driven*), tandis que les formes basses, et les formes courbes aux influences *bottom-up*. En plus du logo, le phare avant droit a aussi suscité plus d'attention. Nous avons aussi observé un comportement d'exploration global pendant les 15 premières secondes suivies d'un comportement d'exploitation focalisé.

En résumé, les travaux effectués ont permis de mettre en évidence différents mécanismes affectifs et cognitifs impliqués dans l'exploration visuelle des éléments de design d'une voiture, suggérant que leur perception visuelle est une expérience esthétique. Basés sur une méthodologie expérimentale originale d'analyse des comportements des consommateurs dans les domaines du design et de l'esthétique, les travaux effectués permettent d'envisager une nouvelle approche de l'étude de l'expérience du consommateur aux différentes étapes de conception du design dans l'industrie automobile.

Abstract

To innovate or improve a current product, it is essential to understand how consumers perceive and experience it. There is an extensive research on consumer experience, but in general these studies focus on subjective measures. Therefore, the goal of this thesis is to propose and test the use of different objective measures in order to gain more insight on the cognitive processes (attentional, perceptive) and the affective processes (psychophysiological) involved in the consumer experience of car exterior design.

In *Study 1*, in order to prove the existence of an attentional capture of car exterior design, a dot probe task was used, and level of innovation and car shape manipulated. Results showed an attentional advantage occurred towards more familiar designs and high shapes. In *Study 2* we tested for the presence of specific affective responses to different designs, as well as examined visual salience and visual exploration. In a free-viewing task, two types of categorizations were analysed: shape and a confidential classification created by Renault. Low cars and curved shapes evoked higher heart rate and preference. Low and angular cars evoked a bottom-up processing (*i.e.* stimulus-driven). The importance of the logo on the visual exploration of car exterior design was also confirmed. In *Study 3*, in order to explore the potential impact of stimuli size on consumer experience, near-real-scale images of cars were presented in a free-viewing task. No differences were observed in terms of electrodermal or cardiac indicators. Curved designs (*vs.* angular) evoked higher pupil dilation. High, as well as angular designs were more prone to top-down influences (*i.e.* goal-driven), while low shapes and curved designs were more prone to bottom-up influences. In addition to the logo, the right front headlight also evoked more attention. We also observed a global exploration behaviour for the first 15s of picture presentation, followed by local exploitation behaviour.

In summary, this thesis has brought to light different affective and cognitive mechanisms involved in the visual exploration of design elements, suggesting that their visual perception is an aesthetic experience. Based on an original experimental methodology for studying consumer behaviour in the fields of design and aesthetics, the present work allows us to contemplate a new approach in the study of the consumer experience at the various stages of design conception in the automotive industry.

I General Introduction

The automotive industry is a highly competitive one. Hence, new ways of innovation must be pursued to overcome competition, and elicit potential consumers' interest. Innovation may be triggered by many factors, such as the need to redefine already existing products or segments, or the need to create new ones (Howell, 2001). Importantly, innovation may take many forms, such as technological-, mechanical-, or design-related. But independently of the type of innovation being achieved, its success depends entirely on consumer appreciation.

Indeed, it is essential to study consumer behavior, since a product's success depends entirely on its acceptance or rejection by the target audience. Historically, consumer behavior is generally understood under two main perspectives: a *positivist* perspective, emphasizing the rational role of the consumer when buying, and an *interpretivist* perspective, that emphasizes the importance of the subjective meaning of each consumer's experience (Solomon et al., 2013). With consumers' experiences and emotions towards products being increasingly studied in consumer research (Hassenzahl, 2008; Van Praet, 2014), the focus has mostly changed from understanding what consumers *need* from a functional perspective, to what consumers *want*, from an experiential point of view.

On one hand, this new approach is supported by the attributed importance of emotion in decision making. Indeed, it has been well established in literature that emotion can play a determinant role in decision making (for a review, see Lerner, Li, Valdesolo, & Kassam, 2015), and, more specifically, in consumer decision making (Achar et al., 2016; Gaur et al., 2014; Lerner et al., 2007).

On the other hand, the introduction of concepts such as *hedonic* and *utilitarian* values or consumer motivation shed a new light on the intrinsic and complex relationships between a given product, and its consumers. Indeed, the hedonic and utilitarian aspects of a product play an extremely important role in the buying process (Kazakeviciute & Banyte, 2012). Whereas the utilitarian value of a product or service refers to its instrumental, functional, and practical benefits, the hedonic value of a product or service refers to its experiential, aesthetic, and amusement benefits (Hirschman & Holbrook, 1982; Stock et al., 2014). Hence, one may consider a utilitarian experience to be driven by extrinsic, and cognitive factors, and a hedonic experience to be motivated by intrinsic, and emotional factors (Botti & McGill, 2011; Hirschman & Holbrook, 1982; Stock et al., 2014). A relevant notion to keep in mind is that the concepts of utilitarian and hedonic value should be considered as opposing ends of the same spectrum, since consumers' perceptions and preferences evoke these two dimensions (Dhar & Wertenbroch, 2000), at possibly different levels. If we take the practical example of a car, we can see that it can both show a utilitarian value (e.g.: buying a car because of its price, or gas mileage) and a hedonic value (e.g.: buying a car because of its comfort when driving, or achieved status evoked by the chosen brand/model, or the role its interior and exterior design, materials used, colors, as well as aspects of man-machine interface may have on car purchase). But the weight of either the utilitarian or hedonic values when buying a product or service are not constant, and may therefore shift depending on the consumer's goal (Botti & McGill, 2011), and the nature of the decision task (Dhar & Wertenbroch, 2000).

Intuitively, one may expect high-priced purchases, such as cars, to be strongly driven by their utilitarian value. However, hedonic value is also a very important element to be considered in car purchase, at least in France. In fact, in France, the main factor of choice when choosing which car to buy is its exterior design (according to the New Car Buyer Survey of 2015), followed by price, and brand. Overall, a lot of studies in consumer research take into consideration the role that emotion and hedonic states can play, notably when studying the relevance of brand heritage (Pecot et al., 2018; Wiedmann et al., 2011), improving brand attachment by introducing an artistic approach (Koronaki et al., 2018), evaluating prices and products (Estes et al., 2018), designing in order to evoke a strong emotional experience (Desmet et al., 2007).

Most studies on consumers' emotional responses focus on subjective methods, such as questionnaires, and interviews (Desmet et al., 2000; Hassenzahl, 2004; Nicolás et al., 2014; Tonetto & Desmet, 2016). The goal of these methods is to explore consumers' opinions by making them ponder on their experiences with the product or service, and verbalizing them in an explicit way. These methods are undoubtedly informative, providing crucial information concerning product conception, development, and ergonomics, but they can also be lengthy, and can be somewhat disruptive of the consumer's experience with the product. Moreover, whenever using these methods, one should be wary of the potential occurrence of social desirability bias (e.g. King & Bruner, 2000; Neeley & Cronley, 2004).

Therefore, the goal of this thesis is to provide new insight that will allow a different understanding of consumers' preferences concerning car design, by focusing on the consumers' cognitive (*i.e.* perception and attention mechanisms, by analyzing eye movement), and affective (*i.e.* psychophysiological mechanisms, by analyzing electrodermal activity, heart rate, and pupil size) processes involved on the perception of car exterior design.

II Literature Review

Chapter 1: Emotion & Aesthetics

Defining emotion, how it arises, identifying its consequences, and the mechanisms involved has been a source of extensive and fruitful research. In order to fully comprehend how emotion and perception of car exterior design can be intertwined, one needs to be able to contextualize *emotion* properly. Therefore, the goal of this chapter is to give an overview of the main perspectives in emotion research, with an emphasis on the main emotion theories, as well as their implications on how to comprehend and measure emotional states.

On the other hand, since the focus of this thesis is on exterior car design, another important notion to introduce and to consider in this thesis is the one of *aesthetics*. Hence, in this chapter, we will define aesthetics, what constitutes an aesthetic experience, and how it can be measured. We further establish a connection between emotion research and aesthetics research, in the hope of shedding a light on how to approach the study of consumers' preferences towards car exterior design.

1.1. Defining Emotion.

The endeavour of defining and understanding what is now commonly known as *emotion* can be tracked down to before the common era: in Sanskrit and Bengali, *bhava* and *rasa* were terms meant to represent notions of emotional experiences, bodily responses, as well as aesthetics, and transcendent states; in Confucian philosophy, in China, the notion of emotion was related to a harmonious state way of living, and Greek philosophers such as Plato, and Aristotle used the term *pathê* to discuss how the soul evoked passions, powers, and habits (Frevert, 2016). The term *emotion*, as we make sense of it now, is a relatively recent one, appearing in the 19th century in English language (Frevert, 2016; Gordon, 2009), and stemming from the Latin *movere*, which signifies *moving*. This portrays well the notion that when emotions happen, and especially when they are intense, there is an action that happens, a movement (Bradley & Lang, 2007; James, 1884).

Despite being something profoundly connected to the human condition (and maybe because of such), it has been incredibly difficult to reach a consensus in emotion research regarding what an emotion *is*, as well as *why*, and *how* it is. Even though there is an unanimity regarding some aspects of emotion, the difficulties involved in reaching a consensus among the research community, as well as the sources of disagreement are well documented in Izard's survey (2010), in which 34 distinguished researchers on emotion answered several questions regarding its definition, activation and function. While no unitary definition of *emotion* was agreed upon, moderate to high agreement was found regarding the role of neural circuits and neurobiological processes, the occurrence of a phenomenal experience or feeling, and finally the involvement of perceptual-cognitive processes.

Despite the lack of consensus, Nico Frijda and Klaus Scherer (2009) detail four aspects of emotion that must be kept in mind when trying to study it. The first aspect to consider is that whenever an emotion occurs, it is because something relevant occurred to the organism. In visual perception, humans need to prioritize information in order to treat it, and address it. Even though all humans prioritize and filter information, it does not mean that they all filter and treat the same information the same way. A stimulus can be relevant to a person because of the person's specific values, beliefs, motivations, and needs, but a stimulus can also be relevant due to its novelty, surprise effect, and its (un)pleasantness (Scherer, 2001). Therefore, the *relevance* of the potentially emotion-evoking stimulus may depend solely on its perceiver, or it can also depend on the intrinsic characteristics of the stimulus. The second aspect of emotion to consider is that in most emotion-evoking scenarios, the organism needs to react, which may imply interrupting a behaviour in order to pursue a more adapted one. This change or adaptation in behaviour in order to handle an emotion is always made in order to be able to attain a goal, with high motivation, and interaction (whether interpersonal or with the world) being essential to this process. The high motivational forces of emotion, and hence the need to react and adjust behaviour accordingly, brings us to the third feature to consider: the entire organism is engaged in this process. In order to interrupt the behaviour so to engage in a more adaptive one, there is a need to adjust the somatovisceral and motor systems. This implies two notions: firstly, that emotions involve numerous components (e.g.: cognitive, feeling, motivational, somatic, and motor; Moors, 2009), and secondly, that the existence of these components does not imply the presence of a set of prototypical emotions. Finally, the fourth aspect to consider is that emotion claims the prioritization of action readiness when in competition with other non-emotional events. However, in some cases, the organism does not respond to this prioritization. In some situations, due to social norms or concerns, for example, the organism needs to *regulate* its emotions. It is also important to keep in mind that, even though an emotional event may not be significant or strong enough to alter behaviour, it may still evoke changes in attention (e.g.: Fernandes, Koji, Dixon, & Aquino, 2011; Holmes, Mogg, de Fockert, Nielsen, & Bradley, 2014; Zhang, Japee, Safiullah, Mlynaryk, & Ungerleider, 2016). Overall, researchers tend to agree on the existence of connections among emotion, action and cognitive processes, in a rapid, unconscious, and automatic way (Izard, 2010).

1.2. Approaches and theories of emotion.

As we will see in the following paragraphs, there are three different paths to emotion research, where one can place all its main theories, namely the *basic emotion*, *appraisal*, and the *psychological constructionist* (or also referred to as *dimensional*) approaches (Gendron & Barrett, 2009). These approaches mainly differ on what constitutes an emotion, and on the roles that the mind and the bodily changes play on emotional expression. These approaches will be briefly presented, but for a more detailed review, see Gendron and Barrett's article (2009).

The *basic emotion* approach may be tracked down to the research of Charles Darwin (1873) on the *expression* of emotion. To Charles Darwin (1873), the relationship between specific states of mind and bodily expressions is so clear, and strong that its physical expression will ensue, independently of their usefulness. Darwin also acknowledged the direct unconscious action that the "excited" (or activated) nervous system will have on the body. Later on, Silvan Tomkins (1962, 1978) developed an affect theory. Tomkins distinguishes among: *affect* a term to portray physiological reactions, *feeling* was meant to signify the realization that an affect was taking place, and *emotion* was considered to be the combination of an affect and the memory of the experiences of that same affect.

Paul Ekman is another researcher whose work has been largely influenced by Darwin's and Tomkins' findings (Ekman, 1999), and tightly connected to the *basic emotion* approach. By comparing facial expressions across cultures, he identified six universal emotions: happiness, sadness, fear, disgust, anger and surprise (Ekman, 1970; Ekman et al., 1969). Later on he also added other positive and negative emotions, reaching 15 basic emotions in total (Ekman, 1999; Ekman & Friesen, 1986; see also Matsumoto, 1992), which according to him show unique universal signals, subjective experiences, distinctive thoughts and physiology, a quick onset and short duration, and occur with no control.

Overall, the crucial statement of the *basic emotion* approach is that a set of different and universal emotions exist, eliciting specific patterns of activation, behaviours, facial expressions, and appraisals (Fontaine, 2013). Nowadays this approach considers the existence of specific neural circuits or hardwiring into the brain, which would explain the universality of emotion, and the lack of need to be socially or culturally learned (Gendron & Barrett, 2009). Critics to this approach claim a problem of differentiation, as the majority of research does not support the idea that a specific pattern of neurobiological, phenomenological, expressive, behavioural, physiological response exists for each basic emotion (Barrett, 2006; for a meta-analysis on emotion specificity and the autonomic nervous system activity, see Kreibig, 2010; Scarantino, 2016). Moreover, the importance of cognition on emotion is seen as a critique to the basic emotion approach, with motivations, appraisals and intentions being prone to be influenced by cultural and social contexts (Ortony & Turner, 1990). Carroll Izard (1992), when addressing these critics in an article, restored the definition of *basic*, and distinguished the experience of emotion as a “feeling state” and motivation as *motive*, which implied a “more cognitively articulated goal”. More recently, this approach took some emotional variability into account by acknowledging the existence of cultural norms and their role on the expression of emotion (Gendron & Barrett, 2009).

The second group of emotion theories is the *appraisal* perspective. David Irons (1894, 1897) gave the first formal steps into this approach by defining five arguments that represent the fundamental ideas of this perspective: 1) an analysis of meaning has to happen in order for an emotion to occur; 2) this analysis of meaning is specific and particular to the emotional experience; 3) which does not necessarily mean that this process occurs in conscious awareness; 4) an emotion is always an experience towards a certain stimulus; and 5) an analysis of meaning is necessarily accompanied by bodily changes, even though the latter are not sufficient for the occurrence of emotion.

The main idea of this approach is that emotion only and always occurs as a direct consequence of the person’s subjective evaluation (*i.e. appraisal*) of an event (Scherer & Ellsworth, 2009, Appraisal Theories section), with theories differing in aspects such as the mechanisms involved in the appraisal process, and the content of the appraisals (Moors et al., 2013; Roseman & Smith, 2001). These appraisals comprise various dimensions, such as intrinsic valence (e.g.: Scherer, 1982) or type of goal (e.g.: Smith & Lazarus, 1990), for instance (for a discussion on the matter, see Moors et al., 2013), with the dimensions to consider differing according to researchers (Scarantino, 2016). This approach also defends the existence of discrete categories of emotion, while acknowledging the dimensionality of the emotional experience (Scherer, 2013). Current theories of appraisal (e.g.: Ellsworth, 1994; Frijda &

Mesquita, 1994) try to discriminate different emotional states, and they acknowledge and include temporal, individual, and cultural aspects of the emotional experience, as well as discuss and explain emotional pathology (Roseman & Smith, 2001).

The third approach on emotion is the *psychological constructionist* one (also known as the *dimensional* approach), which firstly began with James notoriously putting forward the idea that "the bodily changes follow directly the perception of the exciting fact, and that our feeling of the same changes as they occur is the emotion. […] we feel sorry because we cry, angry because we strike, afraid because we tremble, and not that we cry, strike, or tremble, because we are sorry, angry, or fearful" (James, 1884; 1950, p.449-450). The *constructivist* term for this approach stems from James' proposal that the emotion is the experienced bodily reaction caused by perception (Scherer, 2013). Despite the crucial role of bodily responses for an emotion to occur, James did not consider there existed specific brain or muscle structures of emotion (James, 1950). James also considered the role of the interpretation of the stimulus in his theory, but this notion got lost in over-simplifications of his ideas throughout time (Ellsworth, 1994). For James, the absence of bodily changes meant that the perception was purely cognitive, but he did acknowledge the existence of a strict connection between body and mind (James, 1950) by stating for example that an emotion could either be evoked by the presence of the *object* or by just the mere thought of the object (James, 1950). Some critics of William James' work sometimes wrongly associate his views to the ones of Carl Lange (Gendron & Barrett, 2009; Lange, 1922). Indeed, the association of both works is so common that this is referred in literature as the James-Lange theory (see Gendron & Barrett, 2009). A sounding common argument against this theory (and also against the *basic* approach) is the fact that one is not able to differentiate emotions when just taking into consideration the activation of the autonomic nervous system (Scarantino, 2016), since visceral changes are slow, and also play a role in non-emotion related states (Cannon, 1927). However, James never sustained the idea of specific patterns of physiological reactions for each emotion – that was Lange. In fact, James even states that Lange "simplifies and universalizes the phenomena a little too much" (James, 1950, p.446), and reiterates the notion of emotion variability across individuals (James, 1950). Other criticisms evoke the lack of explanation given to the causal effects of emotion on action (Scarantino, 2016), as well as the danger of confusing the process with the mental content it produces, since it can impair research by eroding the difference between the identification and the description of the phenomena (Barrett, 2009).

Later in 1896, it was Wilhelm Wundt who coined the *dimensional* term, by suggesting the existence of three different qualities of what we now call *(core) affective states*: pleasure/displeasure, arousal/calming, and tension/relaxation (see Fontaine, 2009, Dimensional Emotion Models section). The notion of these dimensions was and still is widely accepted, being vastly used in the evaluation of affective experiences, and on research on emotion words (Fontaine, 2013). Wundt made a clear distinction between sensations, ideas (*i.e.* "revivals of previous experiences"), feelings, and voluntary actions, with emotion being a conscious affective process with *ideational connections* (Wundt, 1897). Feelings are seen as "subjective processes" indirectly related to the object, only becoming externally accessible when they turn into emotions, which implies the occurrence of *expressive movements* (Wundt, 1897). These dimensional notions of emotion will be further discussed in section 1.3.

Overall, the *psychological constructionist* (or *dimensional*) approach proposes emotions as combinations of different sensory stimulation and their cognitive counterpart. This approach does not necessarily focus on finding an exact number of emotions, and does not acknowledge the existence of specific areas or structures to emotion. However, Maria Gendron and Lisa Feldman Barrett (2009) warn about the danger of using the term *dimensional* to refer to this approach since it is easy to mistakenly assume that these theories view emotion as simple (un)pleasant states, or that the sole occurrence of affect explains what an emotion is.

Overall, to this day, emotion research is still based on these three main approaches: basic emotion, appraisal, and psychological constructionism. While the basic emotion approach focuses on the specificity and homogeneity of emotion, the emphasis of appraisal theories goes to the intentionality and meaning involved in emotional states. Finally, the psychological constructionist approach highlights the involvement of more basic psychological mechanisms as the basis of all psychological processes, emotion included.

1.3. Measuring emotion.

From declarative to physiological or behavioural methods, a panoply of techniques can be used independently or simultaneously in order to study emotional responses. In this section, we will discuss the overall possibilities to measure emotion, and particularly the methods that concern this thesis. Hence, we will discuss how to measure emotion under a dimensional perspective.

When measuring emotion, one can consider measuring emotion as *traits* or as *states*, with the former being more stable across time and seen as tendencies, and the latter being shorter in duration and time-constrained, of higher intensity, as well as seen as reactions or episodes toward something and depending on the situation rather than on personality, with the function of directing attention (Diener & Larsen, 1984; Ekkekakis, 2013; Roseman et al., 1990; David Watson & Clark, 1991; Zelenski & Larsen, 2000). As in this thesis we are interested in measuring consumers' emotional and attentional reactions regarding car exterior design, we will focus on emotion as a state, or rather a response in the present sub-section.

Self-reports.

Self-reports are used to measure the subjective experience of the emotional state (Mauss & Robinson, 2009). Questionnaires such as the Geneva Appraisal Questionnaire (GAC; Scherer, 2001), or the Geneva Affect Label Coder (GALC; Scherer, 2005) are examples of free-response questionnaires where participants are invited to describe their feelings and emotions in their own words. Examples of forced-choice self-reports commonly used in emotion research are the Multiple Affect Adjective Check List (Zuckerman et al., 1964, 1965), the State-Trait Anxiety Inventory (Spielberger et al., 1970), and the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). While the first two questionnaires are more promptly used to measure negative emotional states, and measure *discrete* emotions, the PANAS is able to measure positive and negative emotional *dimensional* states, while also considering *time* as a factor (and hence introducing the possibility of evaluation emotional states and traits). Indeed, in their review of measures of emotion, Mauss and Robinson (2009) suggest it is more suitable to focus on measuring emotional states or responses along *dimensions* (*i.e.* valence, arousal) rather than taking up a more discrete perspective (e.g.: establishing reactions of sadness, or fear).

Speaking of emotions in terms of dimensions, Wilhelm Wundt (1897) identified three dimensions in order to classify an affective experience (pleasurable-unpleasurable, arousing-subduing, strain-relaxation). Other authors worked on the subject (see Barrett & Russell, 2009, Dimensional Models of Affect section), but Charles Osgood (1952) was the one who established the relevance of these three dimensions existent in natural language in order to measure *meaning*, and not necessarily emotion. Using pairs of antonyms (e.g.: good-bad, kind-cruel, strong-weak) in order for participants to make a judgment between each pair, three unrelated dimensions were identified: 1) an *evaluative* dimension bearing notions of pleasant-unpleasant, positive-negative, and which was later coined and more commonly known nowadays as *valence*; 2) a *potency* dimension, characterized by pairs such as strong-weak, hardsoft, and which is now commonly known as the *dominance* dimension; and 3) an activity dimension, now coined as *arousal* or *activation*, which concerns pairs such as active-passive, excitable-calm (Osgood, 1952, 1962, 1964). With research showing some incongruence on the relevance of the *potency* dimension as a measurement of the emotional experience *per se* (Bradley & Lang, 1994; Russell, 1978), research on emotion under a dimension perspective focuses mainly on the dimensions of valence and arousal.

In fact, four main models try to conceptualize emotional response according to a two-dimensions point of view, with differences among these models being explained by the way researchers approached emotion, and used different terminologies (Ekkekakis, 2013). James Russell (1978, 1980) was the one who consolidated this early work on the identification of dimensions of emotion, and proposed a circumplex model of emotion, with two orthogonal and bipolar dimensions that explain emotional experience as a combination of affective valence and perceived activation. Later on, Watson and Tellegen (1985; Watson et al., 1988) also established the existence of affective valence as a dimension, but they labelled the perceived activation dimension as "strong engagement-disengagement", with both models basically representing "rotational variants of one another" (Watson & Clark, 1997). However, they considered that only states that evoked arousal could be constructed as truly affective (Ekkekakis, 2013). A third model of this two-dimensional structure was proposed by Robert Thayer (1986), who focused on the measurement of arousal, given the postulation that arousal fluctuated between extreme excitement and deep sleep, in correlation with affective state (positive or negative). Hence, four factors were identified and included in the Activation Deactivation Adjective Check List (AD ACL; Thayer, 1986): general activation, high activation, general deactivation, and deactivation-sleep. Given the more or less similar conceptualizations of the circumplex of emotions, a fourth model was developed in order to try to integrate the former views (R. J. Larsen & Diener, 1992), by proposing the existence of octants in the circumplex.

However, many authors criticized this dimensional view of the emotional experience, by pointing out how simplistic, reductive and uninformative they actually are of the emotional experience (e.g.: Clore, Ortony, & Foss, 1987; Smith & Ellsworth, 1985). The most cited example of the lack of granularity of this model is the fact that *anxious* and *angry* are both placed at the high-activation unpleasant octant. This led researchers to acknowledge the possible dimensional similarity between qualitatively different events, and state the main utility of the dimensional approach to measure the *core* affect, instead of the general emotional experience (Barrett & Russell, 1999; Russell & Barrett, 1999). Hence, a distinct-state or dimensional approach to emotion should be chosen according to the research question to be answered (Ekkekakis, 2013). Figure 1 represents the compatibility of the four models – or rather, variants of the same model – of the two-dimensional structure of core affect (for a more complete review see Barrett & Russell, 2009, Dimensional Models of Affect section; Ekkekakis, 2013).

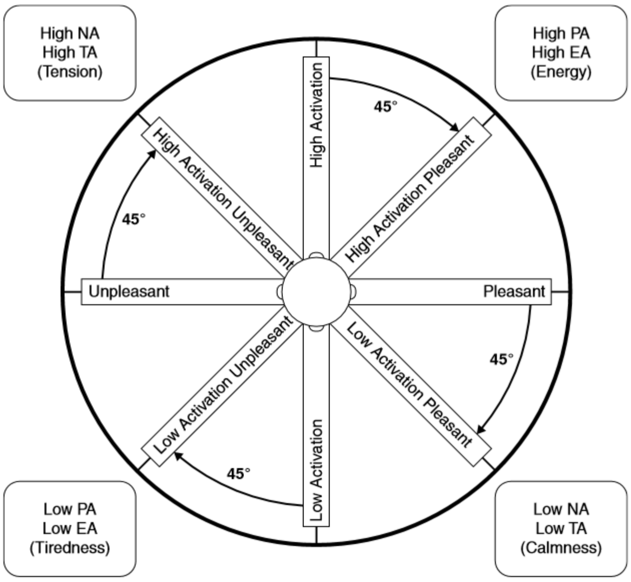

Figure 1. Depiction of the compatibility among the four models of the dimensional view on emotion. The two main axes of pleasure (valence) and arousal (activation) are organised into 45º variants of positive affect/positive activation (PA), negative affect/negative activation (NA), as well as energetic arousal (EA), and tense arousal (TA). Reprinted from "The Measurement of Affect, Mood, and Emotion: A Guide for Health-Behavioral Research" (p.66), by P. Ekkekakis, 2013, New York, US: Cambridge University Press. Copyright 2013 by Panteleimon Ekkekakis.

Besides Osgood's semantic differential, the PANAS or the AD ACL mentioned above, several other questionnaires were developed in order to capture the dimensional properties of the core affect of the emotional experience. For example, the Self-Assessment Manikin (SAM; Bradley & Lang, 1994; Lang, 1980) is a widely used questionnaire that measures the dimensions of pleasure-displeasure, arousal-nonarousal, and dominance-submissiveness by using a series of cartoon-like characters that portray different levels of each dimension. More recently, the Geneva Emotion Wheel (Scherer, 2005; Scherer et al., 2013) was developed in order to measure the emotional reaction to objects, events and situations, with participants being invited to rate the intensity of a single felt emotion according to different intensities of a valence and control/power scale.

Psychophysiological responses.

Another form of emotional measurement is the study of psychophysiological responses. *Psychophysiology* concerns the study of physiology and anatomy in relation to psychological processes, focusing on higher cognitive processes and understanding how they are integrated by central and peripheral processes (Cacioppo et al., 2007). While some authors defend the idea that different emotions evoke different patterns of physiological activation (for a review, see Kreibig, 2010; Larsen, Berntson, Poehlmann, Ito, & Cacioppo, 2008) – which goes in line with the discrete approach to emotion measurement –, others criticize this approach (e.g.: Barrett, 2006; Lang, 2014), with different physiological measures being associated to a more dimensional approach (J. T. Larsen et al., 2008), *i.e.* arousal or valence, depending on which system (sympathetic or parasympathetic, respectively, or both) innervates them.

The nervous system is organised into the central nervous system, which is constituted by the brain and spinal cord, and the peripheral nervous system, which is made of nerves that make the connection between the central nervous system and all the parts of the body. The peripheral nervous system is then organised into the somatic nervous system, and the autonomic nervous system. While the somatic nervous system is in charge of all voluntary control of body movements, the autonomic nervous system (ANS) influences the function of the organs, regulating bodily functions (e.g.: breathing, digestion), and thus working in an unconscious way. The ANS can further be divided into the sympathetic and parasympathetic nervous systems, which are the systems studied in emotion research under a psychophysiological approach. While the *sympathetic nervous system* is associated to a rapid mobilization of responses, preparing the body for action, the *parasympathetic nervous system* is engaged with restorative functions, with generally more slowly activated responses (Larsen et al., 2008). Activity of the sympathetic and parasympathetic nervous systems can change during emotion experience, but changes in these systems can also occur in the absence of an emotion, since these systems are essential to the functioning of the body, such as digestion and homeostasis (Mendes, 2016).

When considering research on the ANS and emotion, one can organise it into two categories: *specificity* of ANS responses for different emotions, and *coherence*, *i.e.* how ANS activity is organised and coordinated by emotions, including with other response systems (Levenson, 2014). Moreover, factors such as development factors, the context of occurrence, a person's cognitive state, as well as sociocultural factors may moderate the relationship between emotion and physiology (see Mendes, 2016).

The most commonly used psychophysiological measures used in emotion research are electrodermal activity, and cardiovascular responses (Mauss & Robinson, 2009), with respiratory measures also being used quite commonly on emotion research. In studies of psychophysiology and emotion, it is quite common to study several physiological measures at the same time, instead of just one.

The *electrodermal activity* refers to the electrical changes of the skin. By measuring the electrical conductance of the skin through the activity of the sweat glands (see Figure 2), which are innervated by the sympathetic nervous system, one can measure attention, and also *arousal or alertedness level*, with a higher arousal meaning the skin becomes a better conductor of electricity (Dawson & Schell, 2009, Electrodermal Response System section). When studying electrodermal activity, one can either measure *skin conductance level* (SCL), *i.e.* the *tonic* phenomena, which refers to a more stable activity throughout time, and non-related to a stimulus, or one can measure *skin conductance response* (SCR), *i.e.* skin conductance *phasic* phenomena that occurs in a short window of time (Boucsein, 2012). Normally, SCRs are due to a reaction to a stimulus, but "spontaneous" or non-specific EDRs may also occur (Boucsein, 2012). Most of the times, researchers want to measure reactions to stimuli presentation, meaning they focus more on SCRs, and more commonly on their amplitude, and variation of amplitude (Dawson & Schell, 2009, Electrodermal Response System section).

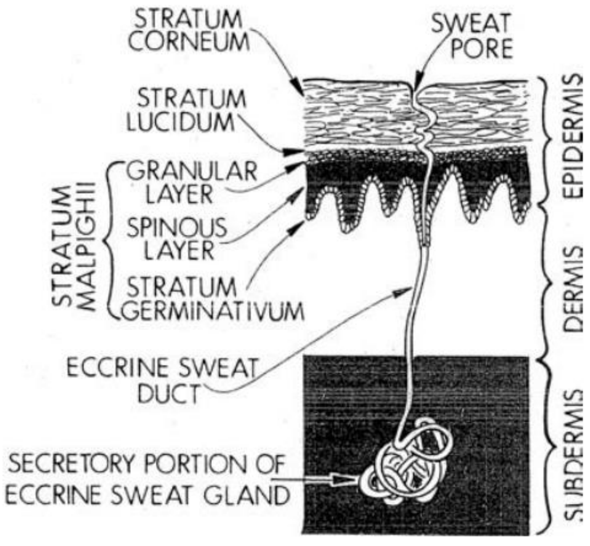

Figure 2. The anatomy of the eccrine sweat gland considering the various skin layers. Reprinted from "The electrodermal system" by M. E. Dawson, A. M. Schell and D. L. Filion in J. T, Cacioppo, L. G. Tassinary, and G. G. Berntson (Eds), *Handbook of Psychophysiology* (p.160), 2007, 3rd edition, New York: Cambridge University Press.

The *cardiovascular system* is controlled by both the sympathetic and parasympathetic branches of the autonomic nervous system (Berntson et al., 2007), being formed by the heart, blood vessels, and blood. Two of the most commonly used measures include *heart rate variability* (*i.e.* the oscillation in the interval between two consecutive heart beats), and *heart rate* (*i.e.* the time interval between two consecutive heart beats), with the first one being associated to parasympathetic activity, and the latter to both sympathetic and parasympathetic activity (Berntson et al., 2007).

Often studied in regard to health issues, the *respiratory system* is also related to emotional experience (Lorig, 2009, Respiration section). The respiration and the cardiovascular system are physiologically coupled (Lorig, 2007), and the respiratory system is also controlled by both sympathetic and parasympathetic systems (Ritz et al., 2002). Two of the most commonly used variables are the *respiratory frequency* (*i.e.* the number of cycles that occur in one minute in respiration), and *tidal volume* (*i.e.* the normal volume of air that is inhaled after exhalation; Lorig, 2007). For detailed guidelines on how to measure lung function, and which variables to study in psychophysiology, check Ritz and colleagues' article (2002).

Brain activation states can also inform on a person's emotional state, with electroencephalography, and neuroimaging studies (*i.e.* functional magnetic resonance imaging, and positron emission tomography) giving respectively important temporal, and spatial information of the emotional experience (for a review, see Mauss & Robinson, 2009; Larsen et al., 2008; Lewis, Critchley, Rotshtein, & Dolan, 2007).

Behaviour.

A person's behaviour can also give information about their emotional state. The study of emotion and behaviour has greatly expanded since Ekman's (1970) germinal paper on the universal *facial expressions* of emotion. Besides the study of facial expressions, the study of bodily expressions of emotion has also been fruitful in understanding how one portrays, detects, and prepares to react to an emotional state (de Gelder, 2006, 2013; de Gelder et al., 2015). A person's general *body posture* also seems to give important information on emotional states, including specific emotions (Coulson, 2004; Dael et al., 2012). Moreover, *vocal character*istics of the voice (*i.e.* emotional prosody) such as pitch and vocal amplitude are used in emotion research (Mauss & Robinson, 2009), as they give consistent information on arousal level, as well as on discrete emotions (see Bachorowski & Owren, 2008).

Importantly, no *standard* emotional measurement exists, since emotions vary across situations and individuals. Hence, the choice of measurement should depend on which part (or parts) of the emotional experience one wants to measure (*i.e.* experiential, physiological and/or behavioural), as well as the type of research question to be answered in terms of the choice of a discrete or dimensional approach to emotion (Mauss & Robinson, 2009; Scherer, 2005).

1.4. Introducing aesthetics.

As Daniel Berlyne (1972) put it, "there is surely no department of life without its aesthetic aspects." This propels us to integrate the concept of aesthetics in a person's emotional and cognitive experience when looking at a piece of art or even at an object. Aesthetics is deeply rooted in philosophy, still being considered to this day one of its branches (see Levinson, 2005), but its intertwinement with psychological processes, and especially with emotion research, is undeniable.

The word "aesthetics" is derived from the Greek *aisthêtikos*, and can be translated into "relating to perception". But it was Alexander Baumgarten who coined the term in regards to beauty and its sensory cognition, acknowledging the existence of perceptual, and intellectual experiences (Halliwell, 2009). The study of aesthetics in art from an experimental point of view (*i.e.* with a theoretical and methodological frameworks) can be traced back to Gustav Fechner, in 1876 (Leder & Nadal, 2014). However, it was the work of Daniel Berlyne that was seminal to the revival of the experimental study of aesthetics. Berlyne focused on arousal as a means of evoking and directing exploration, while associating it with the concepts of interest and hedonic pleasure in the visual exploration of art (Berlyne, 1972, 1973). Later, Gerald Cupchik (1994) acknowledged the existence of both bodily feelings and meanings in the aesthetic process, and thus identified and differentiated two models of functioning: the reactive, and reflective models. While the *reactive* model states that stimuli configurations are associated to the occurrence of bodily reactions in the (dis)pleasure and arousal dimensions, and depends on more automatic mechanisms, the *reflective* model focus on the importance of giving context and meaning to the experience.

In order to elicit an aesthetic experience or response, one can also expect for the artwork or object in question to have what in research are called *aesthetic properties*. Levinson (2005, see Aesthetic Property section) resumes these properties as: affording (dis)pleasure, evoking an evaluative aspect, as well as requiring imagination and metaphorical thought for attribution, and having lower-level perceptual properties and a gestalt character. Both aesthetic properties, and aesthetic experience share similarities by evoking notions of lower and higher-functioning.

Research in aesthetic experience can be seen as a discipline of visual perception (Leder et al., 2004), since it has mainly depended on the visual exploration and appreciation of artwork. Indeed, different models and theories of aesthetics have tried to decipher more formally which components play a role in aesthetic experience, and specifically in visual aesthetics. Anjan Chatterjee (2003) took in knowledge from visual neuroscience and visual processing, and adopted a neuropsychological approach, which aims at creating a parallel between object recognition and visual aesthetics. He defined a framework to guide research on the field (see Figure 3). This framework relies on two assumptions: 1) multiple components play a role in visual aesthetics (as they do in vision), and 2) an aesthetic experience cannot stem from a single component, but rather from multiple ones.

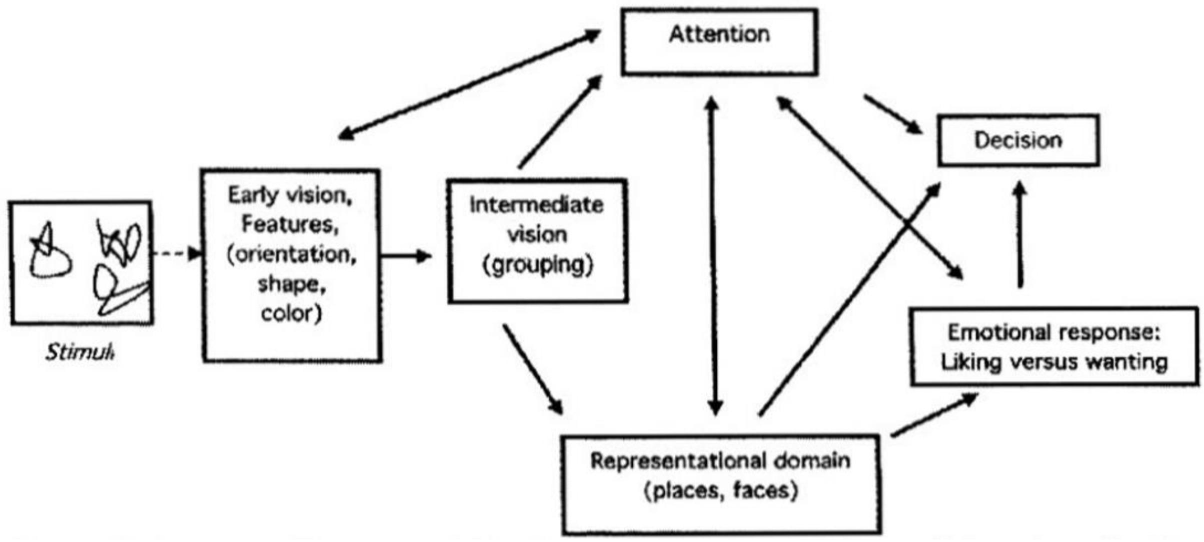

Figure 3. A framework for visual aesthetics. Reprinted from "Prospects for a cognitive neuroscience of visual aesthetics" by A. Chatterjee, 2003, *Bulletin of Psychology of the Arts*, 4, p. 55.

According to this model, visual aesthetics depends on stages of early, intermediate and late visual processing. In early vision, one extracts simple features from the stimulus (such as colour, shape, motion, or location), while in intermediate vision one groups all the information in order to form a coherent representation. It is in late vision that selection of which regions to scrutinize will occur. According to the author, it is once an object is recognized that emotions can be felt, and decisions regarding what action to take can happen. This late vision can also evoke memories and related meanings. When considering the form and content of aesthetic experience, early and intermediate vision are expected to process *form*, while later vision processes *content*. Responses to early and intermediate vision (form) are expected to be universal, while responses regarding late vision (content) are expected to be relative. This framework defines emotional response in visual aesthetics as providing pleasure or interest, with no utilitarian consequences (a feeling of "liking without wanting"), as well as sending feedback information via attentional mechanisms to the perceptual and cognitive system. In this framework, different brain regions are associated to different processes. Occipital areas are related to early visual processing stages while ventral areas are associated to later visual processing stages. Moreover, emotions are mediated by the anterior medial temporal lobe, medial and orbital cortices in the frontal lobe, as well as subcortical structures. Finally, aesthetic decision making relies on dorsolateral frontal and medial frontal cortices (for a review on studies that support this framework, see Cela-Conde, Agnati, Huston, Mora, & Nadal, 2011).

Findings on neural correlates of aesthetic experience go in line with Chatterjee's framework in many aspects (Nadal et al., 2008). More specifically, Nadal and colleagues' (2008) framework of aesthetic experience points to three components: the existence of an emotional response, an enhancement of early visual processes (mediated by occipital areas), and decision making (associated to left dorsolateral prefrontal cortex activity). Emotional response is expected to have two aspects: the representation of reward value (with a higher reward value being associated to beauty; mediated by the orbitofrontal cortex and caudate nucleus), and the awareness of the emotional state, mediated by attentional mechanisms (mediated by the anterior cingulate cortex). The enhancement of early visual processing is considered to be mediated by emotional and attentional mechanisms. Finally, decision making is possibly mediated by perceptual information and information regarding reward value, but further studies are necessary.

Besides this framework for research on aesthetics, a very comprehensive model of aesthetics was proposed by Helmut Leder and colleagues (2004), as depicted in Figure 4. This model sees aesthetic experience as the result of perceptual, cognitive and affective processes, with its variability being explained by the many different ways these components interact as well as by how their relevance may shift in each experience (Leder & Nadal, 2014).

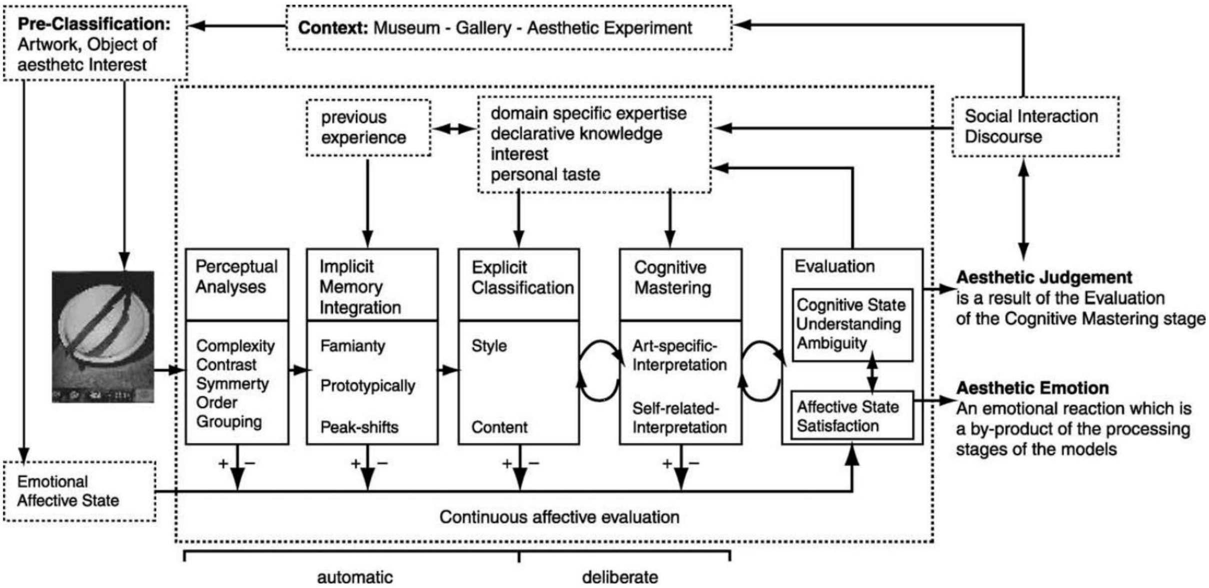

Figure 4. Depiction of Leder and colleagues' model of aesthetic experience. Reprinted from "A model of aesthetic appreciation and aesthetic judgments" by H. Leder, B. Belke, A. Oeberst, and D. Augustin, 2004, *British Journal of Psychology*, 95, p. 492.

Five stages of aesthetic information processing, as well as the variables that might affect each stage are detailed and discussed by Leder and colleagues (2004). For the authors, the first step of the aesthetic experience is represented the occurrence of a *perceptual analysis* (*i.e.* processing of perceptual features, such as contrasts, complexity, intensity, size, colour, order, symmetry), which are effortless and quick. The second stage of the model concerns the *implicit memory integration*, *i.e.* how aspects such as prototypicality (*i.e.* how well does an object represent its class) and familiarity may unconsciously affect the aesthetic processing. In the third stage of the model, an *explicit classification* occurs, with the expertise and knowledge of the perceiver being integrated in the aesthetic processing. In the overall aesthetic experience, this is the first moment that includes explicit (*i.e.* deliberate) representations in terms of content and style (this may occur verbally). The fourth stage of the model is the *cognitive mastering*, followed by the last stage, *cognitive evaluation*. These two stages are strongly intertwined since they form a feedback-loop. The results from the fourth stage of the model are continuously evaluated regarding whether art-specific and self-related interpretations of the stimulus are satisfying or not. In terms of affective processing, the model predicts an increase or decrease of the affective state of the perceiver, according to the result of each processing stage.

In the end, this model portrays the formation of two outputs: an *aesthetic judgement*, and *an aesthetic emotion*. While the former concerns cognitive functioning, such as the thoughts and memories the stimulus triggers, and level of understanding achieved, the latter concerns the feelings the stimulus evoked, and is driven by affective functioning.

Defining what constitutes an *aesthetic experience* has brought up a discussion of the different aspects and components to consider, as well as the different frameworks and findings of the field. Overall, there are three aspects that seem fundamental when establishing an experience as aesthetic, namely the existence of an important state of attention engagement, the existence of a cognitive appraisal, as well as an affective appraisal (Marković, 2012).

1.5. Measuring the aesthetic experience.

So how can one measure this complex experience of cognitive and affective functioning? When measuring aesthetic experience, one may focus on different types of measure, but one may also focus on a single or multiple stages of the aesthetic experience (see models of aesthetic experience depicted in the section above).

Back in 1972, Berlyne listed the methods available in aesthetic research. These methods are quite similar to the ones used in emotion research, from verbal measures to behavioural measures. Indeed, Berlyne (1972) divides three categories of methods, which are the same used as those in emotion research: verbal judgements or the use of questionnaires or self-reports, psychophysiological recording, and the observation of non-verbal overt behaviour. The researcher in question finally identifies a fourth category of measures, which portrays the analysis of artistic material, but which we will not be further explored in this section.

Historically, research on aesthetics has notably relied on self-reports and questionnaires (verbal or written), such as Osgood's semantic differential, in order to identify which features of a stimulus constitute aesthetic dimensions or properties (e.g.: Berlyne, 1972, 1973; Cupchik & Gebotys, 1990; Friedenberg & Bertamini, 2015; Oostendorp & Berlyne, 1978; Tinio & Leder, 2009). Indeed, by studying phenomena like the level of complexity, familiarity, symmetry, novelty, clarity, and hedonic value of a stimulus, such studies try to establish what and how factors categorize aesthetic response.

More recently, the use of psychophysiological methods has gained momentum in aesthetics research, and more notably the use of neural correlates. Indeed, the use of neural correlates has allowed the link between activity of different brain areas and stages of aesthetic experience (as described in the former section; for a more comprehensive view on the neural foundations of aesthetics see Cela-Conde et al., 2011; Kirsch, Urgesi, & Cross, 2016; Pearce et al., 2016). This field of research has become so prolific and influential that it started being denominated as *neuroaesthetics*. The framework developed by Chatterjee (2003) explained in the previous section refers to which areas are associated to which stage of the aesthetic experience, and hence will not be further discussed.

Besides studying brain activity, one may also study the activity of the autonomic nervous system concerning aesthetic experience. Until recently, studies on aesthetics focusing specifically on physiological measures such as skin conductance or heart rate (measures commonly used in emotion research) were scarce, especially in comparison with the multitude of studies on the neuroaesthetics field. However, with the development of more mobile technology, and when one considers the different facets of aesthetic perception (*i.e.* cognitive, emotional, behavioural and physiological), it makes sense to put together new methods that will allow to gain a better grasp on the overall process of aesthetic experience.

An example of this are the studies of Martin Tröndle, Wolfgang Tschacher and colleagues (Tröndle et al., 2014; Tröndle & Tschacher, 2012; Tschacher et al., 2012). They equipped participants with an electronic glove in order to measure variables such as movement speed, heart rate, and skin conductance level, and let them visit a museum. At the end of the visit, participants replied to a standardized interview. In another study, because of the availability of more mobile technology, a researcher was able to see how a portable technological interface created to improve young children's experiences in the museum was perceived (Sparrow, 2016). Here, with the help of a bracelet to measure electrodermal activity, as well as eye-tracking glasses to measure gaze behaviour, the researcher was able to study how young children interacted with their environment (museum and the tablet-based educational platform) in real time.

These studies evoke two notions of ecological approach. Firstly, studies are usually done in a laboratory context, whereas in here the technology allowed researchers to go and work directly at the museum. Secondly, the fact that researchers were able to do the experiment in the museum evoked new questions to be considered, namely the fact that research on aesthetics tends to study reactions towards artworks or stimuli as independent of one another. However, there is a congruence and thought put into how to construct an art exhibition in a museum that should be taken into consideration, which means one must ponder on the possibility that perception of one artwork must be put into the context of its environment, including the presence of other artworks (Tröndle & Tschacher, 2012).

1.6. Applications to product experience.

Very importantly, as noted by Leder and colleagues (2004), even though art has undoubtedly been the prototypical domain of research in aesthetics, other objects can be considered "aesthetically relevant" too. When bearing in mind the frameworks suggested for aesthetics research, the same type of structure has also been applied to the aesthetics of product design, with researchers identifying three levels of processing: *visceral* (*i.e.* automatic reactions that allow quick judgements and the appropriate signals to be sent to the motor system; the so-called affective processing), *behavioural* (*i.e.* processes that concern the control of everyday behaviour, with actions mediating the visceral layer, and being mediated by the reflective layer), and *reflective* (*i.e.* the contemplative layer; Norman, 2013b; Norman, Ortony, & Russell, 2003).

Indeed, one can apply the methods and knowledge from the fields of emotion and aesthetic research to the study of product design, as well as the experience elicited by the use of said products. This approach seems to be extremely relevant considering three particular aspects: 1) the fact that consumers are presented very often with having to choose one product among various ones that offer the same function, price, and performance (Schütte et al., 2008); 2) considering the point made above, the focus of consumer research has shifted from studying the product itself to studying the experience the product elicits on the consumer, which is also justified by the importance of a product's hedonic value (*i.e.* the experiential, aesthetics, and amusement benefits of its use; (Hirschman & Holbrook, 1982; Schütte et al., 2008); and 3) the role of emotion in the purchase decision (Kumar, 2016; Westbrook & Oliver, 1991).

The most formal example of the inclusion of these aspects when designing a product is the development of Kansei Engineering, developed by Mitsuo Nagamachi in the seventies (Nagamachi, 1995, 2002). Briefly, this approach on product design has widely used Osgood's semantic differential on a first stage, and is based on two concepts: the *kansei*, and the *chisei*, which do not have a direct translation into English, but portray the notions of affective reactions and cognitive processing evoked by (aesthetic) products. While *kansei* concerns the reactions evoked by the external sensory stimuli in terms of the senses, *chisei* relates to the knowledge and understanding of that product (S. Lee et al., 2002). Figure 5 portrays the duality of these two aspects when defining an experience evoked by a product.

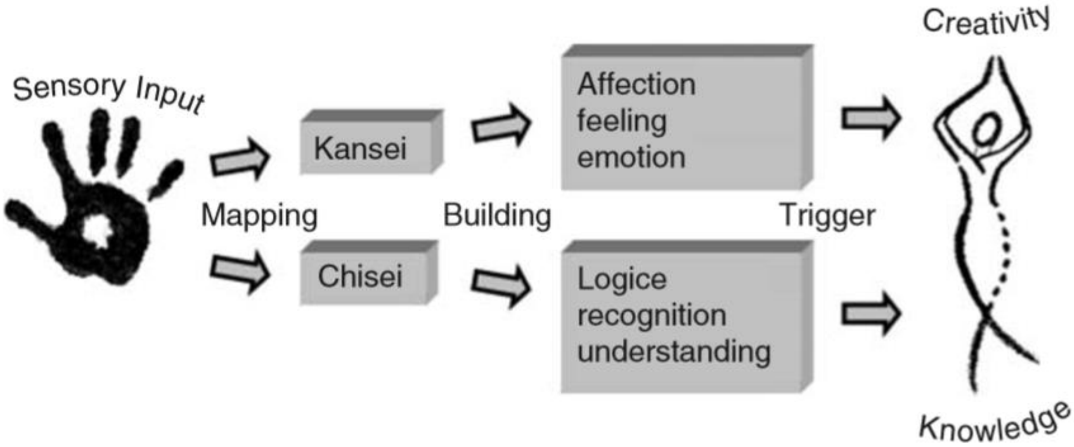

Figure 5. The role of *kansei* and *chisei* to be considered in product design and product experience. Reprinted from “Affective meaning: The Kansei engineering approach” by S. Schütte, J. Eklund, S. Ishihara and M. Nagamachi, in H. Schifferstein and P. Hekkert (Eds), *Product Experience* (p.478), 2008, San Diego: Elsevier. Copyright 2008 by Elsevier Ltd.

If nowadays product design tries to integrate affective meaning in their designs (Schütte et al., 2008), then it seems pertinent to consider the role of the senses on the processing of sensory external stimuli. Indeed, Hendrik Schifferstein (2006) studied the perceived role of sensory modalities when using a product, and identified vision as the most important modality, with the others senses being more used in a complementary fashion.

Since the focus of this thesis relies on car exterior design, the following state-of-the-art will solely concentrate on studies related to emotion and aesthetics research that concern the automotive industry. More specifically, even though a lot of research has been done on the experience of *owning* and *driving* a car, we will focus on studies that concern the perception of car design, which mainly depends on the visual component of the aesthetic experience.

Many studies can be found trying to identify which properties (and how they interact) are involved in the aesthetic experience related to products, in the hope of designing better ones. Examples of studies on consumers’ perception of properties, such as the role of pleasure (Hekkert, 2006); form (Bloch, 1995; Hsu et al., 2000); attributes (Yamamoto & Lambert, 1994), and size (Du & MacDonald, 2014); beauty, appropriateness, and novelty (Khalighy et al., 2015); unity and prototypicality (Veryzer, Jr. & Hutchinson, 1998) in design show the multitude of factors that come into play when studying the reactions evoked by a product.

In the automotive industry, there is a specific concern on how to identify, organise, and measure the aesthetics properties related to car design, in order to better understand consumers' tastes and preferences, and therefore design better cars. A great example of the implications of applying this kind of research is the Mazda MX5, which is one of the most sold sports coupé in the world, and was designed by taking into consideration a Kansei Engineering approach (Schütte et al., 2008). One can also find studies comparing approaches to car design (Yadav et al., 2013), measuring brand design styles in order to find trends (Hyun et al, 2015), and evaluating the impact of car aesthetics in the street (Bayley et al., 2004). Moreover, self-report questionnaires especially designed to measure emotions elicited by car designs (Desmet et al., 2000) as well as driving experience (Tonetto & Desmet, 2016), and tools developed in order to understand the connection between aesthetics features as well as their impact on brand perception (Ranscombe et al., 2011) have been created for the automotive industry.

Studies on car design have also taken a more comprehensive approach when trying to understand design tendencies. By studying preferences to car exterior designs (concerning the dimensions of liking, curvature, complexity, quality, innovation, and safety) when taking into consideration the time period in which they were built and commercialized (from the 1950s until 1999), Claus-Christian Carbon (2010) uncovered a Zeitgest (*i.e.* a kind of "epoch effect") confounded effect. More recently, and going even further on the considered time period, Mohsen Jaafarnia and Adele Bass (2011) studied how car aesthetics evolved from 1885 to present time, and identified seven different eras of car design in history. The seven identified eras to which we can attribute a specific style are, in chronological order, the: Invention era, Innovation era, Manufacturing era, Capsule era, Classic era, Integration era, and Modern era.

Regarding studies on car design, one can consider the use of different methodologies, as well as the study of different elements of design (*i.e.* interior or exterior design, as well as specific features in each). When considering consumers' preferences, studies on *car interior design* that focused on the dashboard area showed the importance of the level of innovation in the aesthetic experience (Carbon et al., 2006; Faerber et al., 2010), with highly innovative designs being considered less attractive than more familiar designs. Indeed, both level of innovation as well as curvature of the elements in interior car design seem to be particularly relevant when rating its aesthetic (Leder & Carbon, 2005). The appearance of certain elements also seems to have an influence on how well consumers perceive them to perform their function. More precisely, the appearance of the car seat has an influence on its perceived comfort, with female participants being more sensitive to this phenomenon (Erol et al., 2016).

Meanwhile, when considering studies on *car exterior design* and consumers' preferences, in an attempt to deconstruct car design, Ranscombe and colleagues (2011) decomposed existing vehicle designs and were able to identify four main aesthetic features relevant to car design: the *outline* (*i.e.* the silhouette of the vehicle), the daylight opening (i.e. the front and rear windshields and side windows), the *muscles* (*i.e.* treatments applied to body work), and *graphics* (*i.e.* headlights, logos and grill elements) of the car. When considering car exterior design, it happens often to establish comparisons between the designs and biological organisms, like animal and human faces. Indeed, when designing a car, a designer might try to use *formgiving*, meaning using inspiration from other forms (normally associated to other entities) in order to design a car. The reason why designers look for inspiration in *animal* form (zoomorphism) is because consumers tend to relate the animal attributes to the design they are seeing (Abidin et al., 2008). The tendency to anthropomorphize cars (*i.e.* to attribute faces to car fronts) is also a well-known phenomenon, although its purpose is attributed to an evolutionary strategy (Windhager et al., 2010).

Besides exploring consumers' preferences, some studies on car design have also focused on the cognitive and affective processes elicited by different designs. More specifically, in terms of *car interior design*, highly innovative designs evoked more fixations and a bigger pupil size compared to low innovative designs (Carbon et al., 2006). Moreover, electrodermal activity has also been linked to the level of innovation of car interior design, with highly innovative designs evoking higher electrodermal activity (Carbon et al., 2008). Meanwhile, in terms of *car exterior design*, an eye-tracking study on aesthetic pleasure and visual complexity of car front images showed the positive correlation between visual complexity and number of fixations, as well as a positive correlation between dwelling time (*i.e.* time spent looking at a certain spot or region) and aesthetic pleasure (Chassy et al., 2015).

In summary, research on emotion and aesthetics have been a great basis for the study of product design and experience, with important and very promising applications for the automotive industry. More recently, there is clearly a new trend, in which researchers are pairing the use of questionnaires or self-reports with the inclusion of neurocorrelates (e.g.: Chatterjee & Vartanian, 2014), psychophysiological measures (Carbon et al., 2006), as well as eye movement (e.g.: Carbon et al., 2006; Windhager et al., 2010). This is why, in the next chapter, we will focus on eye movement research, as well as on the mechanisms involved in visual perception.

Chapter 2: Eye Movement & Visual Perception

In this chapter, we will focus on defining visual processing, and especially how information is treated and integrated by our senses (*i.e.* vision, in this case). Moreover, this chapter gives an overview of how information is processed and treated by our brains, and especially which aspects are expected to be unconscious, while others conscious. But first, we will present eye-tracking and pupillometry as potential useful methodologies when studying aesthetics, and more specifically product design.

Hopefully, this will allow us to recognize certain aspects of visual perception that should be taken into consideration when studying perception of car exterior design.

2.1. Introducing eye tracking and pupillometry.

Eye tracking methodology relies nowadays on the use of infra-red light to illuminate the eye, and a camera that captures the reflected light by the cornea and in the pupil (for methods of eye tracking see Duchowski, 2017; Eggert, 2007).

Eye movement.

Eye movement is organised into saccades, fixations, and smooth pursuit. While *saccades* refer to the fast movements that reposition the fovea (*i.e.* the area of most visual acuity) toward an element of interest, and range between 10 to 100ms (Duchowski, 2017), *fixations* refer to slow stabilizing movements (Land, 2011), that can be as fast as 50ms, and last on average 300ms depending on the task and characteristics of the scene (Rayner, 2009). *Smooth pursuit* refers to the visual tracking of selected foveal (*i.e.* where our vision is the most accurate) targets, in which the eyes can keep up with the moving target's speed (Kowler, 2011), with smooth pursuit being able to occur for long durations after target disappearance (Portron & Lorenceau, 2017). These three oculomotor behaviours allow the study of overt visual attention (Duchowski, 2017).

Indeed, analysing eye movement is a great way to understand how attention mechanisms work, in a manner that would not be possible otherwise. Hence, variables related to fixations (such as number of fixations, and duration) are used often in applied research, such as in advertisement (e.g.: Rayner, Rotello, Stewart, Keir, & Duffy, 2001; Ryu, Suh, & Dozier, 2009; Wedel & Pieters, 2000), memory for brands (e.g.: Wedel & Pieters, 2000), food industry (e.g.: Vu, Tu, & Duerrschmid, 2016; B. Zhang & Seo, 2015), consumer choice (e.g.: Wästlund, Shams, & Otterbring, 2018), as well as product (e.g.: Du & MacDonald, 2014; Guo, Ding, Liu, Liu, & Zhang, 2016; Reid, MacDonald, & Du, 2012), and packaging design studies (e.g.: Husić-Mehmedović, Omeragić, Batagelj, & Kolar, 2017).

While the analysis of fixations, and saccades can be done separately, studying them together may also provide important insight on the attentional and cognitive mechanisms involved in visual perception. More specifically, the study of both fixation duration and saccade amplitude shed a new light on the study of gaze behaviour. Besides being controlled by similar mechanisms, fixation duration and saccade amplitude seem to share a strong nonlinear relationship in picture viewing tasks (Unema et al., 2005). More specifically, variations in saccade amplitude and fixation duration can be categorized into two modes of visual processing: focal and ambient (Follet, Le Meur & Baccino, 2011; Krejtz et al., 2016; Le Meur & Baccino, 2013; Unema et al., 2005). While the association between short fixations and long saccades is translated into *ambient processing*, the association between long fixations and short saccades is translated into *focal processing*. Whereas the former is meant to extract general contextual information in order to identify the gist of the scene, the latter is associated to recognition and conscious understanding processes (Le Meur & Baccino, 2013). The occurrence of ambient processing would be expected to be more relevant at the beginning of picture presentation, followed by focal processing later on (e.g.: (Unema et al., 2005). However, global processing seems to have an interspersed role throughout scene viewing (Tatler & Vincent, 2008), with focal processing also occurring immediately after stimulus onset (Follet et al., 2011). These researchers justified the major role of focal processing from the beginning of picture presentation with a local-to-global scene strategy, due to a central fixation bias.

The central fixation bias is a phenomenon seen in gaze behaviour research, in which observers show a consistent tendency to fixate the centre area of the screen when viewing scenes on a computer screen. This tendency is justified by the simple possibility of the centre of the screen being an optimal location for early visual processing, both in terms of information extraction and of advantageous strategies of visual exploration (Rothkegel et al., 2017; Tatler, 2007). Despite its occurrence, some methodological strategies may be put into place in order to diminish its effect (Rothkegel et al., 2017). Besides the occurrence of biases, there are undeniably systematic general tendencies in oculomotor behaviour to take into consideration. These systematic tendencies refer to the existence of: positively skewed, long-tailed distributions in terms of saccade amplitudes; non-uniform distributions in terms of saccade directions in scenes; complex sequential dependencies, like small amplitude saccades tending to be followed by long amplitude saccades, and *vice-versa*; and saccades typically occurring in the same direction as the preceding one (see Tatler & Vincent, 2008).

Pupillometry.

Other variable made available by the use of eye tracking methodology is the analysis of changes in size of pupil diameter. The pupil is the black area of the eye that allows the entrance of light, and thus it begins the process of visual perception. Pupil size is controlled by two opposing set of muscles in the iris (*i.e.* the coloured area of the eye): the *sphincter pupillae*, and the *dilator pupillae* (see Figure 6). The *sphincter pupillae* is controlled by the parasympathetic system, while the *dilator pupillae* is mediated via sympathetic system. The changes in pupil size are characterized as either dilation of constriction responses. While *constriction* is provoked by the activation of the parasympathetic system (via the efferent pathway originating in the Edinger-Westphal complex of the oculomotor nucleus) that stimulate the *sphincter pupillae* (and relaxation of the *dilator pupillae*), *dilation* is explained by the activation of the sympathetic system that stimulates the *dilator pupillae* (and relaxation of the *sphincter pupillae*). Parasympathetic inhibition can also result in pupil dilation (see Granholm & Steinhauer, 2004). Pupillometry is considered a psychophysiological measure, since the pupil is controlled by the ANS, and most specifically by both the parasympathetic and sympathetic systems (for more information on the pupil's anatomy and research history, see Beatty & Lucero-Wagoner, 2000).

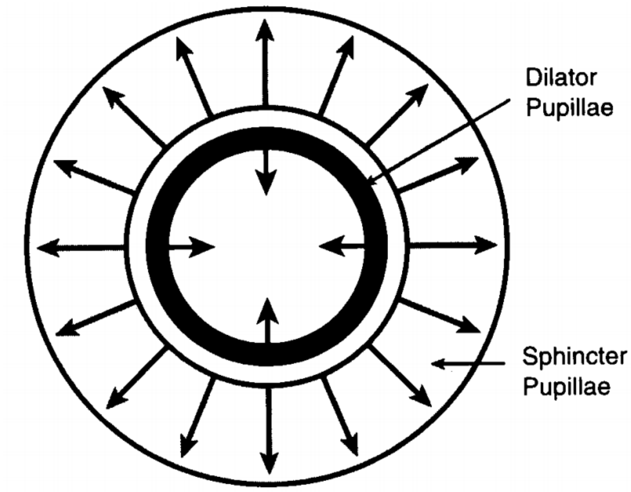

Figure 6. Depiction of the two muscles of the iris that determine the dilation (*dilator pupillae*, if activation of the sympathetic system) or constriction (*sphincter pupillae*, if activation of the parasympathetic system) of the pupil. Reprinted from "The pupillary system" by J. Beatty and B. Lucero-Wagoner in J. T. Cacioppo, L. G. Tassinary and G. G. Berntson (Eds), *Handbook of Psychophysiology* (p.144), 2000, 2nd edition, New York: Cambridge University Press.

Because of the pupil's innervation system, pupillometry has been widely used in research as a measure of level of arousal or activation regarding emotional stimuli. For example, when listening to sounds, participants showed a significantly larger pupil size for emotional sounds, regardless of valence, compared to neutral sounds (Partala & Surakka, 2003), with the same pattern occurring for emotional *versus* neutral pictures (Bradley et al., 2008).

However, and as discussed in section 1.3. of Chapter 1, the ANS functioning is not solely related to emotional phenomena, being responsible for other type of body functions. Indeed, Eckhard Hess and James Polt associated increases in pupil size with emotional visual stimuli presentation (Hess & Polt, 1960), as well as with the increment of mental activity or load (Hess & Polt, 1964). Task-related pupil size changes have been associated to the activity of the *locus coeruleus*, a subcortical structure related to stress, sleep-wake cycle, as well as selective attention and memory retrieval (Sirois & Brisson, 2014), which justifies the use of this variable to measure changes of arousal levels regarding cognitive functioning (see Costa & Rudebeck, 2016). Adding to the findings of Hess and Polt (1964), researchers established a positive association between level of interference (*i.e.* difficulty of the task) and pupil size (Laeng et al., 2011), in a cognitive interference task such as the Stroop task. Tasks of increased difficulty or complexity have consistently evoked an increase in pupil size (e.g.: Eckstein, Guerra-Carrillo, Singley, & Bunge, 2017; Jainta & Baccino, 2010; Piquado, Isaacowitz, & Wingfield, 2010). Changes in pupil size also seem to occur in early visual processing. For example, in rapid serial visual presentation tasks, pupil dilation is positively associated to target detection (Privitera et al., 2010), and when exposed to subthreshold stimuli, participants show lower pupil dilation to old compared to new stimuli (Yoshimoto et al., 2014). For more information on changes in pupil size and emotional and cognitive processes, see Granholm's and Steinhauer's (2004), and Stanners and colleagues' paper (Stanners et al., 1979). Besides being modulated by attentional and cognitive factors, the pupil size can also be modulated by the luminance of the gazed stimulus, with pupil size fluctuating continuously over time (Ajasse, Benosman, & Lorenceau, 2018).

Applications to product design.

In terms of applications to product design, studying eye movement and changes in pupil size can give important information about how consumers perceive an object, as well as consumers' preferences and choices (e.g.: Guo et al., 2016; Khalighy et al., 2015). Regarding car design, Carbon and colleagues' showed how pupils dilated according to the level of innovation of car interior designs (Carbon et al., 2006). Eye-tracking methodology has also been of use in evaluation of a car interior's perceived quality (Callenberg & Hellaker, 2015). Concerning car exterior designs, researchers have analysed participants' gaze behaviour in order to understand how consumers perceive a car's attributes and how the size of the attributes influences visual perception (Chang et al., 2013; Du & MacDonald, 2014).

2.2. Aspects of visual perception to consider.

The knowledge of how visual perception occurs when looking at an object can and should be applied to the study of visual aesthetics (Chatterjee, 2003), and could hence also be applied to product design. In order to understand how a stimulus is appraised, one has to understand how this stimulus is captured by the senses first. In this review, and considering how the study of visual perception is integrated in aesthetics as well as emotion research, we will briefly introduce aspects of visual perception that are useful in product design, and aesthetics. These aspects focus on *how* elements are perceived and integrated in order to be able to be interpreted.

Visual perception refers to the processes that arise when an image reaches the eyes: at first, receptors in the eye capture information, which will then be formed into a pattern, in order to be finally identified and interpreted. In 1923, Max Wertheimer (1938) defined rules that were to guide how the grouping of elements occurs in visual perception. These principles that explain and organise visual perception became known as the *Gestalt Rules*. These rules were constructed under the assumption that we always try to perceive visual stimuli in the simplest and most regular way possible, and hence focus on shape organization, expecting to be able to identify what constitutes a "good shape". Even though, with time, new principles were also discussed (see Wagemans et al., 2012), the basic Gestalt rules are the following (see Figure 7): *good continuation* (curves and surfaces are perceptually grouped even when they appear to be separated), *proximity* (elements that are close enough to each other will consistently be grouped together), *equality* (elements with common features, such as colour or shape, will also be grouped together), *closure* (if the elements are aligned in a particular fashion, one will perceive a closed area or volume), *symmetry* (a figure is the same as its mirror image), and *common fate* (when moving in a common direction and speed, elements are also perceived as one).

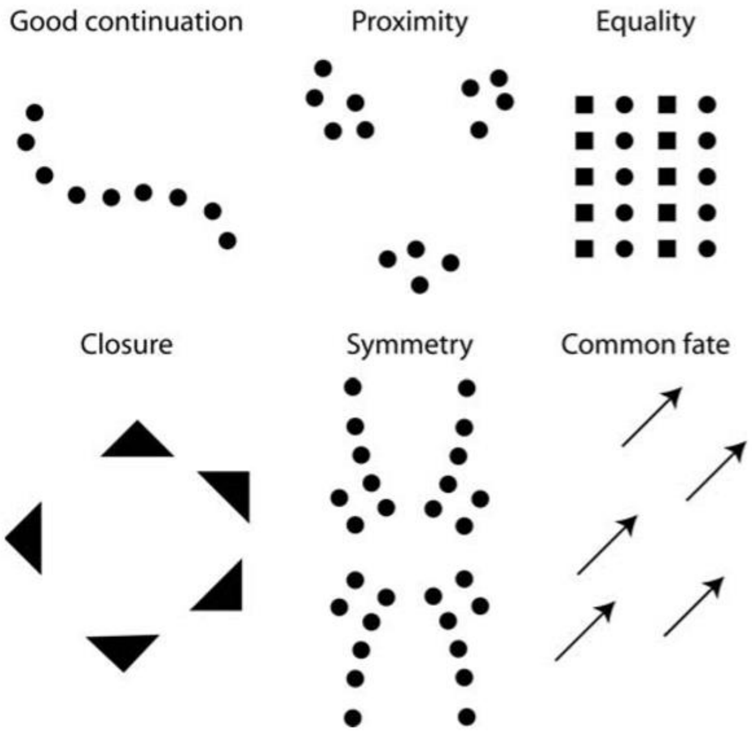

Figure 7. The Gestalt rules. Reprinted from "On The Visual Appearance of Objects", by H. T. Nefs, in H. Schifferstein and P. Hekkert (Eds), *Product Experience* (p.31), 2008, San Diego: Elsevier. Copyright 2008 by Elsevier Ltd.

Even though some limitations to the Gestalt rules have been pointed out, namely the difficulty in testing these rules in experimental paradigms (see Wagemans et al., 2012; Westheimer, 1999), they provide a great deal of information on how we perceive visual stimuli, and they are relevant when considering notions such as *saliency*, and *bottom-up processing* (which we will be discussing in section 2.3).

James Gibson (1979; E. J. Gibson, 2000) added to the discussion of the processes involved in visual perception by focusing on the role of expectations when we extract information from the visual stimuli in order to categorize it. When looking at an object, we always infer its function, or *affordances,* with the latter depending not only on the stimulus itself, but also on the observer. The theory of *affordances* considers the roles of both the context and the object in the identification and categorization process of the latter, putting forward the importance of the *intention* of the perceiver in terms of actions and reactions towards the object (J. J. Gibson, 1941). With his theory, Gibson showed how visual perception cannot be seen simply as an association between a stimulus and a response (*i.e.* that is not just the features of an object, such as colour or shape, that define it), since there is the occurrence of a perceptual learning (Greeno, 1994) in which the observer attributes characteristics (such as function) to the stimulus in preparation for action/reaction.

When perceiving an object, one must also consider the role of *recognition*. In the recognition-by-components theory, Irving Biederman (1985, 1987) establishes how each object is organised according to different main shape elements (which he denominated as *geons*), and how we recognize objects by analysing the organization of those elements. Each type of object is supposed to have a certain configuration of *geons*, which will allow us to infer the identification and function of the former.

Overall, we can establish that visual perception is mediated by the integration of elements. This integration happens through the application of different rules, with other aspects, namely the knowledge and previous experience of the observer, playing an important role in the identification process of an object.

2.3. Top-down and Bottom-up processing of visual attention.

As this review has shown so far, when talking about visual perception (regardless of the existence of an aesthetic experience), there is clearly the occurrence of some more automatic phenomena, such as grouping, as well as some more high-order phenomena, such as previous knowledge of the observer regarding the stimulus. By tracking eye movement, one can gather information on how information processing occurs. In this section, we will focus on the unconscious and conscious mechanisms of information processing.

It has been widely documented in research how a person's eyes are directed towards the important aspects of the stimulus, and how the person's goals have an influence on the performed eye movement when looking at the stimulus (Rayner, 2009). This phenomenon of *directing* our eyes towards something that stands out in some way is a cyclical process, and necessary due to our incapability of processing all the available information, and hence needing to prioritize the information to be treated. When seeing a picture for example, the peripheral vision (*i.e.* lower acuity) allows to identify the interesting features that may *pop out* from the rest, directing attention towards it. The eyes relocate the fovea (*i.e.* high acuity) to this new location, allowing attention to be engaged (see Duchowski, 2017).

So what constitutes an *interesting feature that may pop out from the rest* and guide our focus? *Bottom-up processing* (or stimulus-driven processing) tries to answer this question by focusing on the characteristics that pop out. Anne Treisman and Garry Gelade (1980) set the tone for research on this field by developing the feature-integration theory, in which attention is directed in a serial way, guided by the basic visual features of the stimulus (such as shape and colour). An essential notion to keep in mind when speaking about these *interesting features that pop out* somehow is the fact that it is not exactly the characteristics of the stimulus *per se* that will guide our attention, but rather the interaction between the different features of the stimulus (Itti & Borji, 2014). For example, it is not because we present the letter "T" in red that makes it *salient*, but rather that we present a red letter "T" among black letters "T". This was conceptualized by Christof Koch and Shimon Ullman (1985), who manipulated the visual features of stimuli (such as colour, orientation, contrast, direction of movement) in order to understand how people directed their attention. They also considered the rules of similarity and proximity of the features. This led to the development of models in bottom-up processing that try to measure and predict the *saliency* of a stimulus by analysing and comparing its physical characteristics, with Itti and colleagues' work being essential in this domain (see Itti, 2005; Itti & Koch, 2001; Itti, Koch, & Niebur, 1998). By using bottom-up models of visual attention, we can have a *saliency map* as an output, which is a 2D topographic map of the analysed stimulus that allows us to see which areas of the stimulus are more visually salient, and hence supposedly evoke more attention. Indeed, the goal of these computational models is to identify and predict which areas of a stimulus will direct a person's gaze, which is why these outputs are usually compared to eye movement data in order to test the developed models. The rationale is that the more physically salient a feature is, then more attention is attributed to it, and hence more fixations occur in that area (Kowler, 2011). Bottom-up processing has been associated to tasks such as object recognition (Rutishauser et al., 2004), free-viewing (Parkhurst et al., 2002) and visual search (Wolfe, 1994), and its modelling has many applications, such as evaluating advertisements (Itti, 2005).

But is bottom-up processing enough to explain and predict the mechanisms of visual attention? That does not seem to be the case. For example, in a free-viewing task of pictures of real-world scenes containing one or more people, saliency was not able to account for where people would look at, pointing out the existence of other phenomena than stimulus-driven processing (Birmingham et al., 2009). Indeed, a complete theory of visual attention should also take into consideration the importance of cognitive processes and voluntary intent in stimulus perception (Duchowski, 2017). This takes us to the introduction of the so-called *top-down* or *task-driven* aspects of visual attention. The demanded task may evoke other mechanisms that overshadow the weight of feature-driven aspects of attention (e.g.: Nyamsuren & Taatgen, 2013; Wolfe & Horowitz, 2017). This was explicitly shown in Yarbus' study (1967) of eye movements (and later replicated by DeAngelus & Pelz, 2009), in which depending on the given task (free-viewing *versus* specific task), the gaze patterns changed accordingly. Besides eye movement, pupil size can also be mediated by top-down processes (Sirois & Brisson, 2014), with dilation occurring voluntarily when participants were asked to imagine the object (Laeng et al., 2012). Another example of how volitional processes occur in visual exploration can be found in Baluch and Itti's (2011) review on the mechanisms of top-down attention (Rubin's vase illusion; Figure 5). When looking at Figure 8, we can swiftly shift our perception between seeing a vase or seeing two people, depending on our will.

Figure 8. Rubin's vase illusion. Adapted from "Mechanisms of Top-Down Attention" by F. Baluch and C. Itti, 2011, *Trends in Neurosciences*, 34, p.211. Copyright 2011 by Elsevier Ltd.

Hence, both aspects of stimulus and task-driven processing are involved in visual attention, and are hence integrated in many computational models of visual attention. For a review of different models of visual attention (with bottom-up and/or top-down components), see: Borji & Itti (2013), and Itti & Borji (2014).

Even though, researchers acknowledge the existence of these two processes, there is a tendency to discuss them as opposing mechanisms, in a dichotomic fashion (see Pinto, Leij, Sligte, Lamme, & Scholte, 2013; Theeuwes, 2013), which is somewhat reductive to explain the occurrence of visual attention. As Edward Awh and colleagues (2012) elaborate, a modified taxonomy (*i.e.* acknowledging these mechanisms in a more integrative, and less dichotomic way) may provide new information on these mechanisms. For that, they established the role of *current goals* (which can broadly be associated to the notion of top-down processing), and *physical salience* (which can broadly be associated to the bottom-up processing definition), but they also added a third component, *selection history* (which refers to the possible existence of persistent bias due to former attention-evoking tasks). For example, after we are asked to find the red letters "T" in a pool of black letters "T", the red "T's" will still continue to be salient even if they are no longer related to the current task (for more information on this component, see also Failing & Theeuwes, 2018; Wolfe, 2019; Wolfe & Horowitz, 2017).

Regarding the study of gaze behaviour in emotion research, participants consistently attend first and faster to emotional stimuli, even when presented with neutral and emotionally-valenced pictures at the same time or when instructed not to look at the emotional content (e.g.: Nummenmaa, Hyönä, & Calvo, 2006). This is attributed by many researchers to the saliency of these stimuli (Barrett, 2006). This bottom-up processing of emotional stimuli can be seen as an advantage, especially in cases of clinical or induced anxiety, but being able to ignore these stimuli and maintain attention in order to perform a task may be equally important (Sussman et al., 2016). Indeed, top-down mechanisms can also be involved in the processing of emotional stimuli (Sussman et al., 2016). For example, in a recent study, the presentation of emotionally arousing pictures impaired top-down attention, regardless of the physical saliency of the stimulus (Sutherland et al., 2017).

Applications to the aesthetic experience.

Besides the relevancy of these mechanisms to the processing of emotional stimuli, one can also apply these to the study of *aesthetic experience*. An aesthetic experience supposes the need of maintained attention, since the person will be focusing on one object during a certain period of time. Moreover, the neural mechanisms involved in this experience are not the same as the ones regarding object recognition, for example (Nadal et al., 2008), which raises some questions about the attention mechanisms involved in aesthetic experience. These mechanisms were explored in a study by Gerald Cupchik and colleagues (2009), where they asked a group of participants to observe a set of paintings in a detached and objective manner, in order to obtain content information (*i.e.* the pragmatic condition), while a second group was instructed to observe the same paintings in a subjective and engaged manner, focusing on the feelings they evoked, as well as on their features (*i.e.* the aesthetic condition). Both tasks elicited an important engagement level from the participants, with results from the pragmatic condition being associated to the mechanisms involved in object recognition, while the aesthetic condition elicited an interaction between bottom-up processing in terms of perceptual input, and top-down processing in terms of orienting attention.

Applications to product design.

Finally, one can apply these attention mechanisms to the perception of *product design*. More specifically, different features of package designs for canned beers were tested in an eye-tracking study (Husić-Mehmedović et al., 2017). Participants freely looked at different designs of can beers in two forms: on a supermarket shelf, among other cans *versus* alone. Results showed that – in beer cans – the most important salient aspects are colour and semantic features, which may be explained by the fact that beer cans have a very specific and rigid shape. In another eye tracking study on visual attention and package design features, participants were invited to go to a supermarket and shop as usual, whereas a particular store and jam category were studied (Clement et al., 2013). Participants only looked at a little more than one third of all the available jams. More importantly, the shape or outline of the jam packaging attracted more initial visual attention, and more specifically the high slim packages. Packages with high contrasts also evoked more attention. Surprisingly, the text element of the packaging seemed to have a negative effect on consumers' visual attention. This study showed how important physical features are in engaging visual attention of consumers, more than semantic content.

Eye tracking studies on visual attention and design seem to focus on the role of the physical features of the products, and therefore focus on bottom-up mechanisms of attention. However, it should also be interesting to study product design from an integrative bottom-up and top-down point of view.

Issue

A lot of consumer research focuses on evaluating the *experience* or the *feelings* of consumers towards a product. Indeed, we consider cars as complex stimuli, in the sense that, more than providing transportation, they provide an *experience* to its user, and hence consumers' choice will depend on this experience. It is our understanding that a car is not a neutral object, but it is a source of emotion and hedonic value.

The users' experience englobes different factors, namely the driving experience, but also the perception of the design of the vehicle. In this thesis we focused on car exterior design, which is extremely relevant in the French automotive market, since it is consistently one of the top three factors considered when choosing which car to buy (according to the New Car Buyer Survey of 2015 and 2016), along with price, and brand loyalty. Moreover, it is our hypothesis that – at least to some extent –, consumers can appreciate a car exterior design just as they would appreciate a piece of art, being hence a source of aesthetic experience to be studied.

Given the rich experience a car evokes, it seems fit to explore new approaches other than subjective ones (*i.e.* using questionnaires or interviews) in order to study consumers' reactions. This is why, in order to measure and understand how perception of car exterior design occurs, a behavioural (eye movement) and psychophysiological (skin conductance, heart rate and pupil size) approach was chosen. These methodologies will allow us to measure participants' experience *while* they are actually experiencing it, avoiding any kind of interruptions. Hence, this approach will certainly allow us to gain a new insight on how our bodies and minds react and interpret the information when presented to different car exterior designs.

In this thesis, we consider a parallel can be established between perceiving a car exterior design and perceiving a piece of art, which denotes the relevance of studying and understanding the complex mechanisms involved. Hopefully, the adopted behavioural and psychophysiological approach will shed a new light on the affective and cognitive processes involved in the perception of car exterior design, giving more insight to designers and experts of the automotive industry. In order to achieve this, three experiments were performed.

In Study 1, the goal was to prove the important attentional capture that exterior car design could attain, being it a type of stimulus that is rich in hedonic value, but devoid of biological significance. While using a dot probe paradigm task, level of innovation, as well as shape of car exterior design were manipulated. By measuring gaze behavior, electrodermal activity, reaction time and by applying a questionnaire at the end of the computer task, we expected to observe different affective and attentional mechanisms at play, as well as different preferences according to level of innovation and car shape.

In Study 2, the goal was to further explore the affective and cognitive processes involved in the visual perception of car exterior design, namely by using two car categorisations (based on shape, as in Study 1, and on a confidential categorisation developed internally by Renault), in a free viewing task. By measuring electrodermal activity, pupil size and heart rate, and by applying a questionnaire at the end of the computer task, we expected to gain more insight about the participants' preferences based on affective reactions towards different categories of car exterior design. Another goal was to explore what potential other factors could play a role in the visual exploration of car exterior design, which is why the role of saliency, as well as the potential importance of specific car features were also analysed. By analysing gaze behaviour, we hoped to shed some light on the cognitive processes involved in the visual exploration of different categories of car exterior design.

In Study 3, our goal was to explore potential contextual factors, namely stimuli size. Until here, participants observed the stimuli on computer screens. This is why, in this final experiment, the selected car exterior designs were presented in a 4k screen of 4 x 2m, with the expectation of creating a more ecological situation for the participants. Similarly to Study 2, both car categorisations were taken into account. In a free-viewing task, electrodermal activity, heart rate and pupil size were analysed, and a new form of questionnaire (Osgood's semantic differential) was applied. Also similarly to Study 2, the potential role of saliency, as well as the relevance of different car features on the participants' visual exploration were analysed. A final goal of this study was to explore potential dynamics of gaze behaviour by analysing focal and global processing. By showing the stimuli on a closer-to-reality size, we expected to shed some light on the affective, cognitive, and attentional processes involved in the visual exploration of different categories of car exterior design, as well as overall preference, in a more ecological setting.

III Experimental Framework

Chapter 3: Establishing Attentional Capture of Car Exterior Design

3.1. Study 1: Introduction.

The aim of this first experiment was to probe the attentional capture of car exterior design. But what is "attentional capture"? In an environment full of stimuli, we need to be able to prioritize and select which information to treat. Attention refers to this process of concentrating on certain (useful) information, while disregarding other (and not useful) information present in the same environment. The selection of which information has to be treated in priority relies on the individuals' previous knowledge and experience, the presence of task-dependent relevant information, as well as their current behavioral state. This selection may also depend on the presence of unexpected and possibly significant information (Carrasco, 2011). Attention may be considered overt (*i.e.* when eye movement occurs), or covert (*i.e.* when attention is deployed without eye movements). Moreover, Anne Treisman's (1986; Treisman & Gelade, 1980) feature-based attention theory showed the importance that specific characteristics of the stimulus in a certain context (*i.e.* color, orientation or direction of motion) may have in the deployment of covert attention.

One finding that research on visual attention consistently shows is how biologically significant stimuli are prioritized by our attentional system. By biologically significant stimuli, literature on the matter refers to stimuli that convey a deep meaning in terms of primary needs, such as notions of survival, threat, and danger. In fact, fear-relevant stimuli evoke interference in visual search tasks (Forbes et al., 2011), with participants taking more time to find the target, when presented with distractors, such as pictures of spiders, and snakes. Moreover, this attentional bias may be exacerbated by specific phobias or fears from participants. For instance, the attentional bias towards spiders is exacerbated by the participants' fear towards them, but the attentional bias towards snakes stays constant with or without specific phobias (Lipp & Derakshan, 2005). For Öhman & Mineka (2003), this attentional bias towards snakes even in the absence of a particular phobia is justified by the danger that these reptiles represented in the past. Evolutionary factors, as well as context and period of time may explain differences in perception regarding fear-relevant stimuli. Indeed, a study on skin conductance showed an important level of activation towards pictures of evolutionary fear-relevant stimuli (such as snakes, and spiders), as well as pictures of more modern fear-relevant stimuli (such as guns, and knives; Isaacs, 2016).

Humans seem not only to have particular attentional mechanisms towards evolutionary fear-related stimuli, but more importantly they seem to be able to develop the same type of attentional bias towards other stimuli related to prior experiences. This idea is confirmed by the observation that patients with anorexia nervosa show biased attention towards food stimuli (Neimeijer et al., 2017), or by the observation that veterans with posttraumatic stress disorder who show a more important attentional capture towards cues of war compared to veterans with no posttraumatic stress disorder, and healthy non-veteran controls (Olatunji et al., 2013).

Attentional bias can also occur towards biologically significant stimuli characterised by a positive emotional valence. This is related to the fact that stimuli of positive biological significance may convey notions of survival, reproduction, and satiation. For example, newborns are essential for a species' survival, and indeed pictures of babies are prioritized by our attention system (Brosch et al., 2007; Hodsoll et al., 2010). Also, an attentional bias can be found towards food-related stimuli (Nummenmaa et al., 2011), as well as towards arousing sexual words (Arnell et al., 2007), in healthy subjects.

Another relevant point to discuss is how attentional bias can be shaped when associating stimuli to specific consequences. In particular, how attentional capture can be highly modified by reward learning. Studies have consistently shown how attention selection can be altered if the stimuli (even of neutral valence) have been previously associated to a reward, whether it is a monetary reward (B. A. Anderson et al., 2011, 2012; Sali et al., 2014), or some other type of reward, such as chocolate odor (Pool et al., 2014). For further information on attentional bias towards conditioned stimuli, see (Pool et al., Pool and colleagues (2016). To sum up, attentional biases depend on the individuals' prior experiences (*i.e.* phobias or disorders), but they can also occur towards biologically relevant stimuli (of positive or negative valence), or whenever the stimuli are associated to rewards. However, it is still not yet well understood how attentional biases can potentially influence perception when the stimulus is not biologically relevant, nor conditioned or experience-related, but rich in meaning.

Although a car's function is straightforward (*i.e.* to ensure that a person or cargo can get to point A to point B efficiently), they represent much more than just the function they perform, and therefore cannot be considered as neutral stimuli. Indeed, cars are an example of objects that elicit experiential consumption, in which elements such as the consumers' hobbies, notions of aesthetics, symbolic meanings, and hedonic responses must be taken into consideration in the consumer's choice process (Holbrook & Hirschman, 1982). Objects of consumption, such as cars, can indeed evoke strong hedonic responses. These responses include multiple sensory modalities while seeing and experimenting a product, the role of fantasy imagery (that does not refer to previous experiences *per se*, but rather to the image the consumer creates of the occurred experience), and the role of emotional arousal, that refers to the emotive response towards the product, in both psychological and physiological terms (Hirschman & Holbrook, 1982). Other important notions to keep in mind are the pleasure of use, the search for hedonic experiences on a daily basis (Alba & Williams, 2013), and the search to fill one's psychological needs (Hassenzahl et al., 2010). Therefore, although cars may be considered devoid of biological significance, they are rich in meaning. Moreover, when asked what factors contribute to choosing which car to buy, French consumers place exterior design on top of their list of priorities (according to the New Car Buyer Survey, 2015). This shows that not only performance characteristics, but also the car's design (*i.e.* its hedonic value) is important, and hence may provide an ideal illustration of the potential attentional bias towards biologically neutral stimuli rich in meaning.

Different metrics can be used to quantify the occurrence of attentional bias. Besides reaction time, which is widely used in attention-related tasks in psychology (e.g.: dot probe paradigm, visual search), other metrics may be considered. For example, eye-tracking methodology looks a promising complementary measure to reaction time in order to study the deployment of attentional mechanisms, since it allows for a direct and continuous measure of visual and spatial attention from the moment the stimulus is presented to the moment a response is made (Armstrong & Olatunji, 2012), being used in studies on attention bias related to fear of pain (Yang et al., 2012), or facial expressions (Çek et al., 2016; Mogg et al., 2000), for example. Skin conductance response is also widely used in psychological research in order to evaluate and quantify the affective arousal a certain stimulus may have (Dawson et al., 2007), with applications to attentional bias provoked by phobias (Shiban et al., 2016), and the feeling of threat (Felmingham et al., 2011; Waters & Kershaw, 2015), for example.

In the present study, we investigated attentional capture triggered by cars, by considering two axes of exterior design: innovation level, and shape. We focused on the *level of innovation* of car exterior design, since introducing new design features is fundamental for a company to thrive, even if it is a procedure as profitable as risky (Chaudhuri et al., 2010). Even though some new unexpected features of a product may have a good reception in the market, if there are too many novel features it is possible for the product to be rejected by consumers (Norman, 2013). Indeed, the level of innovation of an object seems to influence the way it is perceived. In a study on car interior design, participants preferred non-innovative designs (Leder & Carbon, 2005) compared to highly innovative designs. However, if exposure to these highly innovative car interior designs is favored, then they become more accepted, being perceived as more attractive (Carbon et al., 2006; Carbon & Leder, 2005). This goes in line with Zajonc's (1968) mere exposure effect, which states that the mere repeated exposure to a stimulus enhances people's attitudes towards it. However, these studies specifically refer to preference and do not focus on the potential attentional capture and bias towards different levels of innovative designs. Indeed, these are two different processes, with preference not being able to occur without attentional capture, but the latter being able to occur in the absence of the former. One study on car interior design proved the occurrence of higher cognitive engagement towards innovative designs (Carbon et al., 2006). Hence, in this study we try to establish attentional capture regarding car exterior design.

As we are studying car exterior design, understanding how the *shape* of a car is perceived by consumers may help us explain why certain designs are better accepted than others. In fact, literature consistently shows how people prefer curved shapes, compared to angular ones (e.g.: Bar & Neta, 2006; Gómez-Puerto et al., 2016; Palumbo & Bertamini, 2016), both for objects (e.g.: a watch, a sofa), and non-objects (*i.e.* random figures with no meaning), with even the same tendency occurring for chocolate and water packaging (Westerman et al., 2012). When studying shape in architecture, high curvature facades are the most preferred, followed by angular, medium curved and rectilinear ones (Ruta et al., 2015). Regarding cars, both curved car interior and exterior designs seem to be preferred compared to more angular options (Carbon, 2010; Leder & Carbon, 2005). Even though it is still not clear why humans have this preference for curved shapes, this phenomenon seems to be intrinsic to humans (Bertamini et al., 2015), with this notion being further supported by the occurrence of curved preferences across cultures (Gómez-Puerto et al., 2018). On the other hand, an explanation for the disliking of more angular outlines is that sharper forms may convey a notion of threat. Supporting this claim is the existence of a higher amygdala activation towards angular shapes (Bar & Neta, 2007), a neural region known to be associated with detection and response to threat (LeDoux, 1994). However, it is still unclear whether this phenomenon is a clear avoidance of sharp shapes or a preference for curved shapes (Bertamini et al., 2015; Gómez-Puerto et al., 2016).

In this context, we were interested in testing the occurrence of attentional capture towards car exterior design, being it rich in hedonic value, but devoid of biological significance and task-relevancy. Therefore, we had to ensure that participants would not be conditioned towards the stimuli in any way, and also that car picture presentation would not be related to the demanded task, which is why we recurred to a dot probe paradigm. By showing car pictures for a very brief period of time followed by a motor task unrelated to the picture presentation, we were able to study how attention is directed, but in a way that it cannot be explained by other phenomena other than the attentional capture exterior car design evokes. In this experiment, we manipulated level of innovation, by comparing concept (*i.e.* cars built to showcase new features, specifically in terms of exterior design for the purposes of this study) and non-concept (*i.e.* commercialized cars with more typical exterior designs) cars, expecting to observe a more important attentional capture to occur towards concept cars, due to a novelty effect, and for participants to find these cars less attractive because of their high level of innovation. We also compared the general shape of car exterior design, expecting for attention to be deployed more importantly towards angular designs (explained by the sense of threat angular shapes convey, as seen in literature), as well as to be considered less attractive.

3.2. Methodology.

Participants.

Twenty-nine university students participated in this study: 14 female (M_{age} = 21.93, SD_{age} = 3.02), and 15 male students (M_{age} = 21.67, SD_{age} = 3.22). All participants gave their participation consent. Due to the duration of the participation session, participants were remunerated. They all had normal or corrected-to-normal vision.

Apparatus.

The SR Research Eyelink 1000 Plus (SR Research, Toronto, Canada) was used to record eye movements, with the correspondent head support, at a sampling rate of 1000 Hz. The Q sensor wristband (Affectiva, 2012) was used to record skin conductance, at a sampling rate of 32 Hz. E-Prime 2.0 software was used to show the stimuli (Psychology Software Tools, Inc, 2014).

Materials.

In this study, we focused on two car exterior design properties: level of innovation, and shape. The level of innovation was manipulated by categorizing cars into non-concept, and concept cars. Whereas the first ones correspond to commercialized cars, the latter are not commercialized, and notoriously showcase a highly innovative trait (see Figure 9).

Figure 9. Example of a concept car (Renault Ondelios; on the left), and a non-concept car (BMW X6; on the right).

Regarding shape analysis, we focused on two different axes portraying the overall shape of a car: height of the car (either low or high), and general contour or outline of the car (either curved or angular; see Figure 10). This categorization is solely based on the visual characteristics of the car.

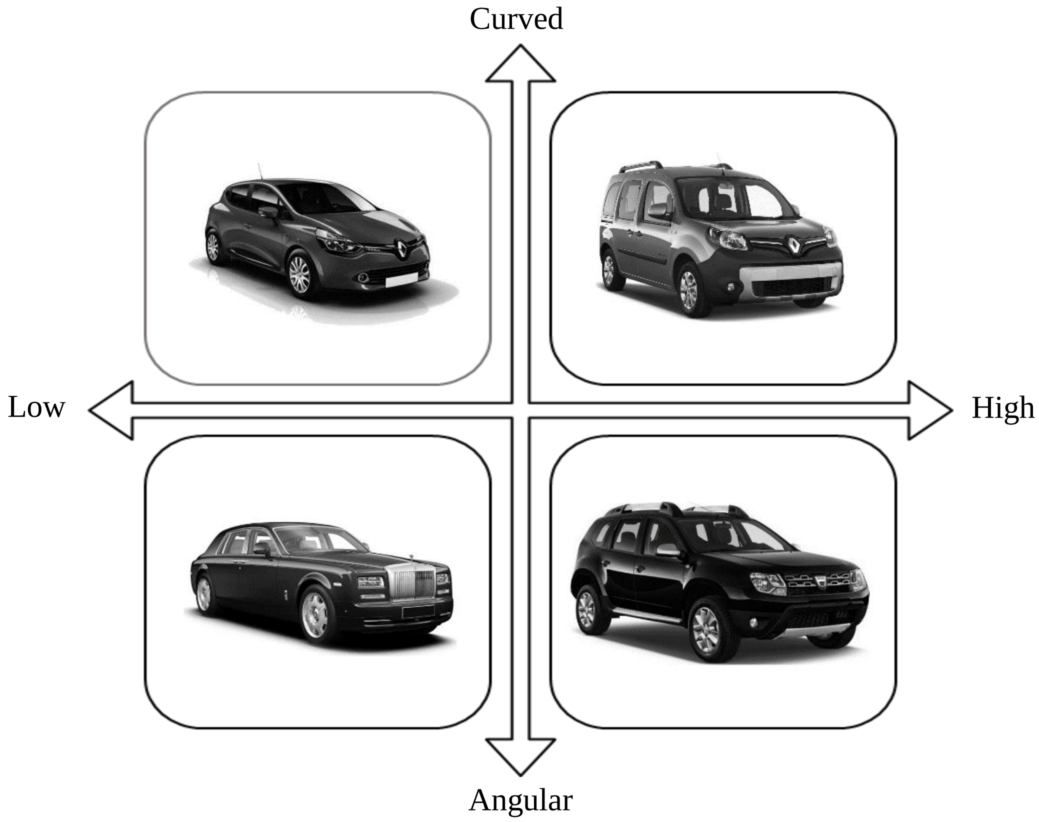

Figure 10. Shape categorization. Shape was organised according to car height (low *versus* high cars), and car outline (curved *versus* angular).

Overall, 36 colourless pictures of car exteriors were used (18 concept, and 18 non-concept), with cars being presented in a 3-quarter front view (*i.e.* showing the top, side and front of the car; as also depicted in Figure 10). The pictures of car exteriors were always presented in pairs, and car pairs were shown in a screen of 1024x768 pixels, with each picture measuring 3 cm in length approximately. All car logos were removed from the stimuli list. The presented pairs were constituted by one concept, and one non-concept car. Hence, the analysis on the level of innovation was a within-trial one, whereas shape was analysed in a between-trials fashion. This was done to avoid attention being deployed because of size differences among cars that are structurally very different. For a full list of the stimuli used in this study, please consult Appendix 1.

Considered measures.

Behavioural measures. Reaction time, and eye movements were measured throughout the dot probe task. In terms of reaction time, we were interested in the time duration between the dot presentation (right after the car pictures presentation), and the moment when participants pressed the button. Due to a novelty effect, participants were expected to show lower reaction time towards concept cars, compared to non-concept cars. Moreover, faster responses towards curved shapes compared to angular shapes were also expected.

Concerning eye movement, due to the nature of our task and the duration of the pictures' presentation, we measured saccadic peak velocity. Saccadic peak velocity has been associated to attentional shifting, with a higher velocity meaning a stronger cognitive engagement (Di Stasi et al., 2013). This is also why we measured saccadic peak velocity at the moment of the dot presentation (*i.e.* after viewing the car pictures). If a certain car design deployed an important attentional shift, then saccadic peak velocity was expected to be faster. We expected concept cars to evoke a higher cognitive engagement than non-concept cars, also due to a novelty effect. Also, we expected angular shapes to elicit a higher saccadic peak velocity, for evoking a sense of threat (due to the existence of more acute angles).

Physiological measures. Skin conductance was recorded during the dot probe task. It refers to the continuous electric variations that arise when the skin receives innervating signals from the sympathetic autonomic nervous system, and it is an established indicator of the level of arousal (level of activation) evoked by a stimulus on emotion research (e.g.: Lang, 2014;

Levenson, 2014; Mauss & Robinson, 2009). Due to the same novelty factor, concept cars were expected to elicit higher arousal compared to non-concept cars. Angular shapes were also expected to elicit more arousal than curved shapes, due to the possibility of more acute angles triggering a sense of threat.

Rating measures. Responses of a Likert-scale questionnaire were also analysed. Here, participants had to decide how much they liked each car exterior design they had previously seen (0 – not at all; 5 – very much). Because highly innovative designs may not be well received at first (as discussed in the introduction of this study), we expected higher scores for non-concept cars compared to concept cars. Moreover, curved cars were expected to get higher scores compared to more angular shapes.

Procedure.

At the beginning of the experiment, participants were asked if they had a driving license, if they were car owners, and whether they could be considered car enthusiasts. This was done for control purposes, in order to ensure that results could not be explained by these variables. No differences were found in this study between car enthusiasts or not, as well as between participants with, and without a driving license, and a car.

Participants were then asked to perform the dot probe task on the computer. Here, a fixation cross was presented for 2s, followed by the simultaneous presentation of two car pictures during 500ms, “forcing” participants to look at one of the car pictures. This was followed by a dot presentation. This dot randomly appeared at the same place as where one of the cars had been previously shown (*i.e.* either on the left or on the right side of the screen). Participants had to push a button depending on which side of the screen the dot appeared on. After pressing the button, a dot was presented at the centre of the screen, for 2s (resting phase), and then another trial would begin.

Importantly, all participants were told that their responses should be fast, but accurate. The side where each car picture was presented, as well as the side where each dot appeared were counterbalanced, with each car pair being presented a total of four times. These pictures were presented at the level of parafoveal vision, which translates into a lower visual acuity, being more sensible to emotional stimuli (*i.e.* it is the parafoveal vision that determines where our gaze will rest next).

Skin conductance, and eye movement calibrations were made only once per participant at the beginning of the computer task.

Once the computer task was completed, participants were given a Likert-scale-questionnaire, in which they were shown the same 36 car pictures. Participants were asked "What do you think about the visuals of this car?", with answers varying from 1 ("I don't like it at all") to 5 ("I like it a lot"). This questionnaire was made to assess participants' appreciation of each car exterior design (see Appendix 2).

3.3. Results.

All analyses were performed with SPSS Statistics version 23 (IBM Corp, 2015), and an alpha level of 0.05 was used throughout the data analysis. A Shapiro-Wilks test was used to test the normality of the distributions, per variable. Skin conductance did not show normal distributions, hence a correction was made by using Venables and Christie's (1980) formula of $y = \log(1+x)$, but adding 2 instead of the proposed 1, which was necessary to make all values positive (Field, 2009, p. 155). Hence, parametric tests were used.

Since looking at the car pictures was not related to the demanded task (which was pressing the button depending on which side of the screen a dot appeared at), there was a risk of participants deploying response strategies to press the button accurately, and faster.

Participants could either keep looking at the centre of the screen waiting until the dot appeared, or they could just press the button automatically (because there were no trials with no dot presentation, participants knew that even if they were looking at a side with no dot, the dot would be on the other side of the screen, and hence push a button in the absence of viewing the dot). To avoid these scenarios, only trials in which participants were looking at the side of the screen corresponding to the button they pushed were taken into consideration (an example of a valid trial would be if the dot appeared on the left, and participants pressed the button corresponding to the left, *while* looking at the left). This is why only 81% of the overall trials among all participants were used in the data analysis.

Only saccadic peak velocity higher than 50degrees/sec was taken into consideration for statistical analysis. Regarding reaction time, responses above 1200ms were discarded, as well as the data above or below 2 standard-deviations per participant. In terms of skin conductance, a difference was calculated between each trial and the 2s prior to the car pair presentation.

Left and right balance analysis.

A control analysis was made to make sure there were no significant differences between presenting, and pressing the dot when it appeared on the left or on the right side of the screen. Paired samples T-tests were performed for the variables associated to the computer task (see Table 1). No significant results were found for any of the variables. Hence, no preference seems to exist for neither the right nor the left side of the screen, while performing the dot probe task.

Table 1. T-test results comparing results between both sides of dot presentation.

	Side of dot presentation			
	Left	Right		
Variables	Mean (SD)	Mean (SD)	*t*	*p*
Reaction time	502.70 (119.79)	514.69 (133.50)	-1.42	.17
Saccadic peak velocity	348.11 (77.53)	324.88 (95.23)	.82	.42
Skin conductance	.695 (.004)	.693 (.002)	1.9	.07

Note: Reaction time is presented in milliseconds, saccadic peak velocity in degrees/sec, and skin conductance in microsiemens.

Attentional capture and innovation level.

Car pairs were constituted by one concept and one non-concept car. Paired samples T-tests were used for all the considered variables (see Table 2).

Table 2. T-test results comparing concept and non-concept cars regarding reaction time, saccadic peak velocity, skin conductance, and questionnaire.

	Innovation Level			
	Concept	Non-concept		
Variables	Mean (SD)	Mean (SD)	*t*	*p*
Reaction time	507.86 (128.22)	509.30 (125.39)	-.19	.85
Saccadic peak velocity	324.50 (50.35)	344.56 (47.51)	-2.36	.03
Skin conductance	.692 (.004)	.695 (.005)	-2.37	.05
Questionnaire	2.69 (.38)	2.93 (.46)	-2.38	.02

Note: Reaction time is presented in milliseconds, saccadic peak velocity in degrees/sec, and skin conductance in microsiemens.

Regarding reaction time, no differences were found between concept and non-concept cars, *t* (28) = -.19, *p* = .85. Non-concept cars differed from concept cars in terms of saccadic peak velocity, *t* (28) = -2.36, *p* = .03, skin conductance, *t* (28) = -2.37, *p* = .05, and questionnaire, *t* (28) = -2.38, *p* = .02. Non-concept cars elicited higher saccadic peak velocity, higher skin conductance, and higher ratings than concept cars (see Figure 11).

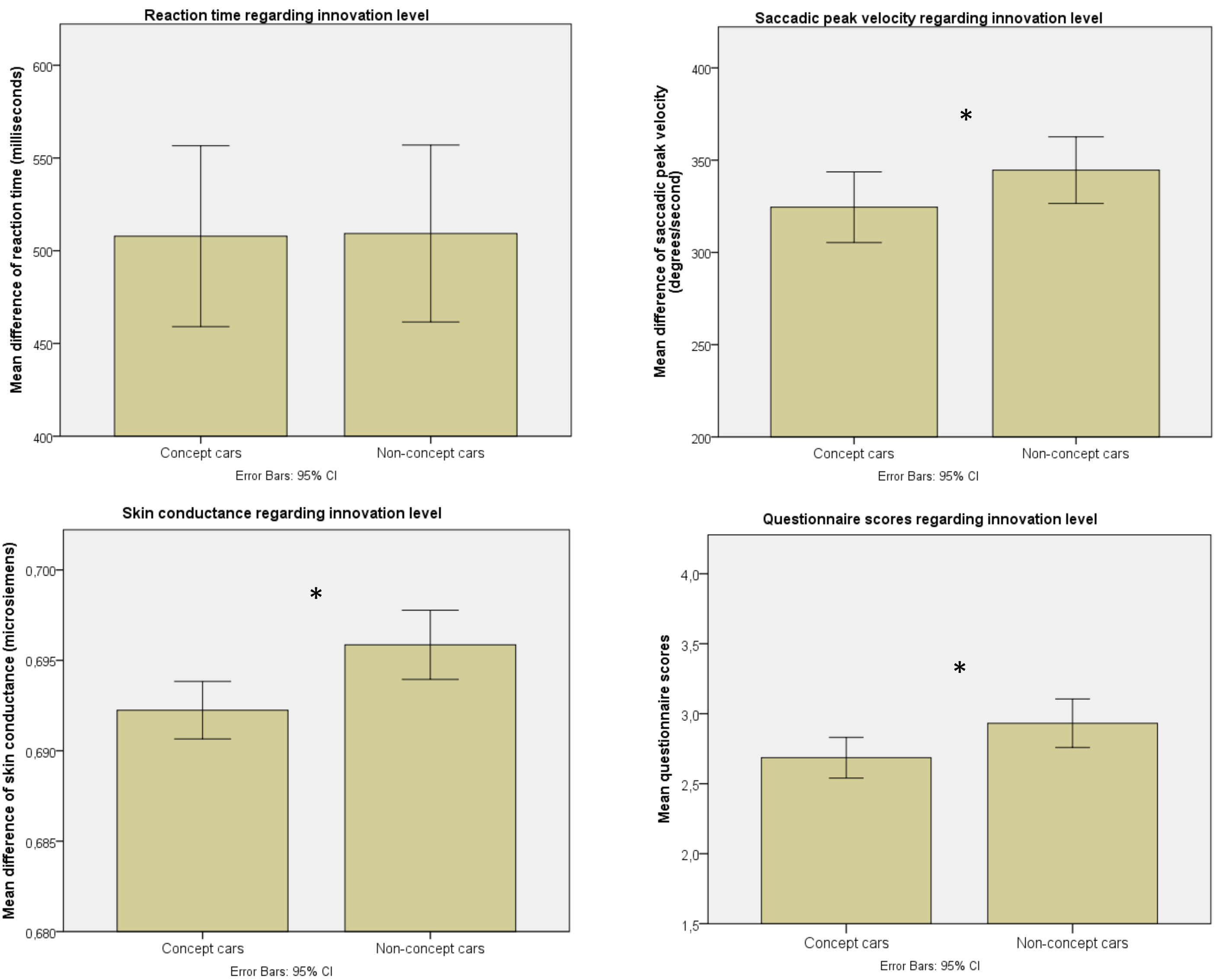

Figure 11. Graphic representations of the innovation level comparison portraying the mean values of: reaction time (in milliseconds, top left), saccadic peak velocity (in degrees/second, top right), skin conductance (in microsiemens, bottom left), and questionnaire scores (bottom right). * *p* < .05.

Attentional capture and car shape.

Car shape was organised into two categories: height (low or high), and outline (curved or angular). Between-trial comparisons were performed, as height and outline differed among trials or car pairs (*versus* within-trial, as it was the case of the innovation level comparison). Paired samples T-tests were performed for all the considering variables regarding car outline (Table 3) and height (Table 4).

Table 3. T-test results comparing angular and curved cars regarding reaction time, saccadic peak velocity, skin conductance, and questionnaire.

	Car Outline			
	Angular	Curved		
Variables	Mean (SD)	Mean (SD)	*t*	*p*
Reaction time	504.80 (120.59)	510.40 (127.63)	-1.26	.22
Saccadic peak velocity	338.07 (52.27)	332.17 (42.26)	1.03	.31
Skin conductance	.696 (.006)	.693 (.003)	1.94	.06
Questionnaire	2.66 (.42)	2.96 (.38)	3.96	<.001

Note: Reaction time is presented in milliseconds, saccadic peak velocity in degrees/sec, and skin conductance in microsiemens.

Table 4. T-test results comparing low and high cars regarding reaction time, saccadic peak velocity, skin conductance, and questionnaire.

	Car Height			
	Low	High		
Variables	Mean (SD)	Mean (SD)	*t*	*p*
Reaction time	506.98 (125.14)	510.32 (125.20)	-.98	.34
Saccadic peak velocity	324.70 (45.03)	345.54 (49.17)	-3.31	.003
Skin conductance	.695 (.004)	.692 (.003)	2.05	.05
Questionnaire	3.10 (.40)	2.52 (.46)	6.14	<.001

Note: Reaction time is presented in milliseconds, saccadic peak velocity in degrees/sec, and skin conductance in microsiemens.

Concerning car outline, no differences were found in terms of reaction time, t (28) = -1.26, p = .22, nor saccadic peak velocity, t (28) = 1.03, p = .31. Car outline marginally differed in terms of skin conductance, t (28) = 1.94, p = .06, and significantly differed in terms of questionnaire scores, t (28) = 3.96, p < .001. Participants overall preferred curved cars designs compared to angular ones (see Figure 12).

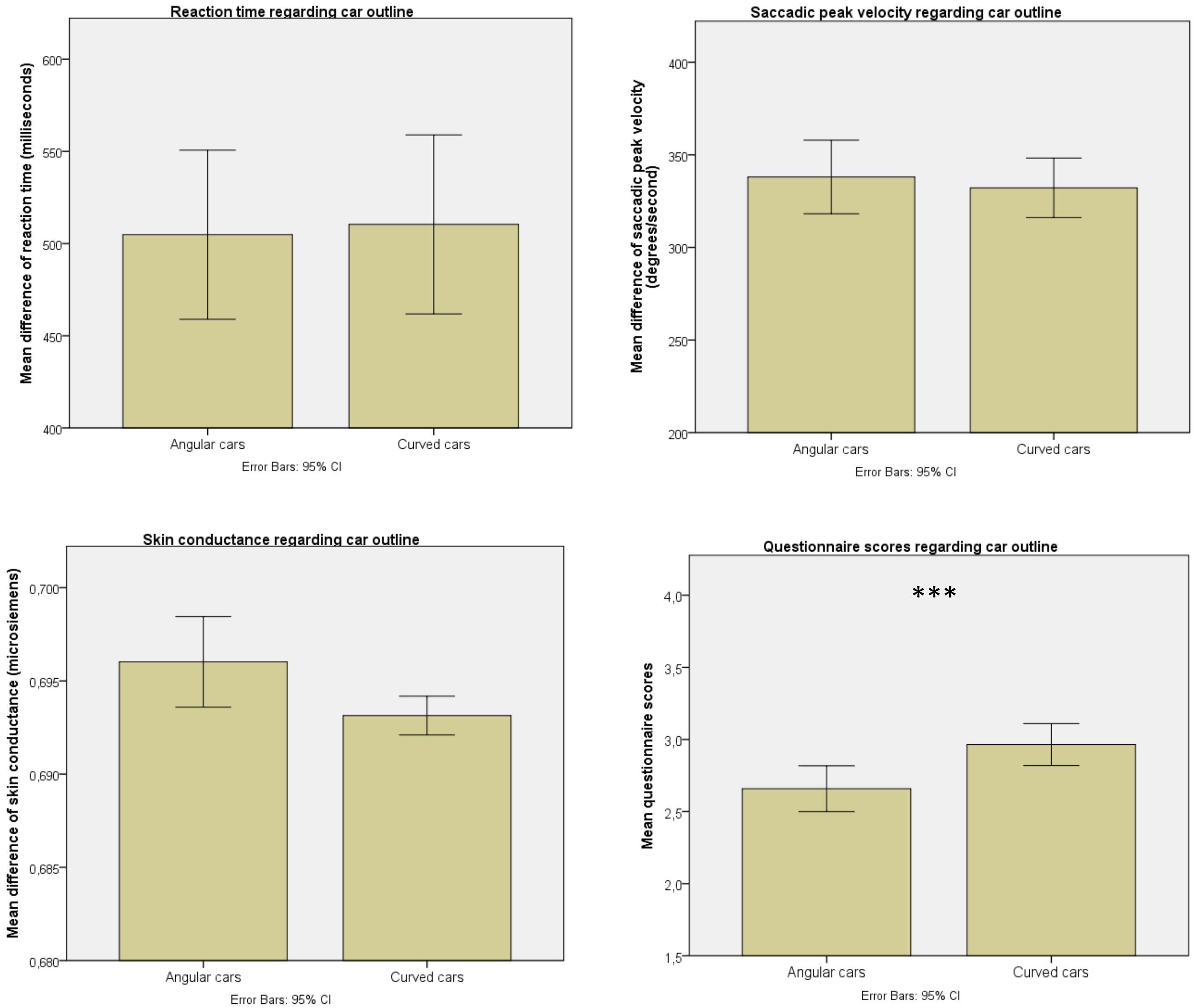

Figure 12. Graphic representations of the car outline comparison portraying the mean values of: reaction time (in milliseconds, top left), saccadic peak velocity (in degrees/second, top right), skin conductance (in microsiemens, bottom left), and questionnaire scores (bottom right). *** $p < .001$.

Regarding car height, there were no differences in terms of reaction time, t (28) = -.98, p = .34. However, saccadic peak velocity, t (28) = -3.31, p = .003, skin conductance, t (28) = 2.05, p = .05, and questionnaire scores, t (28) = 6.14, $p < .001$, differed according to car height.

High cars evoked higher saccadic peak velocity, whereas low cars presented higher skin conductance, as well as higher scores in the questionnaire (see Figure 13).

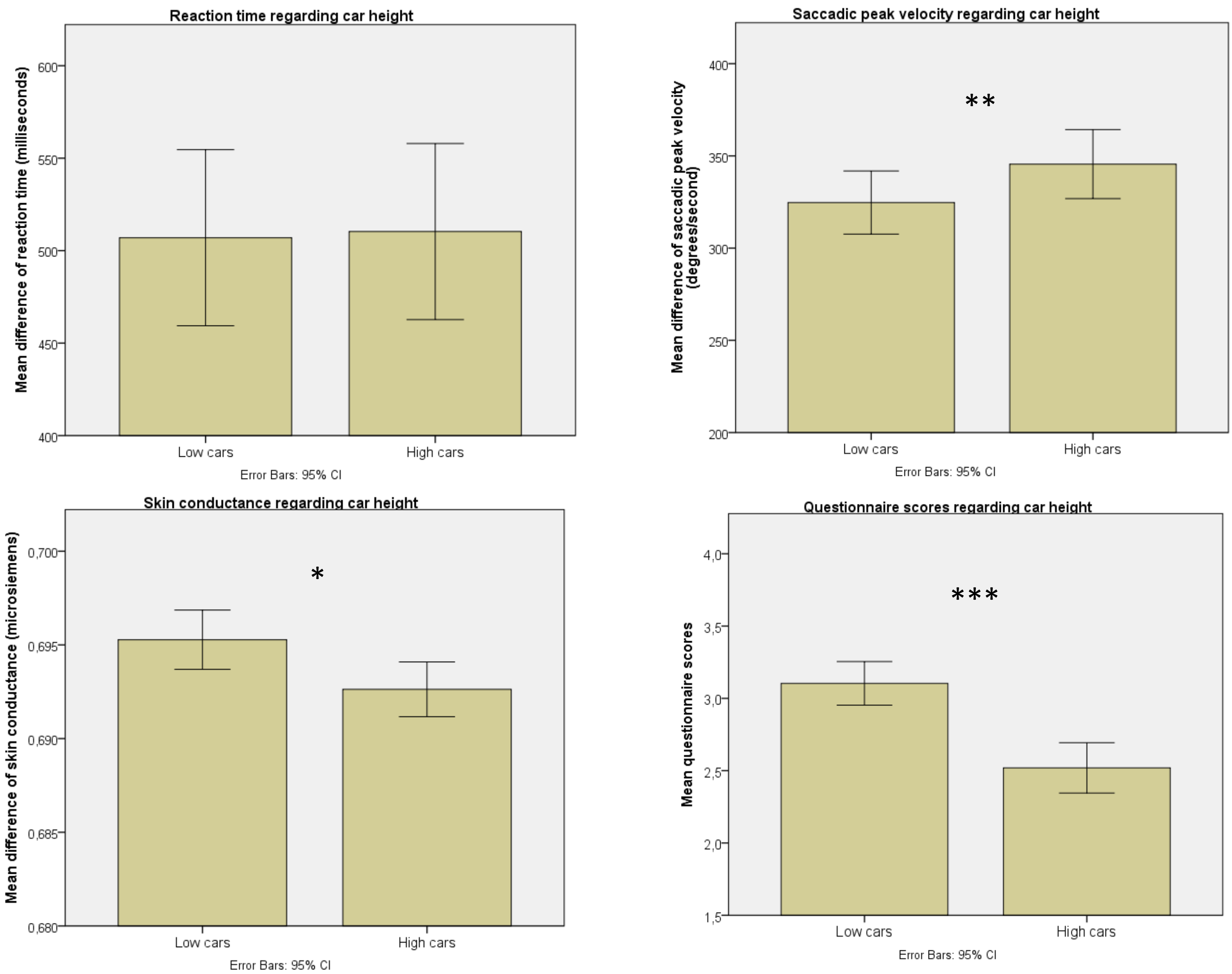

Figure 13. Graphic representations of the car height comparison portraying the mean values of: reaction time (in milliseconds, top left), saccadic peak velocity (in degrees/second, top right), skin conductance (in microsiemens, bottom left), and questionnaire scores (bottom right). *** $p < .001$, ** $p < .01$, * $p < .05$.

3.4. Discussion.

Our aim was to establish the attentional capture of biologically neutral stimuli rich in meaning such as cars focusing particularly on exterior design, by using a dot probe paradigm. We also presented a liking questionnaire at the end of the computer task. When referring to car exterior design, our study focused on the level of innovation (by comparing concept and non-concept cars), and on car shape (by comparing car designs in terms of height - low or high -, and outline - curved or angular).

Regarding level of innovation, participants gave higher liking scores to non-concept cars compared to concept cars. These results are in accordance with the expected results. Indeed, as shown in literature, people tend to dislike highly innovative designs (Carbon & Leder, 2005; Norman, 2013), with this preference for more familiar designs being explained by the higher exposure participants have regarding more conventional designs (Carbon et al., 2006; Carbon & Leder, 2005). This also goes in line with Zajonc's (1968) mere exposure effect, which states that the mere repeated exposure to a stimulus enhances people's attitudes towards it, which in this case justifies the preference for non-concept designs by force of being more often exposed to them on a daily basis. Contrary to what we expected, non-concept cars evoked higher cognitive engagement, and arousal compared to concept cars. One explanation for these results is that perhaps the designs of the concept cars were too innovative, meaning they introduced too many novel features. This "over-innovation" allied to the size of the presented stimuli, and brief presentation period may have brought some disruptions to the process of object recognition, making the identification of the car-related *affordances* more difficult.

Affordance was a term coined by James Gibson (1978) to represent the existing complementarity between a being and its environment, or more specifically between people and objects. According to Gibson, we do not only perceive objects according to their objective qualities, but also regarding the affordances they provide, *i.e.* the functions the objects allow us to perform (grab, push, throw, cut, etc.). For example, when we see the handle on a car's door, it fosters the movement of curling our fingers around it and pull, due to its size and shape. When we see the car tyres, we perceive that the object *affords* us movement. Hence, because some of the concept cars were missing some important and well-established affordances (e.g.: some concept cars did not have tyres), they may not have been recognized as such, explaining why participants directed their attention towards what they already knew (*i.e.* non-concept cars). This is further justified by Biederman's (1985) theory of object recognition, which takes a bottom-up approach towards object recognition by acknowledging the existence of 24 different basic shapes (*i.e. geons*) that humans are able to recognize, with more complex objects being composed by a set of geons.

In terms of shape, cars were categorized according to their outline (curved or angular) and height (low or high). Regarding car outline, as predicted, participants gave higher liking scores to curved cars than to angular cars. This goes in line with literature that has vastly showed a preference for curved shapes (Gómez-Puerto et al., 2016; Palumbo & Bertamini, 2016), and even a dislike towards more acute shapes (Bar & Neta, 2007), even though one does not seem to depend on the other. A possible explanation for this preference for round shapes is the Gestalt principle of good continuation, which occurs when the eye goes through one object, and smoothly continues to the next one (see Quinn, Brown, & Streppa, 1997; Wertheimer, 1938).

Regarding car height, participants preferred low cars compared to high cars. This may be explained by a possible unspoken association between low shapes and sports cars, and the association between high cars and family cars. Since our participants were mostly University students with an average age of 22 years, it seems possible that they would feel a greater appeal towards sportier car models compared to more "family-oriented" ones. There was a higher cognitive engagement for high cars, compared to low cars, which cannot be explained by the actual size of the stimuli, since shape analysis consisted of a between-trial comparison.

In terms of skin conductance response, participants showed a marginal higher skin conductance towards angular shapes compared to curved ones, as well as a higher arousal towards low cars compared to high cars. When comparing the structure of low and high car exterior designs, it is clear that low designs imply the existence of more acute angles, which goes in line with the skin conductance results of the outline comparison. Skin conductance is an indicator of psychophysiological arousal, being controlled by the sympathetic nervous system (related to fight-or-flight responses). Hence, the current results support the notion that car designs presenting more acute angles convey a sense of threat, justifying thus a stronger arousal response. This is further supported by higher amygdala activation towards more acute shapes (Bar & Neta, 2007), and by the overall dislike for these shapes showed in the present study.

Studies on attention bias usually take upon an experimental methodology in which researchers focus on eye movement, physiology, or reaction time. The present study is original in the way it approaches the study of attentional bias, since the three methodologies were joined. Specifically, eye movement and physiological measures were added to the application of the dot-probe paradigm, in order to gain a broader perspective on the cognitive, and affective mechanisms involved in the visual perception of car exterior design.

When considering reaction time responses, the attentional capture that occurred was similar throughout all conditions, with attentional biases occurring on a physiological and cognitive level, and not reaching a differentiating motor level.

In the outline analysis, the absence of eye movement differences, and the marginal differences of skin conductance response were not expected, which may raise some questions to consider in the present study. Limitations to this study may be related to the chosen task (very brief stimuli presentation period, for example), or to the characteristics of the stimuli (limited categories of shape, disregarding the impact of color on visual perception). It would, therefore, be interesting to further study car perception regarding different shape categories, especially when considering the existent literature on the visual perception of shape. It would also be interesting to better understand how human perception's prioritization and integration of complex forms, such as car exterior design, and how this may change according to different factors, such as: the demanded task or duration of stimuli presentation, as well as the context of stimuli presentation or even 3D image rendering. Extending on this research would allow us to gain more insight on how top-down and bottom-up influences occur in the visual perception of cars.

This study showed a cost in attentional mechanisms, activation and preferences in terms of novelty, and a benefit for more familiar designs (*i.e.* less innovative designs). In terms of car outline, angular designs were disliked, and evoked higher activation. Regarding car height, there was a benefit in terms of attentional mechanisms for high shapes, with low designs evoking higher preference, and activation. By further comparing attentional capture on level of innovation and shape, this study showed how sensitive human perception can be towards extremely complex forms (*i.e.* car exterior design), even in very particular conditions (in this case, in a dot probe paradigm task).

Chapter 4: Studying The Perception of Car Exterior Design

The first study showed how attentional mechanisms towards car exterior design are sensitive to the manipulated variables, with an advantage for more familiar designs and in detriment of a high level of innovation. Moreover, participants showed a higher dislike and activation towards angular designs, as well as higher activation and preference for low designs.

However, new questions arose due to the chosen methodology (*i.e.* dot probe paradigm task). Therefore, in the following study, our focus was to explore the aforementioned shape differences, as well as to better understand visual perception of car exterior design by adopting a free-viewing task. By changing the type of task, we hope to gain some perspective on the perceived aesthetics of car exterior design.

4.1. Study 2: Introduction.

Aesthetics concerns the "understanding through sensory perception", and the aesthetic response concerns the result of such perception regarding an artwork or an object (Hekkert & Leder, 2008). Different theories exist regarding the considered type of framework, but researchers tend to agree in three fundamental aspects in order to identify one experience as being aesthetic: the existence of an important state of attention engagement, the existence of a cognitive appraisal, as well as of an affective appraisal (Marković, 2012). In Study 1, we focused on studying the attentional capture of car design, and we documented the existence of different physiological responses and gaze behaviour regarding car exterior design, namely concerning level of innovation, and shape.

Hence, in this study, our aim was to get a grasp on the perceptual aspects of the visual exploration of car exterior design. This was made by analysing how visual exploration of car exterior design occurred, as well as by measuring participants' core affect reactions to different categories of car exterior design. In order to do so, this study focused on commercialized car exterior designs (*i.e.* less innovative, and more familiar). Moreover, in Study 1, a very specific task was demanded to participants, with two cars being presented at the same time for a brief period of time (500ms), and included a motor response. In the present study, we wanted to let participants explore the car designs at their own will, in order to stimulate the occurrence of visual exploration of car designs as an aesthetic experience.

Visual attention is what allows us to handle and filter relevant from irrelevant information, in a more or less cluttered context, through an array of cognitive operations (McMains & Kastner, 2009). In fact, visual perception can be modulated by complementary bottom-up (referring to the characteristics and saliency of the stimuli) or by top-down (referring to the demanded task, or prior experiences and goals of the perceiver) processes, with the former being characterized as a *stimulus-driven* mechanism, and the latter as a *goal-driven* mechanism (Buschman & Miller, 2007; Corbetta & Shulman, 2002; Gao & Vasconcelos, 2007).

The bottom-up aspect that may influence how we deal with and prioritize visual information is the *saliency* of the visual content to consider. Indeed, saliency is defined by the interaction between the context of the stimuli and the properties or features of the latter, such as orientation, direction of movement, colour, texture and contrast (Kastner & Buschman, 2017; Koch & Ullman, 1985; Shariatmadar & Faez, 2019). The features of the stimulus are analysed and computed, in order to create a so-called "saliency map", which portrays a visual representation of the areas of the stimulus that are physically more *different* (*i.e.* salient), evoking thus more fixations, and attention from a bottom-up approach (Itti, 2005; Koch & Ullman, 1985; Orquin & Lagerkvist, 2015). The most obvious and famous example of the bottom-up saliency of a stimulus is the pop-out effect (Treisman, 1986; Treisman & Gelade, 1980; see Figure 14).

Figure 14. Example of a pop-out effect, in which the colour is the salient aspect that creates boundaries in picture perception. Adapted from "Features and Objects in Visual Processing" by A. Treisman, 1986, *Scientific American*, 255(5), p.116. Copyright 1986 by Scientific American.

Even though literature clearly states the existence of top-down and bottom-up processes, it still remains unclear what is the impact of bottom-up processes on attention (Orquin & Lagerkvist, 2015). In fact, salient features may play as distractors when unrelated to the given task (Theeuwes, 1992), but saliency also seems to be overridden by top-down processes depending on the demanded task (Henderson et al., 2007; Hsieh et al., 2011), or even on the phase of the demanded task (Kurz et al., 2018). Indeed, when considering the impact of the given task on eye movement, various studies show how patterns of gaze behaviour differ depending on the demanded assignment, from a free-viewing task to a specific task (DeAngelus & Pelz, 2009; Tatler et al., 2010; Yarbus, 1967), which confirms the relevance of top-down mechanisms on visual exploration (Wade & Tatler, 2011). Considering how vision is a dynamic process that occurs over time with numerous fixations (e.g.: Henderson & Hollingworth, 1998; Yarbus, 1967), and how cars are complex objects, one may inquire how visual processing occurs (in terms of top-down and/or bottom-up processing) when participants are invited to visually explore each design as they wish. Hence, in this experiment, we study gaze behaviour, notably by measuring the impact of saliency on the visual exploration, as well as the impact of the absence of a given task (*i.e.* in a free-viewing assignment) on the visual perception of car exterior design.

Physiological responses are often studied in emotion research, especially under a dimensional perspective. Indeed, different physiological responses have been associated to different dimensions of emotion, namely *valence* and *arousal* (for a review on the dimensions of emotion, see Ekkekakis's (2013) chapter 3; see also section 1.3.). While valence is associated to pleasantness/unpleasantness, arousal is associated to the level of activation evoked by a certain stimulus. Whereas the valence dimension has been associated to the expression of behaviour, as well as cardiovascular responses and the startle reflex magnitude, the arousal dimension has been associated to skin conductance response (see Kreibig, 2010 for a review; Russell & Barrett, 1999). In terms of measuring core affect responses, in Study 1, we focused on skin conductance, whereas in this study we added heart rate, and pupil size measures, in order to gain further insight of the ANS activity related to the visual perception of car exterior design.

Therefore, in this study, we wanted to investigate participants' reactions towards different shape combinations, in a less restrictive experimental design, namely in a free-viewing task. In order to do this, this study aimed at answering three questions. Firstly, are there any particular core affect responses related to specific combinations of car design? In order to answer this question, physiological measures (namely skin conductance, heart rate, and pupil size) were recorded, a liking questionnaire was also used, and we took into consideration two different car categorizations. Even though we started answering this question on the first study, the conditions of car picture presentation were extremely specific, hence the need to further explore this question in a free-viewing task. Secondly, does saliency play a significant role on the visual exploration of car exterior design? Here, we focus on the importance of saliency in information processing, and its potential role in the visual exploration of cars. Thirdly, are there specific features that are more relevant when visually exploring car exterior design? In order to answer this question, cars were divided into specific components (logo, right headlight, left headlight, right front handle, right rear-view mirror, right front wheel, and right back wheel), so that we could understand their impact on the visualization of car exterior design.

4.2. Methodology.

Participants.

This study was composed by 50 participants, in total: 24 female (M_{age} = 45.15, SD_{age} = 13.74), 26 male (M_{age} = 41.58, SD_{age} = 12.11). Participants were organised into 3 age groups: from 21 to 35 years old, from 36 to 50 years old, and from 51 to 65 years old (see Table 5).

Table 5. Descriptive statistics of participants in Study 2.

Participants' Gender	Age Group	*n*	Mean	SD
Female	21-35	8	29.00	4.11
	36-50	9	43.67	4.39
	51-65	9	61.00	3.20
Male	18-35	8	29.63	3.16
	36-50	11	41.55	5.30
	51-65	5	60.80	2.77

Other criteria for participants' selection were: a) owning a car (from segments A, B, C or D); b) driving it at least three times per week; c) having a 3-year-driving experience minimum; and d) having personally chosen at least one car they owned in their lives (*i.e.* having been the ones choosing the car without necessarily having had to pay for it themselves). These criteria were established as an attempt to simulate a broad, and representative group of consumers. Regarding the liking questionnaire, and the eye movement data, all data from 50 participants was considered. Due to technical problems, the physiological analysis only took into consideration 44 participants: 23 female (M_{age} = 46.13, SD_{age} = 14.09), and 21 male (M_{age} = 41.62, SD_{age} = 12.01).

Apparatus.

The SR Research Eyelink 1000 Plus system (SR Research, Toronto, Canada) was used to record eye movement, with the correspondent head support, at a sampling rate of 1000 Hz. The E4 wristband (Empatica Inc, 2015) was used to record skin conductance, at a sampling rate of 4Hz, and heart rate, at a sampling rate of 64Hz. E-Prime 2.0 software was used to show the stimuli (Psychology Software Tools, Inc, 2014).

Materials.

Overall, all participants saw 40 car pictures, one at a time. The 40 cars were selected according to their shape categorization (as considered in Study 1, see Figure 10), as well as their universal decoder of car styling (see Figure 15), with some of the same car designs having been used in Study 1. The universal decoder of car styling was created by Renault ©, in order to develop a common design language that intends to portray a source of inspiration, as well as to better understand consumers' perceptions, needs, and expectations. This categorization is focused on other cues besides than the car itself, as well as besides the usual automotive categories based on segments, body types, brands, functions and usages, and it aims at classifying cars according to their exterior design and shape. The chosen approach was developed by a group of specialists, who took into consideration formal criteria of eligibility, including past designs, and contemporary concept cars' designs, and who analysed more than a thousand stimuli (pictures and real cars). For the purposes of this study, we focused on eight specific categories, with the letters of the categories representing a specific code: BO, BU, N, P, R, S, T, and W. Due to the confidentiality of this categorisation, no further description of the categorisation will be presented.

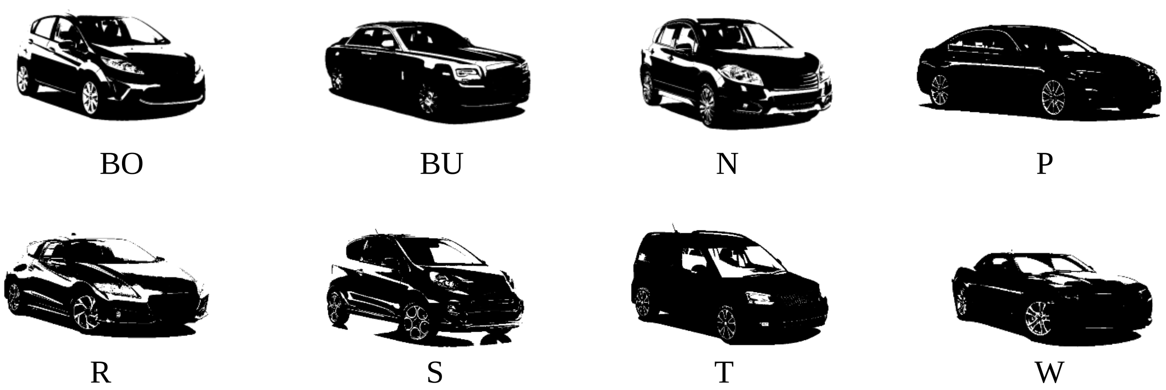

Figure 15. Considered categories of the universal decoder of car styling.

Moreover, due to the nature and duration of the task of the present study, it was important to take into consideration the level of familiarity of each car. In order to do so, a pre-test was made to assess the familiarity level of 60 cars, from which the 40 car models for this experiment were chosen.

Hence, in order to avoid a possible familiarity effect regarding car model (since we can indeed suppose that different observation strategies may be triggered depending on the level of familiarity of the car model), 46 participants (26 female (M_{age} = 26.84, SD_{age} = 8.41), and 20 male (M_{age} = 29.10, SD_{age} = 6.05)) answered an online questionnaire regarding the familiarity level of 60 cars. In this questionnaire, 60 car pictures were randomly presented, and participants' had to answer from 1 to 5 how well they knew that car (see the questionnaire in Appendix 3). Forty cars were selected from this pool of 60 cars (see Appendix 4). This allowed us to guarantee a balanced level of familiarity regarding the presented designs by each evaluated category (in terms both of shape categorization, and of the universal decoder of car styling).

Overall, there were 5 cars belonging to each universal decoder of car styling categories (BO, BU, N, P, R, S, T, and W). Regarding the shape categorization, there were 40 designs per height (20 low, and 20 high cars), and 40 designs per outline (20 round, and 20 angular). Both car categorizations were treated and analyzed independently.

Considered measures.

Physiological and subjective responses to different car categories. In this study, we focused on measuring changes of skin conductance, heart rate, and pupil size in terms of physiological reactions. Participants filled in a questionnaire on car exterior design at the end of the computer task (on a 7-point Likert scale questionnaire), which represents the subjective measurement. We focused on comparing reactions to two different car categorizations: car shape (in terms of outline, and height), and its universal decoder of car styling.

Changes in skin conductance signify changes in the electric variations of the skin, which are controlled by the sympathetic autonomic nervous system, and are seen as an established indicator of arousal (*i.e.* level of activation) evoked by a specific stimulus (e.g.: Balters & Steinert, 2017; Lang, 2014; Levenson, 2014; Mauss & Robinson, 2009).

Heart rate refers to the number of beats (or contractions) of the heart per minute, being measured in beats per minute (bpm), and regulated by both the sympathetic and parasympathetic systems (Cacioppo et al., 2007; Mauss & Robinson, 2009). A higher heart rate has been observed for emotional stimuli, of positive and negative valence (Bernat et al., 2006; Cacioppo et al., 1993; Kreibig, 2010),

Pupillometry refers to changes in pupil size, which is mediated by both sympathetic and parasympathetic systems (Steinhauer et al., 2004). A bigger pupil dilation is associated to a higher cognitive demand or mental effort (Hess & Polt, 1964; Jainta & Baccino, 2010; Stanners et al., 1979).

Results regarding the universal decoder of car styling are to be considered exploratory, as the goal was to quantify and understand participants' responses to this car classification. Regarding car shape, as the task from the current study differed from the task of Study 1, we could only expect a preference for low and curved shapes, and a dislike for high and angular curves, as seen in literature.

The impact of saliency on the visual perception of car exterior design. Here, we took the saliency of the car pictures into consideration. When directing our visual attention towards an element, several factors come into play, which a so-called saliency map is expected to identify from a bottom-up (*i.e.* stimulus-driven) perspective. A saliency map graphically displays the areas of the picture that represent the most physically different characteristics in terms of intensity, colour, and orientation (Itti & Koch, 2001). In this study, a saliency map for each car picture was calculated (Appendix 5) using the Graph-Based Visual Saliency model (Harel et al., 2006). The goal was to compare the most salient parts of each picture to where participants directed more fixations, in order to understand what type of information processing mainly occurred and how it potentially evolved with time: bottom-up (in the case where participants mainly visually explored the most salient areas of the car pictures) or top-down (in the case where participants mostly explored other areas than the salient areas of the car pictures). We wanted to understand whether a certain type of information processing could be attributed to a certain car shape or universal decoder of car styling.

Furthermore, a comparison was made between the most salient area and the logo of each picture. We chose this approach since the logo is the first feature that gives information about which car is being presented (*i.e.* its brand). In here, we studied eye movement metrics, namely first fixation index (*i.e.* the ordinal sequence of the first fixation that occurred within the defined area of interest), dwell time (*i.e.* the summation of all fixation durations within the defined area of interest), and number of fixations (*i.e.* the total number of fixations within the defined area of interest) in order to understand what evoked more attention: the most salient feature of the picture (translating a more bottom-up processing) or the logo (translating a more top-down processing). The compared areas of interest were defined by locating the centre coordinate (x, y) of each logo and the most salient region, and delineating a square of 50x50 pixels from there, per car.

The relevancy of specific features on the visual exploration of car exterior design. Finally, in this study we were interested in understanding whether specific car features elicited more attention than others. In order to do so, we divided each car picture into 7 different components, namely: logo, right headlight, left headlight, right car handle, right rear-view mirror, right front wheel, and right back wheel; see example in Figure 16). All car pictures with the delineated components are available in Appendix 6. The components were defined by identifying each central (x,y) location and allocating a 50x50-pixeled-square for each area. The gaze metrics analysed were also first fixation index, dwell time, and number of fixations.

Figure 16. Example of the identified components for the components' analysis according to car shape and universal decoder of car styling.

Procedure.

After signing a consent form, participants were asked about possible heart, as well as vision, problems, with no problems being revealed. At the beginning of the experiment, participants were asked to list all previously and currently owned cars. This was a control measure in order to check whether cars previously or currently owned by participants elicited biased reactions (which was not the case).

Moreover, a questionnaire was built and given to participants in order to understand their profile in terms of level of preference for cars in general (Appendix 7). This last questionnaire was made as a control measure, in order to ensure results could not be explained by the level of car enthusiasm portrayed by participants (*i.e.* how much participants liked cars in general).

In terms of instructions, participants were told that they were going to see pictures of cars on a computer screen, and that their task was to look at each picture, at their will. At the beginning of the computer task, the Eyelink system, and the E4 wristband were calibrated. The task was divided into two parts (each one composed by 20 cars each), and a head support was used to avoid fatigue. The 40 cars were shown in a pseudorandomised order, and all participants saw all cars. At the beginning of each trial, a fixation cross was presented for 2s. Before presenting the actual car picture for 30s, the same car picture with all the pixels mixed was presented for 3s, in order to control light reflection, since pupil size was one of the considered variables. At the end of each trial, a dot was presented at the centre of the screen for 2s (resting phase).

At the end of the computer task, participants were given a 7-point-Likert scale questionnaire. The purpose of this questionnaire was to measure how participants liked or not each one of the previously presented car exterior designs (Appendix 8). Before answering to this questionnaire, participants were instructed to exclusively consider the aesthetic value of each car exterior design, and to disregard any other information they might know, as well as any buying intention concerning the presented car pictures.

4.3. Results.

Data extraction and analysis were performed with the help of Matlab 2015b, the SR Research software Dataviewer, as well as with SPSS Statistics version 23. An alpha level of 0.05 was used throughout the data analysis.

In terms of data analysis, there was a discussion of whether to choose a more marketing- or sensory-oriented statistical approach *versus* a more psychological approach. Hence, both types of analysis were carried out, with the former focusing more on potential patterns of consumer behaviour and being performed and more suitable for company use, whilst the latter focused more on the processes involved in the visual perception of car exterior design, and therefore was the one described and discussed in the current manuscript.

Physiological and subjective responses to different car categories.

In this analysis, we considered mean skin conductance response, and mean heart rate (the difference between the 30s of picture presentation and the 2s prior to the car picture presentation, corresponding to the baseline). To avoid negative values in terms of skin conductance response and heart rate, a correction was made by using Venables and Christie's (1980) formula of $y = \log(1+x)$, but adding 2 instead of the proposed 1, which was necessary to make all values positive (Field, 2009, p. 155). We also analysed mean pupil size (the difference between the first 5s of picture presentation and the 2s prior to the car picture presentation, corresponding to the baseline). Lastly, we also considered the questionnaire results, in the form of a 7-point Likert scale questionnaire (with a lower score corresponding to a design dislike, and a higher score corresponding to liking a design).

Physiological and subjective responses to car shape. Regarding car shape, two-way repeated measures ANOVAs were performed for each considered measure as a dependent variable, with outline (curved; angular), and car height (low; high) as within-subject factors. The participants' sample group was balanced in terms of sex and age as a control measure to guarantee the simulation of a consumer group. Table 6 presents the descriptive statistics of the considered measures.

Table 6. Descriptive statistics for the variables of skin conductance, heart rate, pupil size, and questionnaire considering car height and car outline.

	Height		Outline	
	Low	High	Curved	Angular
Variables	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Skin conductance	.291 (.002)	.292 (.003)	.292 (.002)	.290 (.003)
Heart rate	.305 (.007)	.274 (.008)	.309 (.006)	.271 (.011)
Pupil size	115.16 (12.52)	120.36 (9.62)	125.10 (11.43)	110.42 (10.31)
Questionnaire	4.34 (.11)	3.77 (.11)	4.38 (.10)	3.73 (.14)

Note: Skin conductance and heart rate are presented in log values, but were originally recorded in microsiemens and beats per minute, respectively. Pupil size is presented in pixels.

There were no significant differences in terms of skin conductance response regarding height, F (1, 43) = .62, p = .44, η^2_p = .01, nor outline, F (1, 43) = 1.60, p = .21, η^2_p = .03. No interaction effect occurred between height and outline, F (1, 43) = .49, p = .49, η^2_p = .01.

The analysis of mean heart rate showed a main effect of height, *F* (1, 43) = 9.66, *p* = .003, η^2_p = .18, indicating that the evoked mean heart rate was stronger for low compared to high car designs (see Table 6). A main effect of outline also occurred, *F* (1, 43) = 8.93, *p* = .005, η^2_p = .17, with curved exterior designs eliciting a stronger heart rate than angular designs (see Table 6). The interaction effect was non-significant, *F* (1, 43) = .56, *p* = .46, η^2_p = .01.

Several studies have linked mean heart rate to valence (e.g.: Bernat, Patrick, Benning, & Tellegen, 2006; Brouwer, van Wouwe, Muehl, van Erp, & Toet, 2013; Fernández et al., 2012; Gomez, von Gunten, & Danuser, 2016; Kreibig, Wilhelm, Roth, & Gross, 2007). In this study, the liking questionnaire is the explicit measure of valence towards the shown car designs (*i.e.* a low score is the equivalent of disliking a car design, which portrays a negative valence, whereas a high score is the equivalent of liking a car design, which portrays a positive valence). Hence, Pearson correlation tests were also performed between mean heart rate and mean liking scores, according to each car shape. However, no significant correlation was found between car design preference and mean heart rate.

Pupil size also differed significantly according to outline, *F* (1, 49) = 8.63, *p* = .005, η^2_p = .15, with curved designs eliciting a bigger pupil dilation compared to angular designs (see Table 6). No main effect of height, *F* (1, 49) = .54, *p* = .46, η^2_p = .01, nor interaction effects, *F* (1, 49) = 1.65, *p* = .21, η^2_p = .03, occurred.

Finally, the statistical analysis of the questionnaire showed a main effect of height, *F* (1, 49) = 27.96, $p < .001$, η^2_p = .36, with participants preferring low compared to high designs (see Table 6). There was also a main effect of outline, *F* (1, 49) = 17.52, $p < .001$, η^2_p = .26, with a higher mean score for curved compared to angular car exterior designs (see Table 6). An interaction effect between height and outline also occurred, *F* (1, 49) = 11.43, *p* = .001, η^2_p = .19. Pairwise comparisons with a Bonferroni correction showed how: a) in terms of angular designs, participants significantly preferred angular and low shapes ($p < .001$; *M* = 4.16, *SD* =

.18) compared to angular and high shapes (*M* = 3.30, *SD* = .15); b) when considering curved designs, participants significantly favoured curved and low shapes (*p* = .01; *M* = 4.52, *SD* = .12) compared to curved and high shapes (*M* = 4.25, *SD* = .12); and c) in terms of high designs, high and curved shapes were preferred ($p < .001$; *M* = 4.25, *SD* = .12) compared to high and angular shapes (*M* = 3.30, *SD* = .15).

Physiological and subjective responses to the universal decoder of car styling. Repeated measures ANOVAs were performed for each considered measure as a dependent variable, with the universal decoder of car styling (BO; BU; N; P; R; S; T; W) as a within-subject factor. The participants' sample group was balanced in terms of sex and age as a control measure to guarantee the simulation of a consumer group. Table 7 presents the descriptive statistics of the considered measures per car category.

Table 7. Descriptive statistics for the variables of skin conductance, heart rate, pupil size, and questionnaire considering the universal decoder of car styling.

Variables	BO	BU	N	P	R	S	T	W
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Skin conductance	.294 (002)	.288 (.004)	.296 (.002)	.285 (.005)	.292 (.003)	.290 (.004)	.294 (.003)	.291 (.003)
Heart rate	.316 (.017)	.243 (.027)	.246 (.034)	.313 (.011)	.290 (.013)	.316 (.009)	.299 (.010)	.213 (.041)
Pupil size	140.83 (12.32)	93.31 (12.09)	135.23 (12.28)	100.18 (12.87)	113.48 (13.69)	126.12 (15.43)	122.05 (9.28)	117.51 (13.18)
Questionnaire	5.05 (.14)	3.89 (.21)	3.37 (.15)	4.66 (.16)	4.31 (.15)	4.30 (.14)	3.08 (.16)	3.77 (.21)

Note: Skin conductance and heart rate are presented in log values, but were originally recorded in microsiemens and beats per minute, respectively. Pupil size is presented in pixels.

Regarding the statistical analysis of skin conductance response, Mauchly's test indicated that the assumption of sphericity was violated, χ^2 (27) = 122.34, $p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .52$). The results show that there were no significant changes of skin conductance response regarding the universal decoder category, F (3.60, 154.90) = 2.15, $p = .08$, $\eta^2_p = .05$.

Considering mean heart rate response, Mauchly's test indicated that the assumption of sphericity was violated, χ^2 (27) = 188.62, $p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .51$). The results show that there was a significant main effect regarding the universal decoder of car styling, F (3.59, 154.30) = 2.87, $p = .03$, $\eta^2_p = .06$. However, pairwise comparisons with Bonferroni corrections showed no significant differences among the car categories.

In the pupil size statistical analysis, Mauchly's test indicated that the assumption of sphericity was violated, χ^2 (27) = 62.90, $p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .71$). Pupil size varied significantly according to the universal decoder of car styling, F (4.98, 243.80) = 4.74, $p < .001$, $\eta^2_p = .09$. Pairwise comparisons with Bonferroni corrections showed that the BU category evoked a significantly lower pupil dilation compared to BO ($p < .001$), N ($p = .007$), S ($p = .02$) and T ($p = .02$) categories (see Table 7 for mean values). Moreover, the pupil size elicited by the P category significantly differed from the pupil size evoked by the BO ($p = .01$), and N ($p = .03$) categories (see Table 7 for mean values).

In terms of the questionnaire analysis, Mauchly's test showed that the assumption of sphericity was violated, χ^2 (27) = 134.28, $p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .46$). A main significant effect of universal decoder of car styling occurred, F (3.23, 158.21) = 20.67, $p < .001$, $\eta^2_p = .30$. Pairwise comparisons with Bonferroni corrections revealed that the participants' favourite category was

BO, with its score differing significantly from the scores of the BU ($p = .002$), N ($p < .001$), R ($p = .001$), S ($p < .001$), T ($p < .001$), and W ($p < .001$) categories (see Table 7 for mean values). The second most preferred design was the P category, with its score being significantly different from the ones of the B ($p = .01$), N ($p < .001$), T ($p < .001$), and W ($p < .001$) categories (see Table 7 for mean values). The least favorite category was the T one, which also differed significantly from the BU ($p = .004$), and R ($p < .001$) categories (see Table 7 for mean values). The second least favourite category was the N one, which also differed significantly from the R ($p < .001$), and also the S ($p < .001$) categories (see Table 7 for mean values).

The impact of saliency on the visual perception of car exterior design.

In this analysis, we were interested in comparing the locations of the salient areas of each car picture with the location of fixations made by participants. In order to do so, a receiver operating characteristics (ROC) curve was calculated per participant, and per picture, in which the Area Under the curve ROC-Judd metric was used (*i.e.* AUC-Judd; Judd, Durand, & Torralba, 2012; Riche, Duvinage, Mancas, Gosselin, & Dutoit, 2013) to calculate when saliency could either correctly predict the position of the gaze (*i.e.* a hit), or predict a position that would not be fixated by the eye (*i.e.* a false alarm). On a ROC curve, the probability of false alarms is shown on the x axis while the probability of hits is represented on the y axis. The higher the hits (y = 1), and the lower the false alarms (x = 0), the more ideal the curve is. These ROC curve scores were calculated and transformed in z scores per participant, and per car picture, for blocks of 5 seconds each corresponding to the first 15 seconds of picture visualization (first 5 seconds – ROC5 –, second 5 seconds –ROC10 –, third 5 seconds – ROC15).

Saliency and car shape. A repeated measures ANOVA was performed by taking the ROC *z* scores as the dependent variable, and height (low, and high), outline (angular, and curved), and time (5s, 10s, and 15s) as within-subject factors. Table 8 presents the descriptive statistics of the considered measures.

Table 8. Descriptive statistics of the ROC *z* scores during the first 15 seconds of picture presentation according to car height, and outline.

	Height		Outline	
	Low	High	Curved	Angular
Variables	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
ROC5 scores	.270 (.004)	-.318 (.005)	-.212 (.013)	.164 (.012)
ROC10 scores	.255 (.010)	-.299 (.011)	-.186 (.007)	.142 (.006)
ROC15 scores	.288 (.010)	-.333 (.011)	-.171 (.010)	.125 (.009)

Note: ROC5 refers to the ROC *z* scores of the first 5 seconds of picture presentation, ROC10 means the ROC *z* scores of the second 5 seconds of picture presentation, and ROC15 represents the ROC *z* scores of the following 5 seconds of picture presentation.

Regarding the within-subject factor of time, Mauchly's test showed that the assumption of sphericity was violated, χ^2 (2) = 48.83, $p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .61). A main significant effect of time occurred, F (1.22, 159.81) = 7.73, p = .005, η^2_p = .14, showing how the type of information processing evolved with the passing of time. Pairwise comparisons with Bonferroni corrections revealed a significant difference between ROC *z* scores of the first 5s of the picture presentation (p = .007; M = -.024, SD = .001) and ROC10 (M = -.022, SD = .001), as well as between ROC10 and ROC 15 (p = .001; M = -.023, SD = .001).

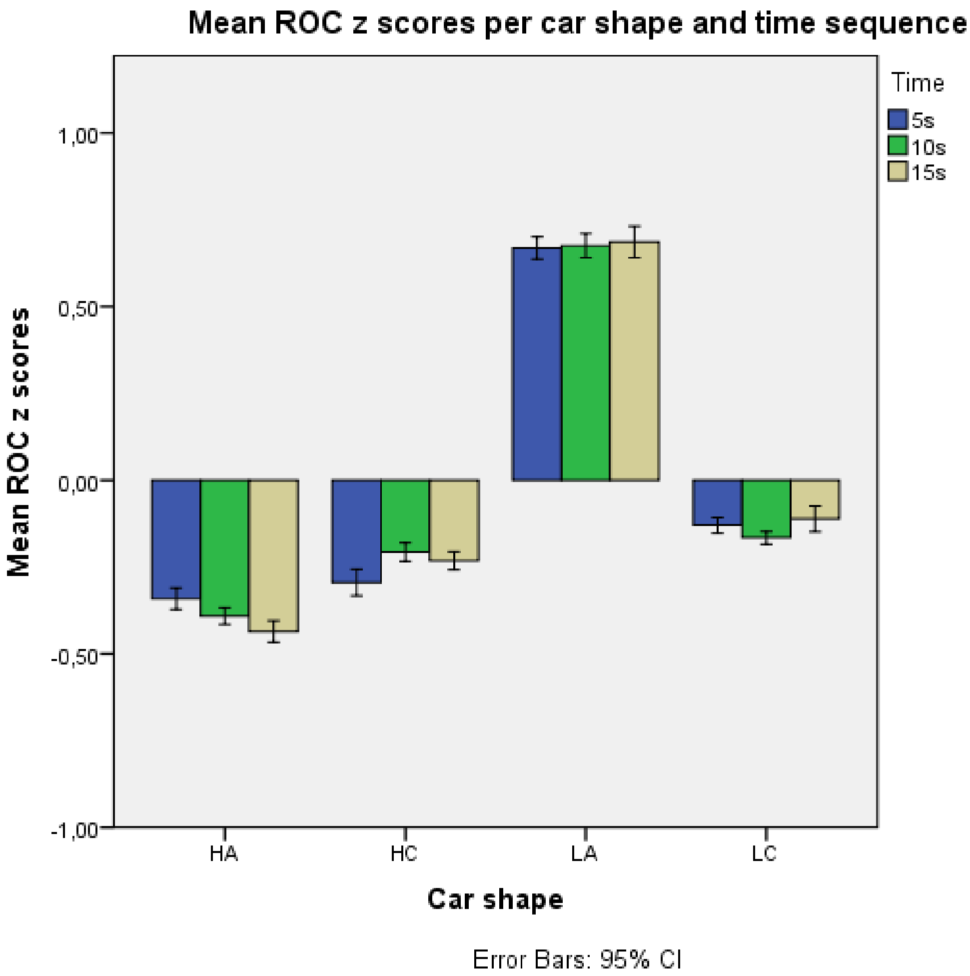

Figure 17. Mean ROC *z* scores along time, considering car height and outline. HA: high and angular shapes; HC: high and curved shapes; LA: low and angular shapes; LC: low and curved shapes.

Concerning the role of saliency on the perception of each type of car exterior design, a main effect of height occurred, F (1, 49) = 1405.11, $p < .001$, $\eta^2_p = .97$, with high designs (M = -.317, SD = .008) significantly showing lower ROC z scores compared to low designs (M = -.271, SD = .007). A main effect of outline also occurred, F (1, 49) = 345.99, $p < .001$, $\eta^2_p = .88$, with angular designs (M = .144, SD = .008) showing lower ROC z scores than curved designs (M = -.190, SD = .010). An interaction effect between height and outline also occurred, F (1, 49) = 1569.17, $p < .001$, $\eta^2_p = .97$, which mirrored the differences already described found in the main effects ($p < .001$). Regarding the triple interaction effect between height, outline and time, Mauchly's test showed that the assumption of sphericity was violated, χ^2 (2) = 21.1, $p <$ .001, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .74). Pairwise comparisons with Bonferroni corrections showed the same differences found in the main effects. Whereas high and angular designs, high and curved, and low and curved designs showed significant differences among time sequence, the same did not happen for the low and angular designs (*i.e.* no changes). Even though the ROC *z* scores of some designs varied significantly along time, these differences were not important enough to signify a change of type of processing. Overall, low and angular designs showed the highest ROC *z* scores (*M* = .677, *SD* = .018), and high and angular designs showed the lowest ROC *z* scores (*M* = -.389, *SD* = .012), followed by high and curved designs (*M* = -.244, *SD* = .011), and finally low and curved ones (*M* = -.135, *SD* = .011; see Figure 17).

Saliency and the universal decoder of car styling. A repeated measures ANOVA was performed by taking the ROC *z* scores as the dependent variable, and the universal decoder of car styling (BO, BU, N, P, R, S, T, and W), and time (5s, 10s, and 15s) as within-subject factors. Table 9 presents the descriptive statistics of the considered measures. The goal was to see whether visual exploration changed according to the universal decoder of car styling, and if there were changes along time.

Concerning the main effect of time, Mauchly's test showed that the assumption of sphericity was respected, χ^2 (2) = .36, p =. 84, so no correction was needed. A main effect of time did not significantly occur, F (2, 98) = .06, p = .94, η^2_p = .001, showing how the type of information processing stayed virtually unchanged with the passing of time.

Table 9. Descriptive statistics of the ROC *z* scores per universal decoder of car styling during the first 15 seconds of picture presentation.

Variables	BO Mean (SD)	BU Mean (SD)	N Mean (SD)	P Mean (SD)	R Mean (SD)	S Mean (SD)	T Mean (SD)	W Mean (SD)
ROC5 scores	-.883 (.029)	.059 (.011)	.097 (.018)	.563 (.028)	.327 (.012)	-.250 (.013)	-.553 (.012)	.639 (.021)
ROC10 scores	-.795 (.022)	.164 (.020)	.242 (.018)	.840 (.048)	.190 (.011)	-.651 (.030)	-.523 (.018)	.534 (.034)
ROC15 scores	-.732 (.030)	-.159 (.031)	-.043 (.024)	.763 (.040)	.389 (.019)	-.393 (.022)	-.482 (.022)	.657 (.020)
Total mean	-.803 (.023)	.021 (.010)	.099 (.014)	.722 (.033)	.302 (.008)	-.431 (.013)	-.519 (.015)	.610 (.021)

Note: ROC5 refers to the *z* ROC scores of the first 5 seconds of picture presentation, ROC10 means the *z* ROC scores of the second 5 seconds of picture presentation, and ROC15 represents the *z* ROC scores of the following 5 seconds of picture presentation.

Regarding the potential attribution of specific information processing strategies to the different categories of the universal decoder of car styling, the main effect of the universal decoder was analysed. Mauchly's test showed that the assumption of sphericity was violated, χ^2 (2) = 467.66, p < .001, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .24). The main effect of universal decoder was significant, F (1.69, 82.95) = 747.31, p < .001, η^2_p = .94, with pairwise comparisons with Bonferroni corrections revealing a significant difference of p < .001 among all interactions, with the exception of the significant interactions between BU and N (p = .04), and P and W (p = .001). The P category evoked the highest ROC *z* scores, followed by the W category. Meanwhile, the BO category elicited the lowest ROC *z* scores, followed by the T and S categories. In the interaction effect of the universal decoder and time, Mauchly's test showed that the assumption of sphericity was violated, χ^2 (104) = 1121.26, p < .001, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .23). This interaction effect was significant, F (3.26, 159.85) = 41.70, $p < .001$, $\eta^2_p = .46$. For the evolution of ROC z scores along time, check Figure 18. For the vast majority, pairwise comparisons with Bonferroni corrections showed significant differences among all interactions.

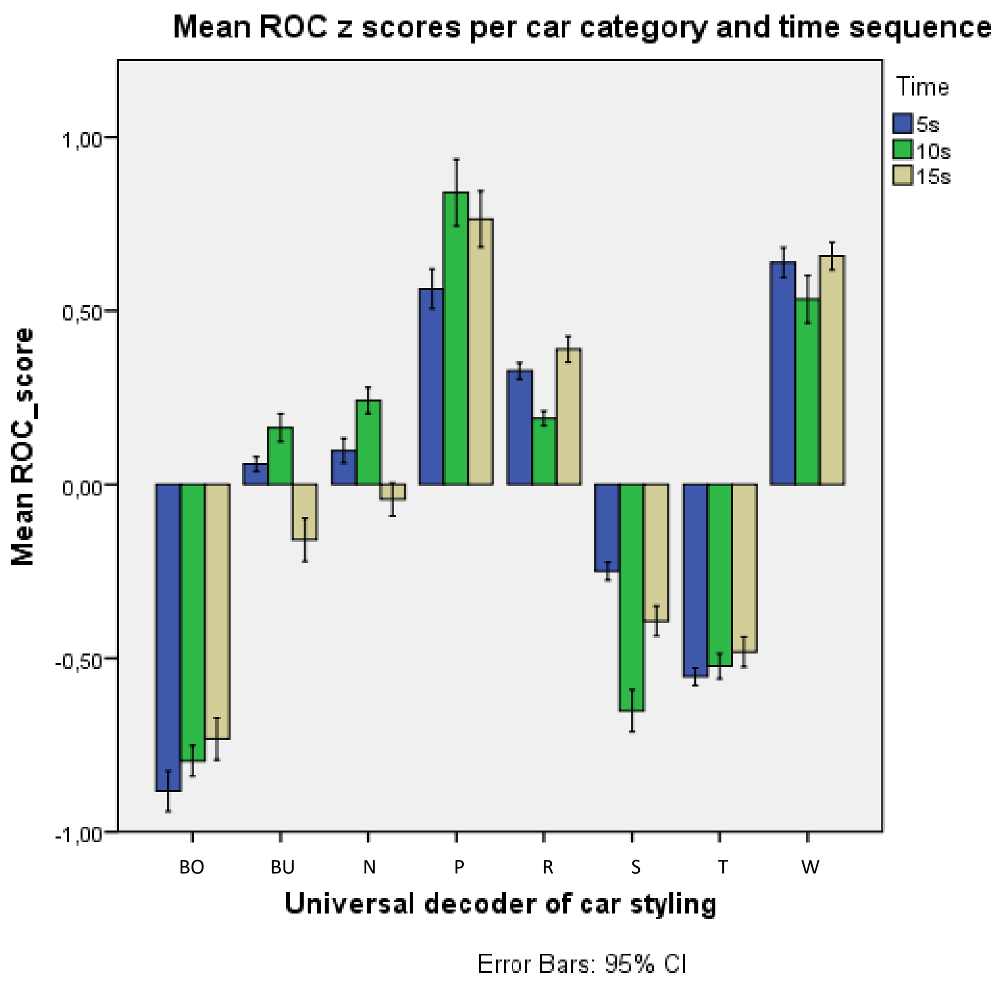

Figure 18. Mean ROC z scores along time, considering each category of the universal decoder of car styling, the categorization created and developed by Renault.

Even though, in this analysis in general, we were expecting to observe a change of type of information processing to occur among all car shapes and categories, that was not the case. Each car shape or category of universal decoder of car styling showed the same pattern of type processing (whether with more top-down or bottom-up influences) in a mostly continuous way.

The importance of the logo versus the most salient area. In this analysis, we were interested in comparing participants' gaze regarding two specific areas of each car picture: the logo, and the most salient area. As normality tests showed data were normal, paired-samples T tests were performed for the data of each variable: first fixation index, dwell time, and number of fixations. Regarding the index of first fixation, in the situations where no first fixation occurred for the defined areas of interest, the same number was applied throughout trials and participants (*i.e.* the maximum value of the overall first fixation index + 1). Only the first five seconds of picture presentation were considered for the present analysis. This analysis included all 50 participants.

Table 10. T-test results comparing gaze behavior between the logo and the most salient areas of each car picture for the first 5s of picture presentation.

	Logo	Salient area		
Variables	Mean (SD)	Mean (SD)	*t*	*p*
First fixation index	6.13 (1.84)	7.55 (2.34)	-.362	< .001
Dwell time	.160 (.049)	.060 (.019)	13.89	< .001
Number of fixations	5.77 (1.79)	.058 (.017)	22.50	< .001

Note: All data is expressed in percentages, except for first fixation index.

The statistical analysis showed how participants significantly looked first at the logo area (first fixation index), spent more time looking at the logo area compared to the salient area (dwell time), and also made more fixations at the logo area compared to the salient area (number of fixations; see mean values in Table 10).

The relevancy of specific features on the visual exploration of car exterior design.

In this analysis, we aimed at comparing gaze metrics among the cars regarding seven car features: the logo, front wheel, back wheel, rear-view mirror, right headlight, left headlight, and the right front handle. The nomenclature of *right* and *left* was defined according to the driver's perspective. Hence, the right headlight from the driver's point of view (and which was used in our nomenclature), is the left headlight from the observer's point of view, when facing the car front. It is also convenient to remember that all the cars were presented in the same position, *i.e.* front of the car facing the right direction, with visible front and side of the car. Repeated measures ANOVAs were performed for each considered measure: percentage of dwell time (*i.e.* the percentage of trial time spent on the specific interest area), percentage of fixations (*i.e.* the percentage of all fixations in a trial falling in the specific interest area), and the index of the first fixation (*i.e.* the ordinal sequence of the first fixation within an area of interest), and with the cars' features (logo, front wheel, back wheel, rear-view mirror, right headlight, left headlight, right front handle) as a within-subject factor. Regarding the index of first fixation, in the situations where no first fixation occurred for the defined areas of interest, the same number was applied throughout trials and participants (*i.e.* the maximum value of the overall first fixation index + 1). The 30 seconds of picture presentation were considered for the present analysis. This analysis included all 50 participants.

In terms of the first fixation index analysis, Mauchly's test showed that the assumption of sphericity was violated, χ^2 (20) = 57.38, $p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .71$). A main significant effect of car features occurred, F (4.28, 209.80) = 5.61, $p < .001$, $\eta^2_p = .10$. Pairwise comparisons with Bonferroni corrections revealed that participants made their first fixation significantly more often in the logo area compared to the right headlight ($p = .001$), right front handle ($p = .003$), rear-view mirror ($p < .001$), and front wheel ($p = .03$) areas (check Table 11 for mean values).

Table 11. Descriptive statistics of dwell time, number of fixations and first fixation index for the considered specific car features for the 30s of picture presentation.

	First fixation index	Dwell time	Number of Fixations
Car features	Mean (SD)	Mean (SD)	Mean (SD)
Logo	13.28 (.65)	.063 (.005)	.056 (.004)
Front wheel	16.37 (.74)	.035 (.003)	.031 (.002)
Back wheel	15.20 (.92)	.023 (.003)	.021 (.002)
Rear-view mirror	18.25 (.64)	.037 (.002)	.037 (.002)
Right headlight	17.11 (.95)	.052 (.004)	.050 (.003)
Left headlight	16.27 (.93)	.030 (.004)	.028 (.003)
Right front handle	16.77 (.67)	.036 (.002)	.036 (.002)

Note: All data is expressed in percentages, except for first fixation index.

Regarding the percentage of time spent looking at each component, Mauchly's test showed that the assumption of sphericity was violated, χ^2 (20) = 93.60, $p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .66$). There was a significant effect of car features regarding the dwell time, F (3.97, 194.30) = 19.73, $p < .001$, $\eta^2_p = .29$. Pairwise comparisons with Bonferroni corrections revealed that participants spent significantly more time ($p < .001$) looking at the logo than any other feature (with the exception of the right headlight). Participants also spent significantly more time looking at the right headlight compared to the left headlight ($p = .01$), right front handle ($p = .003$), rear-view mirror ($p = .02$), back wheel ($p < .001$) and front wheel ($p < .001$; check Table 11 for mean values). Moreover, participants also spent significantly less time observing the back wheel compared to the right front handle ($p < .001$), rear-view mirror ($p = .002$), and front wheel ($p = .002$; see Table 11).

Finally, in terms of number of fixations, Mauchly's test showed that the assumption of sphericity was violated, χ^2 (20) = 108.49, $p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .63). A main significant effect of universal decoder of car styling occurred, F (3.76, 184.02) = 21.26, $p < .001$, $\eta^2_p = .30$. Pairwise comparisons with Bonferroni corrections revealed the same significant differences than the ones observed at the dwell time analysis. That is, participants made significantly more fixations ($p < .001$) looking at the logo than any other feature (with the exception of the right headlight). Participants also made significantly more fixations looking at the right headlight compared to the left headlight ($p = .003$), right front handle ($p = .004$), rear-view mirror ($p = .04$), back wheel ($p < .001$) and front wheel ($p < .001$; check Table 11 for mean values). Moreover, participants also significantly made less fixations towards the back wheel compared to the right front handle ($p = .007$), rear-view mirror ($p < .001$), and front wheel ($p = .001$; see Table 11).

4.4. Discussion.

The present study offers an insight on the affective, and cognitive aspects are involved on the visual exploration of car exterior design. Three main questions guided the chosen experimental approach.

Regarding the *psychophysiological and affective responses* to car exterior design, this study complements the findings of Study 1, regarding skin conductance and the liking questionnaire. In the present study, besides the liking questionnaire and skin conductance, we also measured heart rate, and pupil size. Two different car categories were taken into consideration: car shape (based on the shape of the car exterior design), and the universal decoder of car styling (a car exterior design categorization created by Renault).

Regarding car shape, in terms of heart rate, low cars (*vs.* high cars) evoked a higher heart rate, as well as curved designs (*vs.* angular). Despite literature showing the correlation between mean heart rate and valence (e.g.: Gomez et al., 2016; Pollatos et al., 2007), such association was not found here (*i.e.* between mean heart rate, and the liking scores from the questionnaire). One possible explanation is the similarity among the mean scores per car shape (see Table 6 – with the maximum score being 5.54 and the lowest 3.36). Participants also showed a bigger pupil dilation towards curved designs, meaning a higher cognitive load ensued when looking at more curved car exterior designs. Finally, in terms of the questionnaire analysis, participants preferred low cars, as well as curved designs, with low and curved cars being the most preferred design, and high and angular being the most disliked design. These results showed the same tendency in literature, with people showing a propensity to favour curved shapes (Gómez-Puerto et al., 2016; Palumbo & Bertamini, 2016), and to dislike angular shapes (Bar & Neta, 2007).

Concerning the universal decoder of car styling categorization, no significant differences were found in terms of skin conductance, nor mean heart rate. In terms of pupil size, participants showed the lowest pupil dilation towards the BU category, followed by P, and the highest pupil dilation towards the BO category, followed by N. In terms of the liking questionnaire, participants' preferred category was BO, and the least preferred one was T, followed by N. As explained before, due to the nature of this categorization, results of this analysis were exploratory, and were expected to shed a light on the type of processing involved in a more cognitive characterization of car exterior design.

In terms of both car categorisations, and contrary to the findings in Study 1 in terms of car shape, there were no significant differences on skin conductance response. We hypothesise this result is due to the lack of motor task involved (*i.e.* a passive task). Most studies on skin conductance use either extremely strong emotional stimuli and/or involve some kind of motor response (e.g.: pressing a button; *i.e.* an active task). Indeed, the demanded task is going to have a significant role on ANS changes on a functional point of view (Mendes, 2009), justifying thus the lack of skin conductance response in this study.

Concerning these overall results, it is important to keep in mind that we hypothesize there is a parallel to be established between visual exploration of a car exterior design, and an aesthetic experience. Whereas a lot of studies on emotion response concern the use of psychophysiological measures, studies on aesthetics have historically focused more on the neural mechanisms involved in the aesthetic experience (e.g.: Belfi et al., 2019; Chatterjee & Vartanian, 2014). By joining psychophysiological and cognitive measures in this study, we intended to prove whereas the visual perception of a car exterior design could be seen as an aesthetic experience, which it can (for curved designs, as seen in this study).

Regarding the study of the *impact of saliency on the visual perception of car exterior design*, gaze behaviour was recorded and analysed. One has to keep in mind that attention is mediated by both bottom-up and top-down processes. In light of the goals established for this study, a free-viewing task was chosen. Indeed, most studies on visual saliency adopt a free-viewing task in their procedure, and by letting participants explore the pictures freely, we were hoping to attenuate possible top-down processes due to the existence of a task. However, we must acknowledge that when looking at a stimulus, we can also trigger other related processes that will have an impact on the subsequent visual exploration, like memories, beliefs, cognitive interferences or emotions, and especially during task completion (Itti & Borji, 2014). Therefore, in this study we wanted to understand if saliency could have an impact on visual exploration, and how this impact would evolve in time.

The saliency analysis was performed for both design categorizations. Regarding car shape, all shapes elicited a top-down processing (*i.e.* their mean ROC *z* scores were very low, which translates the dissimilarity between where people were expected to look at – according to the saliency map – and where people actually looked at), with the exception of low and angular car exterior designs. Low and angular car exterior designs evoked a bottom-up processing, since there was a high similarity (as seen in their high mean ROC *z* score) between where people were predicted to look at (according to the saliency map) and where people actually looked at. Low and angular designs clearly evoke more bottom-up influences, and we attribute this to the fact that it is undoubtedly the car shape with the most acute angles. The perception of acute angles may have most likely been exacerbated by the constrained size of the stimuli (*i.e.* computer screen). This plus the known association of acute angles to dislike and sense of threat (as already discussed in Study 1; see Bar & Neta, 2006, 2007), may explain this visual processing more guided by the characteristics of the visual elements available. Moreover, even though mean ROC *z* scores varied significantly during the first 15 seconds of picture presentation, the type of processing attributed to each car shape stayed constant, which suggests that visual perception of car exterior design will mostly be guided either by top-down or bottom-up influences, but that these influences will occur in a mostly rigid and persistent way.

Regarding the saliency analysis of the universal decoder of car styling, while the P category showed the highest mean ROC *z* scores, being associated to a more guided bottom-up type of processing (followed by the W category), the BO category showed the lowest scores, which conveys a more top-down type of processing (along with the S and T categories).

Overall, the current saliency analysis surprisingly showed how the way participants process the visual information depends on the car shape/category, instead of simply being a matter of visual saliency playing a more vital role at the beginning of the stimulus presentation. Knowing how the brain specifically processes the type of design being observed will have clear implications on how designers compose new forms. Whether this may be simply explained by the size of the stimulus or by the car forms themselves is to be further explored.

By *comparing the gaze behaviour towards the logo area and the most salient area*, we wanted to assess how essential and important the logo is on the visual perception of car exterior design. When comparing the logo area with the most physically salient area of each car picture, participants consistently drew more attention (*i.e.* looked first, longer, and more often) to the logo area. Indeed, when we look at an object, we try to identify/recognize it by establishing its components (Biederman, 1985, 1987; Treisman, 1986; Treisman & Gelade, 1980), and function (E. J. Gibson, 2000; James J. Gibson, 1979; Greeno, 1994). The logo is a very essential part in the identification of the car brand, and by follow-up, the car model. Therefore, it makes sense for participants to look right away at the logo even though there was no particular task to be performed. This shows how these processes are - or can become - automatic, and should be taken into consideration when designing a product.

Finally, we also studied the potential impact that specific *car features* may have on the visual exploration of car exterior design. Before going any further, it is convenient to state that the "right" and "left" identifications of the components were made on a driver's perspective. This analysis showed how participants looked significantly first, longer and more often to the logo, followed by the right headlight area. As already discussed here, the logo is the most influential cue for car identification. In this task, participants were told they would be shown car pictures, and that they were expected to look at them freely. However, participants were not told which specific car models or brands they were going to see. This might have propelled the need to engage attention at the logo in order to identify the car they were looking at. Moreover, the right headlight also elicited more attention. This may have happened for several, and potentially cumulative reasons. First, the logo and the right headlight are closely located on the car's design/angle of the picture, and therefore there may be a sense of *good continuation* as well as *proximity* that justifies this visual exploration (for Gestalt rules, see Wagemans et al., 2012; Wertheimer, 1938; Westheimer, 1999). Secondly, when visually exploring a picture, participants have a tendency to make a horizontal visual exploration, unless encouraged to do otherwise by the task (e.g.: Solman, Foulsham, & Kingstone, 2017). This may also exacerbate the elicited sense of *good continuation*. Finally, cars are highly prototypical objects, and hence it should not be surprising for there to be features or even whole areas of the design (e.g. the front) that are more relevant than others.

Indeed, participants looked less often and spent the least time of their visual exploration on the back wheel area, followed by the left headlight. Regarding the back wheel, this could be attributed to the lack of manipulation by designers. However, if this were the case, the front wheel area should also not be regarded, and this is not the case. The front wheel is evoking more time spent and more fixations, which makes us attribute these results to the angle of presentation of each car exterior design. Again because of the angle of car presentation, the left headlight might have been perceived as being "far away", and not "as available" as the other car components, and hence participants focused on other car features. In fact, the left headlight was sometimes hardly visible, which may have played a role in the visual exploration. People have been shown to replicate the gaze pattern of face-observations when looking at car fronts (Windhager et al., 2010). However, this was not the case in the present study. We hypothesize this also has to do with the positioning of the car (*i.e.* front and side, and not just front).

Similarly to the specificity of gaze behaviour according to the demanded task, these results show how the context of picture presentation can influence participants' eye movement. More specifically, how the position and angle of the presented car picture may have potentially influenced the participants' experience. This becomes particularly relevant when we think of how consumers are firstly presented to or how they get more accustomed to see a particular car model or brand: whether it is on a newspaper/internet/television advertisement, or in real life.

Surprisingly enough, centre features on the screen, such as the right front door handle and the rear-view mirror, did not elicit particular numerous fixations nor observation time. The fact that participants did not linger at the centre region of the car pictures shows how no central fixation bias occurred (Rothkegel et al., 2017; Tatler, 2007), and more importantly how participants were engaged in the task, and were involved in the visual exploration of the designs.

With this study, by taking a psychophysiological and cognitive approach on the visual exploration of car exterior design, we were able to recognize different reactions among different shapes and car categories. The eye movement analysis highlighted the importance of studying the cognitive mechanisms involved in the visual perception of car exterior design, as well as their dynamics over time, in order to have a better grasp on the development of the aesthetic experience. Indeed, putting together the shown preference for curved shapes, the higher cognitive load, as well as heart rate, along with the strong top-down influences involved, suggests that the visual perception of curved car exterior design is similar (or very approximatively, in the very least) to an aesthetic experience. Similarly, the BO category seems also to evoke a more aesthetic experience compared to the other car categories, when one considers its higher preference scores, higher pupil, and top-down influences. The analysis of the car features evoked an interesting discussion on the relevance different features seem to have on the visual exploration of car exterior design, as well as the potential impact the way we present a product may have on its initial perception. Overall, studying consumers' gaze behaviour on car exterior design has shown to be useful to understand which areas are engaging the most and least attention, and hence give designers' some directional cues on how to approach the follow-up design of the shown car models.

Chapter 5: Exploring the Importance of Context factors (namely size of the stimuli) on the Visual Perception of Car Exterior Design

By proposing a free-viewing task to participants, we were able to expand on the study of the affective and cognitive mechanisms involved in the visual perception of car exterior design. We addressed these mechanisms in an exploratory way when using a confidential categorisation created by Renault. In terms of car shape, low cars, and curved designs evoked higher heart rate, and preference. The absence of differences in terms of skin conductance response was justified by the lack of motor response. While overall car design evoked a general top-down processing, low and angular cars invited a bottom-up processing, with these findings having potential straightforward repercussions on how car exteriors are designed. Finally, we confirmed the importance that the logo plays on the visual exploration of car exterior design. In Study 2, although not presented in this manuscript, potential local/ambient mechanisms of visual attention were also analysed. However, due to the fact of the stimuli being presented on a computer screen, and that we were analysing objects (and not scenes), saccade amplitudes were not important enough to pursue with this analysis.

Until here, car exterior design has been presented in a computer screen, which does not portray very often the reality in regard to consumers' exposure to cars. Given the different possibilities (e.g.: media outlets) and characteristics (e.g.: the car's position, size, colour) that are in play when exposing a potential consumer to a product, in this final study, we will try to address the potential relevancy of context (namely the size of the stimuli) on the exposure of the potential consumer to car exterior design. By showing car exterior design in a closer-to-reality setting, we hope to go further on our findings in regard to the mechanisms of visual attention in play.

5.1. Study 3: Introduction.

Thus far, we were able to establish and quantify the occurrence of an important attentional capture towards more familiar designs (*i.e.* non-concept cars), and how this attentional capture is also sensitive to the shape of the presented car design. Moreover, by letting participants explore each presented design at their will (*i.e.* in a passive task), we were able to associate the visual experience of curved designs to more of an aesthetic one. By referring to research on visual perception and, more specifically on the role of saliency, we also studied the dynamics of visual exploration of car exterior design over time. This allowed us to identify different processes of visual exploration – whether guided by more top-down or bottom-up influences – according to car shape (a categorization solely based on the height and outline of each design) and universal decoder of car styling (a categorization created by Renault). We also confirmed the significant role that the logo plays in the visual exploration of car exterior design, showing how important top-down influences can be in this process.

Looking at these results, the more direct follow-up question that arises is whether these responses can be transposed to other contexts, and notably when considering the different ways of exposure to car exterior design. Indeed, one can see a car for the first time in a magazine, website, outdoor poster, television advertisement, or simply by seeing it in the street (whether parked or in motion). This evokes other several questions, starting from the psychological state to the concentration level of the observer at the moment of visual exposure to the car design, from the actual size of the car (real life *versus* a picture or video which may also portray differences in terms of car size) to the angle in which it was presented and/or perceived.

In this final study, we focused on the context of the size of the stimulus. This approach seemed relevant for various reasons. First of all, by showing a car picture in a bigger size, we are also making available fine-grained details that would otherwise be below the discriminability threshold, and therefore not perceived (De Cesarei & Codispoti, 2008). By making more details of the design available, the visual experience will expectedly be more demanding or cognitively charged, and hence elicit more attention. Furthermore, in our daily lives we are more often than not exposed to visual content shown on screens. Not only are we exposed to screens, but these are usually very different in size (from smartphones to tablets, from computers to televisions, etc.). One can wonder whether our perception and attention may change depending on – not only the content *per se* but – the size of the screen in which we are watching content. Interestingly, when viewing advertisement videos on Youtube, where window size (Youtube default window *vs.* full screen) and image quality (high *vs.* low quality) were manipulated, only the latter seemed to have an important impact on advertising effectiveness (Moon, 2014). However, when viewing segments of emotional videos, participants have shown a greater heart rate deceleration and skin conductance response to content shown in bigger screens (56inches ≅ 1.4m) compared to medium (13inches ≅ 33cm) and smaller screens (2 inches ≅ 5cm; Reeves et al., 1999). When looking at emotional pictures in different sizes, skin conductance was shown to increase linearly with stimulus size, with no differences in terms of heart rate and Corrugator Supercilii muscular activity, and with slight variations in terms of subjective ratings (Codispoti & De Cesarei, 2007). These physiological and rating differences illustrate the potential implications contextual factors (in this case, size of the screen) may have on the perceived experience of the presented visual content. What then could we expect in terms of potential differences in visual perception when considering stimuli that are rich in meaning but lack biological significance (*i.e.* cars, as discussed in Study 1)?

Similarly to the former experiments, we were interested in studying variations of activation of the ANS, and therefore skin conductance and heart rate responses, as well as changes of pupil size were recorded and analysed. In the present study, we were also interested in analysing potential changes of posture of participants. Indeed, by asking participants to stand on a force platform that detects and quantifies small bodily oscillations, studies have shown how participants can display approach-avoidance behaviours towards emotional visual stimuli (e.g.: Lelard et al., 2014; Ly et al., 2014).

Regarding participants' subjective responses, Likert scale questionnaires are commonly used. Here, participants are asked to consider a statement or question and express how much they agree or disagree on a scale of usually 5 different points (even though Likert scales also commonly use 7 or 9 points), with each point having a label (e.g.: "strongly disagree", and "strongly agree" at the extremes). Even though these scales are of easy use (both for the participant and researcher), they may show some response bias. Notably, there is what is called the "anchor effect", with participants tending to use less often the extremes and use more often the middle-points (Bishop & Herron, 2015). Moreover, effects of acquiescence (where participants show a propensity to respond more positively by default), as well as a lower involvement in the task (since the participant is only asked to what extent they disagree or agree with a statement) may also occur (Friborg et al., 2006; Rocereto et al., 2011). Therefore, when suitable, researchers started using another type of scale to measure participants' subjective responses. A widely used form of questionnaire is the one developed by Charles Osgood (1952, 1962), the semantic differential. The principle is to ask participants to choose where their position lies on a scale (that can be numerical) between two extremes represented by antonymous adjectives (e.g.: "pleasant-unpleasant"). This type of scale elicits more attention and comprehension of each item content by the part of participants (Rocereto et al., 2011), hence avoiding some of the Likert-scale criticisms. The semantic differential has been shown to have better internal consistency, as well as robustness, reliability and validity in comparison to Likert-scale questionnaires (Friborg et al., 2006; Verhagen et al., 2015). Osgood's semantic differential has been widely used in several domains, from the creation of positive psychological constructs (Friborg et al., 2006), to study preferences toward product form (Chuang et al., 2001), and odors (Dalton et al., 2008).

Also similarly to the second study, this experiment focused on the potential impact of saliency, as well as on the potential relevance some car features may have on the visual perception of car exterior design, and specifically of different car shapes and categories (similarly to Study 2). Regarding the potential impact of saliency, as already explained, we were interested in exploring the top-down and bottom-up influences on the visual perception of car exterior design. While top-down influences refer to the person's prior experiences or goals, for instance, the bottom-up influences refer to the saliency of the characteristics of the stimuli. By using saliency maps (i.e. color-coded maps that portray the different levels of saliency present in a picture) and comparing them to the fixations made by participants, we intend to gather more information on the potential top-down and bottom-up influences on the visual perception of car exterior design. The novelty regarding this study being the application of this methodology to bigger stimuli size.

By studying the potential importance different car features might have, we were interested in being able to provide designers with more insight on which features to adjust. That is, when launching new versions, there are usually some design differences among the same car models. By knowing if or which specific features elicit more attention by consumers gives an upper-hand to designers on where to apply said design changes. This methodology can have surprisingly direct and straightforward implications for the automotive company. For example, just by reducing the size of one single feature by two percent may implicate a ten percent savings of the production costs (Du & MacDonald, 2014).

Even though typical eye movement metrics (such as first fixation duration, number of fixations, etc.) give already a lot of information on the participants' attentional mechanisms in the visual processing of content, there has been an increasing demand for further and more complex analyses of eye movement. More specifically, researchers are interested in exploring both the spatial and temporal aspects of gaze behaviour, and its dynamics. Several methods of scanpath (i.e. the sequence of fixations and saccades) comparison have been developed, differing on the methodology they apply. According to the needs of the experiment, *i.e.* whereas researchers want to compare within- or between-participant scanpath similarity when looking at the same picture twice or when looking at different pictures, or whereas researchers want to focus more on the temporal aspects of the gaze sequences, different methods should be applied (for a review on several methods, see Anderson et al., 2015). More recently, Krzysztof Krejtz and colleagues (2016) developed a method in which, by using a score to distinguish between *ambient* and *focal* viewing, it allows researchers to have information on the fluctuations of gaze behaviour. While *ambient* viewing refers to the occurrence of short duration fixations followed by long saccades, *focal* viewing refers to longer duration fixations followed by shorter saccades (Unema et al., 2005). Krejtz and colleagues (2016) took these definitions into consideration and added the time course of the participant's gaze behaviour in order to create the coefficient K. Besides being a metric easy to use and interpret, it also allows to perform statistical comparisons among individuals and groups. The coefficient K has been proven to discern very well the dynamics of visual attention of participants in tasks of visual search (parallel *vs.* serial search), during art viewing (Krejtz et al., 2016), as well as performing cartographic tasks (Krejtz et al., 2017). Therefore, it would be interesting to gain some insight on the dynamics of gaze behaviour in the visual exploration of car exterior design, since we have already established the presence of bottom-up and top-down influences in this process.

In this final study, one of the questions we are trying to answer is whether we can expect participants' core affect responses and preferences to vary when exposed to a closer-to-reality setting. By using pictures of cars in a 4x2m screen, we wanted to study possible shifts in terms of top-down and bottom-up influences in the visual perception of car exterior design. Moreover, because more details of each car exterior design are visually available (due to the size of the stimuli), we wanted to study the role different car features have. Finally, we were also interested in exploring the dynamics of visual attention in the visual perception of car exterior design. Similarly to the former study, we also took into consideration the shape of the car design, and the universal decoder of car styling, in the hope of shedding some light on the perceptual aspects and stages involved on the visualization of the aforementioned car categories.

5.2. Methodology.

Participants.

This study was composed by 34 participants (see Table 12). Data analysis of physiological and subjective response took all these 34 participants into consideration. Due to technical problems regarding the eye movement data, 5 participants were disregarded from data analysis. Hence, for all eye movement analysis, 29 participants were taken into consideration (M_{female} = 39.18, SD_{female} = 11.71, M_{male} = 38.17, SD_{male} = 11.41). The same criteria in participants' selection from Study 2 were applied to Study 3, with age groups being introduced to better represent the consumer market.

Table 12. Descriptive statistics of participants in Study 3.

Participants' Gender	Age Group	*n*	Mean	SD
Female	21-35	6	23.17	6.73
	36-45	6	40.83	3.31
	+46	6	50.50	4.72
Male	21-35	5	25.00	2.91
	36-45	7	39.85	4.95
	+46	5	49.80	4.38

Apparatus.

An E4 wristband (Empatica Inc, 2015) was used to record skin conductance, at a sampling rate of 4Hz, and heart rate, at a sampling rate of 64Hz. The eye tracker SMI RED 120 (Sensomotoric Instruments, Teltow, Germany) was used to record eye movement. Finally, posture was measured with a Kistler force plate (Kistler Instruments Ltd., Hampshire, United Kingdom). However, due to technical difficulties, the posture data were not possible to analyse. The experiment was built with Experiment Centre (version 3.0; SMI GmbH, 2010). The stimuli were presented in a 4k screen with the dimensions of 4m x 2m, and with a screen resolution of 4096 x 2160 pixels (display of 1mm per pixel). For more details on the 4k screen setup, as well as the experimental procedure, see Appendix 9.

Materials.

Participants were shown 12 pictures of cars (with a resolution of 3840x2160 pixels). The stimuli list was composed by photographs of the selected car models purposefully taken for this study, in order to guarantee a better image quality, with more controlled lighting, and a greater similarity in terms of the car positioning and angle (*vs.* in Study 2, where pictures were taken from Google Images).

The selection of the car models was done by taking into consideration both car categorizations of shape and universal decoder of car styling (as in Study 2). Regarding the universal decoder of car styling, there were 4 car models for each of the following categories: BO, P, and T. These categories were selected due to the scores of the liking questionnaire of Study 2: the most preferred category (BO), the most disliked category (T), and a more neutral one (P). Regarding car shape, there were 5 angular cars, 7 curved cars, 5 low cars, and 7 high cars (see Appendix 10 for the full stimuli list).

Considered measures.

Physiological and subjective responses to different car categories. As in Study 2, we measured mean skin conductance response, heart rate, and pupil size. As in the former study, we were interested in the mean difference (*i.e.* the difference between response to the image presentation and the baseline) of skin conductance and heart rate regarding the 30 seconds of picture presentation, and the mean difference of pupil size for the first 5 seconds of picture presentation.

Taking into consideration the results of the former study, we were expecting no differences in skin conductance response; higher mean heart rate for low, as well as curved designs, and no differences in terms of universal decoder of car styling; wider pupil for curved designs, as well as for BO; preference for low designs, as well as curved shapes, with the specific design of low and curved being the most preferred, and high and angular the least preferred, and BO being the most liked category, and T the least preferred. Even though both studies 2 and 3 shared the same task, there were some vital differences, namely in terms of the constitution of the stimuli list (number of car pictures, and considered car models), the position of the participant during the task (in Study 3, participants were standing up), and the size of the presented stimuli (with real-size pictures being shown in the present study) which may be more than enough to justify differences in terms of results in both studies. Moreover, in Study 2 we used a 7-point Likert scale liking questionnaire in order to have a declarative measure of participants' preferences towards car exterior design (see Appendix 11). Because participants tended to reply with more or less neutral scores, in this study we opted for the use of an Osgood's differential scale (Osgood, 1952, 1962). Here, the questionnaire is organized by pairs of antonyms, with participants having to decide where they stand on this bipolar scale. Like this, we were expecting participants to be more decisive when judging each car exterior design. Five pairs of antonyms were presented for each car exterior design, forcing participants to make a decision for each of the presented antonyms.

The impact of saliency on the visual perception of car exterior design. In this study, we were interested in further exploring the value of saliency when presenting pictures of car designs and if specific information processing could be attributed to specific categories or shapes. The same reasoning and methodology of Study 2 were applied (see p.85-86), where: a) a high ROC *z* score means a great similarity between the salient areas (*i.e.* where participants were expected to look at first) and where participants actually looked at, which we associate to a processing with more bottom-up influences, and b) a low ROC *z* score means a great incongruity between the salient data and the participants' gaze behaviour, and which we therefore associate to a processing more driven by top-down influences. As in Study 2, ROC z scores of saliency were organized in blocks of 5 seconds each, for the first 15 seconds of picture presentation. Similar to the former study, we expected to find a constant type of information processing according to the car shape and category, with a more bottom-up processing for low and angular designs (and more top-down for all the other shape combinations), and a more bottom-up processing for the P category, followed by W (opposed to other categories with a more top-down processing). The saliency maps corresponding to the stimuli used in this study can be found in Appendix 12.

The relevancy of specific features on the visual exploration of car exterior design. Six areas of interest (AOIs) were formed per car exterior design. These 6 AOIs corresponded to relevant features of a car: logo, right headlight, right rear-view mirror, right door handle, right front wheel, and right back wheel (see Figure 19 for an example, and Appendix 13 for the complete list of stimuli with the designated AOIs).

Two variables were taken into consideration in this analysis: fixation time (*i.e.* sum of fixation durations inside each AOI, in milliseconds), and sequence (*i.e.* order of fixations into the AOIs, with lowest entry time corresponding to first in sequence).

As in Study 2, we expected some car features to elicit more attention than others. More specifically, that the logo would be looked at first, as well as elicit more and longer fixations compared to all the other car features, during the 30s of picture presentation.

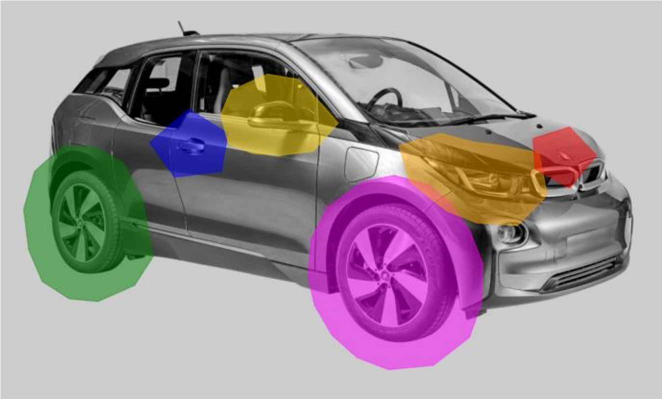

Figure 19. Example of a stimulus with the 6 post-defined AOIs: logo (in red), right headlight (in orange), right rear-view mirror (in yellow), right front door handle (in blue), right front wheel (in pink), and right back wheel (in green).

Ambient/focal visual attention towards car exterior design. In this analysis, we were interested in studying the dynamics of gaze behaviour, and if/how these dynamics changed according to the car's shape or category of universal decoder of car styling. In order to do so, we used the coefficient *K*, which takes into consideration how the fixation duration and saccade amplitude ratio changes over time (Krejtz et al., 2016). If the coefficient *K* is close to zero, this means there is a relative similarity between fixation duration and saccade amplitude, if the coefficient *K* is positive, this means participants performed longer fixation durations followed by shorter saccade amplitudes, which translates into *focal* visual attention. Finally, if the coefficient *K* is negative, this means participants performed shorter fixation durations followed by longer saccades, which suggests the occurrence of *ambient* visual attention. In terms of what to expect in the present experiment, we can expect *ambient* attention to occur at the beginning of the picture presentation, since usually participants are able to get the main idea of the visual content, or what is commonly referred to the "gist" of the content very quickly even under brief exposures (Hafri et al., 2013; Potter, 1975; Rasche & Koch, 2002).

Procedure.

The procedure of the present study was similar to the one of Study 2. After signing the consent form, and filling a questionnaire to assess the general level of liking for cars (see Appendix 7), and listing former owned cars, participants were given the E4 bracelet. The RED SMI 120 was placed 4.5m away from the 4k screen, and participants stepped on the force plate in front of the eye tracking system. After calibration (of the E4 bracelet, force plate and eye tracking system), participants were invited to perform a free-viewing task with the same characteristics as the one of Study 2. The stimuli were presented in a pseudorandomized fashion, with a pause after the presentation of the first 6 car pictures. After the completion of the free-viewing task, participants replied to a liking questionnaire on a computer (see Appendix 11). The questionnaire was made with Limesurvey.

5.3. Results.

Data extraction and analysis were performed with the help of Matlab 2015b (MathWorks, Natick, MA), Begaze (version 3.7; SMI, 2017), as well as SPSS Statistics version 23 (IBM Corp, 2015). An alpha level of 0.05 was used throughout the data analysis.

Physiological and subjective responses to different car categories.

Mean skin conductance response, and mean heart rate (the difference between the 30s of picture presentation and the 2s prior to the car picture presentation, corresponding to the baseline) were measured. To avoid negative values in terms of skin conductance response and heart rate, a correction was made by using Venables and Christie's (1980) formula of y = log (1+x), but adding 2 instead of the proposed 1, which was necessary to make all values positive (Field, 2009, p. 155). Pupil size was also analysed (the difference between the first 5s of picture presentation and the 2s prior to the car picture presentation, corresponding to the baseline), during the first 5s of picture presentation. Due to technical problems, no data from the force plate could be explored nor analysed, hence this analysis was discarded. Lastly, we also considered the questionnaire results, in the form of an Osgood differential scale composed by 5 pairs of antonyms. Participants had to evaluate on each car exterior design according to 5 different pairs of antonyms: beautiful-ugly, soft-aggressive, pleasant-unpleasant, modern-classic, sophisticated-basic (the original questionnaire was in French). The scores were numerated from 1 to 7, with the order of each pair-naming here corresponding to the end of each scale. For the reasons already stated above, two repeated-measures ANOVAs were performed, one for the height category, and other for the outline category. As main effects are not interpretable, this analysis focused solely on the interaction effects.

Car shape analysis. Due to the restrict number of stimuli per specific shape (namely the existence of only one stimulus corresponding to a low and angular car shape), shape analysis was made by comparing height and outline independently. Hence, paired-samples T test were performed to compare high and low cars, as well as curved and angular cars in terms of mean skin conductance response, heart rate, and pupil size (see Table 13 and Table 14 for height and outline statistics, respectively). No significant differences were found among all considered measures for both height and outline shapes, with the exception of pupil size in the outline comparison, t (28) = 2.71, p = .01. Participants showed a significantly bigger pupil when visually exploring curved designs in comparison to angular designs.

Table 13. T-test results comparing low and high cars regarding mean skin conductance response, heart rate, and pupil size.

	Car Height			
	Low	High		
Variables	Mean (SD)	Mean (SD)	*t*	*p*
Skin conductance	.304 (.019)	.303 (.025)	.35	.72
Heart rate	.354 (.112)	.341 (.068)	.66	.51
Pupil size	48.74 (1.48)	48.46 (1.45)	1.65	.11

Note: Skin conductance and heart rate are presented in log values, but were originally recorded in microsiemens and beats per minute, respectively. Pupil size is presented in pixels.

Table 14. T-test results comparing curved and angular cars regarding skin conductance response, mean heart rate, and pupil size.

	Car Outline			
	Curved	Angular		
Variables	Mean (SD)	Mean (SD)	*t*	*p*
Skin conductance	.304 (.018)	.302 (.029)	.47	.65
Heart rate	.345 (.084)	.349 (.096)	-.19	.85
Pupil size	48.74 (1.47)	48.34 (1.46)	2.71	.01

Note: Skin conductance and heart rate are presented in log values, but were originally recorded in microsiemens and beats per minute, respectively. Pupil size is presented in pixels.

Regarding the questionnaire and car height analysis, Mauchly's test indicated that the assumption of sphericity was violated, χ^2 (9) = 38.48, $p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .66$). The analysis of variance showed a significant interaction effect between car height and the measured dimensions, *F* (2.64, 87.20) = 11.18, $p < .001$, $\eta^2_p = .25$. Pairwise comparisons with Bonferroni corrections showed that low and high car designs differed significantly regarding the dimensions of beautiful-ugly ($p < .001$), soft-aggressive ($p < .001$), and pleasant-unpleasant ($p = .001$; see Table 15 for mean values). See Table 15 for descriptive statistics, and Figure 20 for the semantic differential chart.

Table 15. Descriptive statistics per car height and mean scores of the questionnaire.

	Car Height	
	Low	High
Variables	Mean (SD)	Mean (SD)
beautiful-ugly	3.22 (.122)	4.11 (.139)
soft-aggressive	3.20 (.149)	4.35 (.105)
pleasant-unpleasant	3.16 (.171)	3.97 (.138)
modern-classic	3.63 (.148)	3.58 (.155)
sophisticated-basic	3.68 (.167)	3.76 (.163)

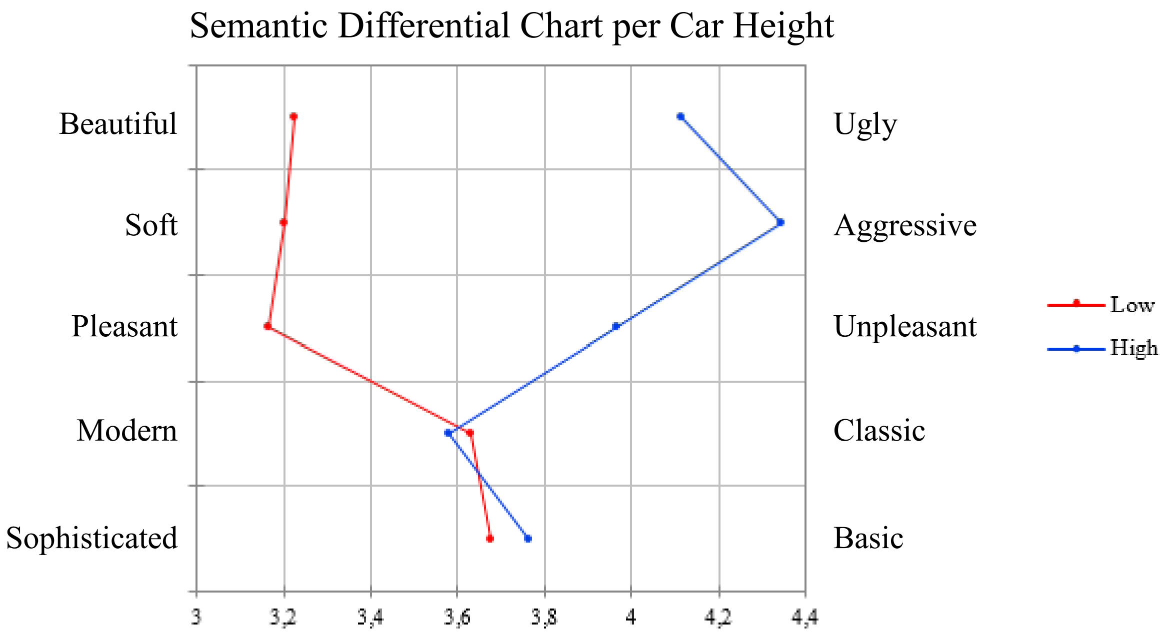

Figure 20. Profile of car height, taking into consideration each measured dimension of the Osgood semantic differential scale.

Concerning the questionnaire and car outline analysis, Mauchly's test indicated that the assumption of sphericity was violated, χ^2 (9) = 45.04, p < .001, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .65). There was a significant interaction effect between car outline and the measured dimensions, F (2.60, 85.80) = 8.24, p < .001, η^2_p = .27. Pairwise comparisons with Bonferroni corrections showed that curved and angular car designs differed significantly regarding the dimensions of beautiful-ugly (p < .001), soft-aggressive (p < .001), pleasant-unpleasant (p < .001), modern-classic (p < .001), and sophisticated-basic (p < .001; see Table 15 for mean values). Check Table 16 for descriptive statistics, and Figure 21 for profiles of curved and angular shapes concerning the questionnaire's dimensions.

Table 16. Descriptive statistics per car outline and mean scores of the questionnaire.

	Car Outline	
	Curved	Angular
Variables	Mean (SD)	Mean (SD)
beautiful-ugly	3.34 (.085)	4.30 (.161)
soft-aggressive	3.51 (.124)	4.37 (.102)
pleasant-unpleasant	3.29 (.117)	4.12 (.181)
modern-classic	3.17 (.106)	4.22 (.187)
sophisticated-basic	3.35 (.124)	4.26 (.187)

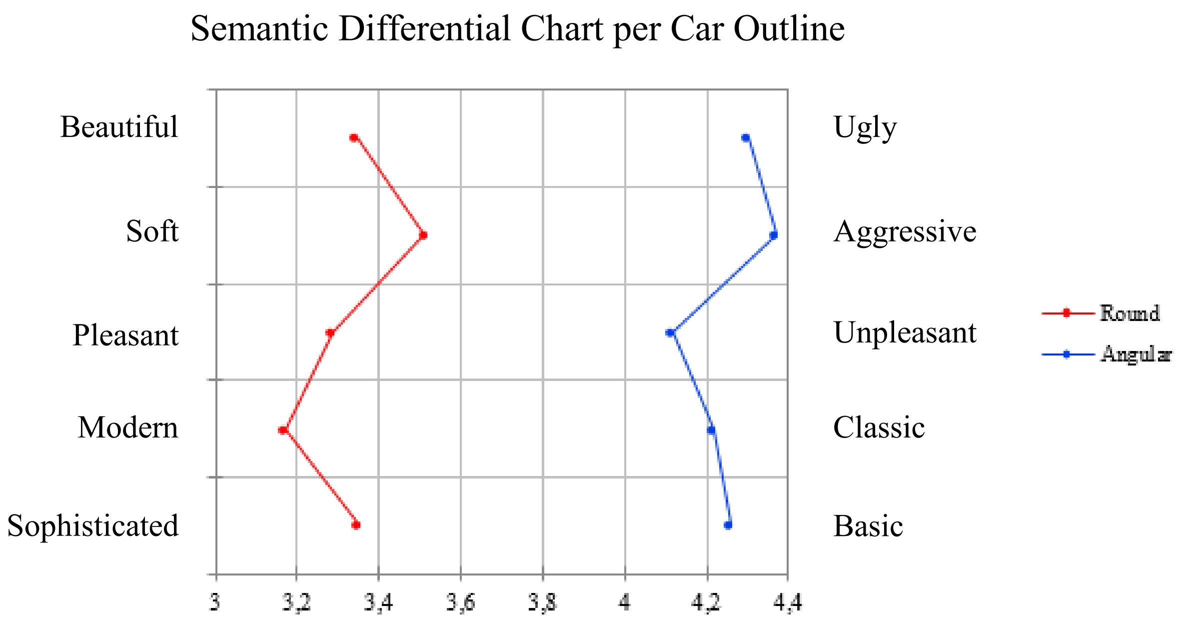

Figure 21. Profile of car outline, taking into consideration each measured dimension of the Osgood semantic differential scale.

Universal decoder of car styling analysis. In this experiment, only three categories of the universal decoder of car styling were chosen considering the liking questionnaire from Study 2: BO (the most liked category), P (a rather neutral category), and T (the most disliked category). A repeated measures ANOVA was performed for each measure as a dependent variable, with the within-subject factor of the universal decoder of car styling (BO; P; T). Table 17 presents the descriptive statistics of the considered measures.

Table 17. Descriptive statistics for the variables of skin conductance, heart rate, and pupil size, considering the universal decoder of car styling.

	BO	P	T
Variables	Mean (SD)	Mean (SD)	Mean (SD)
Skin conductance	.303 (.003)	.305 (.004)	.302 (.005)
Heart rate	.385 (.015)	.319 (.025)	.337 (.019)
Pupil size	48.73 (1.45)	48.68 (1.50)	48.31 (1.46)

Note: Skin conductance is presented in microsiemens, heart rate in beats per minute, and pupil size is presented in pixels.

Concerning skin conductance response, Mauchly's test indicated that the assumption of sphericity was respected, χ^2 (2) = .73, p = .70. The results show that there were no significant changes of skin conductance response regarding the universal decoder category, F (2, 66) = .22, p = .73, η^2_p = .70.

Regarding mean heart rate, Mauchly's test indicated that the assumption of sphericity was violated, χ^2 (2) = 10.07, p = .006, therefore degrees of freedom were corrected using Hynh-Feldt estimates of sphericity (ε = .79). There were no significant differences in terms of mean heart rate among car categories, F (1.64, 54.12) = 2.94, p = .07, η^2_p = .08.

When considering mean pupil size, Mauchly's test indicated that the assumption of sphericity was respected, χ^2 (2) = 4.50, p = .10, with the performed repeated measures ANOVA showing no significant results regarding the universal decoder of car styling, F (2, 56) = 1.61, p = .21, η^2_p = .05.

Finally, regarding the dimensions of the questionnaire given at the end of the free-viewing task, Mauchly's test indicated that the assumption of sphericity was violated, χ^2 (35) = 83.69, p < .001, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .61). There was a significant interaction effect between the universal decoder of car styling and the measured dimensions, F (4.88, 161.02) = 10.14, p < .001, η^2_p = .23. Check Table 18 for the mean scores per car category and measured dimension. Pairwise comparisons with Bonferroni corrections are described in Table 19, and showed how all car categories differed significantly among them for all the measured dimensions, with the exception of the comparison between P and T in the soft-aggressive and pleasant-unpleasant dimensions. The profile of each category of the universal decoder of car styling taking into consideration each of the measured dimensions can be observed on Figure 22.

Table 18. Descriptive statistics considering the universal decoder of car styling and mean scores of the questionnaire.

	BO	P	T
Variables	Mean (SD)	Mean (SD)	Mean (SD)
beautiful-ugly	3.11 (.123)	3.77 (.148)	4.33 (.189)
soft-aggressive	3.18 (.132)	4.00 (.147)	4.44 (.121)
pleasant-unpleasant	2.98 (.134)	3.75 (.176)	4.17 (.209)
modern-classic	3.62 (.138)	2.87 (.190)	4.32 (.211)
sophisticated-basic	3.67 (.156)	3.13 (.152)	4.37 (.210)

Table 19. Pairwise comparisons with Bonferroni corrections of the interaction effect of the measured dimension and car category.

	Pairwise comparisons		
	BO*P	BO*T	P*T
Dimension	*p* value	*p* value	*p* value
Beautiful-Ugly	.008	< .001	.05
Soft-Aggressive	< .001	< .001	N.s.
Pleasant-Unpleasant	.001	< .001	N.s.
Modern-Classic	< .001	.01	< .001
Sophisticated-Basic	.02	.006	< .001

Note: Only significant *p* values are portrayed. N.s.: non-significant.

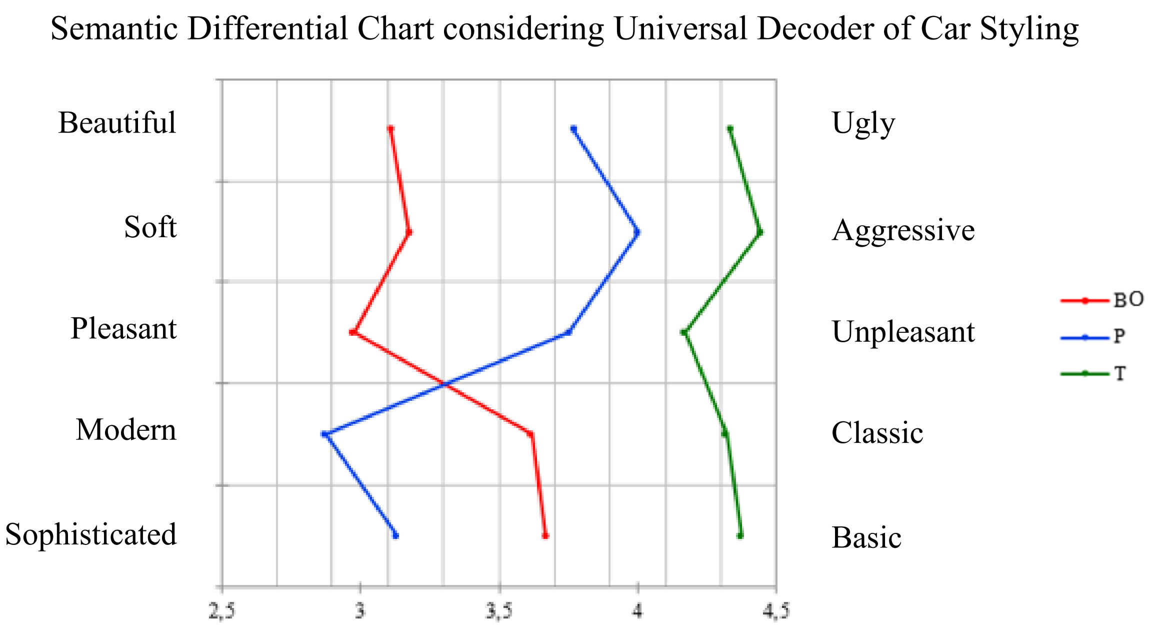

Figure 22. Profile of each universal decoder of car styling, taking into consideration each measured dimension of the applied Osgood semantic differential scale.

The impact of saliency on the visual perception of car exterior design.

This data analysis followed the exact same parameters than in Study 2. As explained in Study 2, we compared the gaze behaviour of participants to the saliency map of each car, in order to see whether participants were mostly guided by the physical characteristics of the stimuli or by higher-order processing strategies in terms of the visual exploration of each car exterior design. In the case of the former, the ROC score will be high (*i.e.* high similarity between where people were expected to look at – the salient areas –, and where people actually looked at), being associated to a more important bottom-up processing, while in the latter case, the ROC score will be low (*i.e.* high dissimilarity between where people were expected to look at, and where people actually looked at), which is translated into a more important top-down processing. The presented analysis refers to car shape, and the universal decoder of car styling.

Car shape analysis. In the shape analysis, two repeated measures ANOVAs were done, one with the within-subject factor of height (low, high), and other with the within-subject factor of outline (curved, angular). In both analyses of variance, the time block of the ROC *z* scores were also considered as a within-subjects factor, similarly to Study 2 (ROC5, ROC10, ROC15). Table 20 presents the descriptive statistics of the considered measures for car height, and Table 21 for car outline.

Table 20. Mean ROC *z* scores for the first 15 seconds of picture presentation regarding car height.

	Car Height	
	Low	High
ROC *z* scores	Mean (SD)	Mean (SD)
ROC5	.235 (.054)	-.152 (.042)
ROC10	.203 (.066)	-.145 (.047)
ROC15	.161 (.052)	-.099 (.039)

Regarding the saliency analysis and car height, there was a significant effect of car height, F (1, 28) = 33.42, p < .001, η^2_p = .54, where low cars (M = .220, SD = .032) evoked significantly higher ROC *z* scores compared to high designs (M = -.132, SD = .026). Regarding the effect of time, Mauchly's test indicated that the assumption of sphericity was respected, χ^2 (2) = .82, p = .66, therefore there was no need to correct the degrees of freedom. The effect of time was not statistically significant, F (2, 56) = .48, p = .62, η^2_p = .02, meaning scores stayed constant over time. Finally, in the interaction effect between saliency and time, Mauchly's test indicated that the assumption of sphericity was respected, χ^2 (2) = 2.54, p = .28. The interaction effect did not reach statistical significance, F (2, 56) = .43, p = .66, η^2_p = .01.

Concerning the car outline and saliency analysis, there was a significant main effect of car outline, F (1, 28) = 49.62, p < .001, η^2_p = .64, with angular cars (M = -.254, SD = .039) evoking significantly lower ROC *z* scores than curved designs (M = .192, SD = .025). Mauchly's test on the time effect indicated that the assumption of sphericity was respected, χ^2 (2) = .534, p = .77, with no significant effect of time occurring, F (2, 56) = .80, p = .46, η^2_p = .03. Finally, in terms of the analysis of the interaction between saliency and car outline, Mauchly's test indicated that the assumption of sphericity was respected, χ^2 (2) = 2.61, p = .27, with no significant statistical differences being found, F (2, 56) = 1.70, p = .19, η^2_p = .06.

Table 21. Mean ROC *z* scores for the first 15 seconds of picture presentation regarding car outline.

	Car Outline	
	Curved	Angular
ROC *z* scores	Mean (SD)	Mean (SD)
ROC5	.258 (.037)	-.338 (.055)
ROC10	.150 (.041)	-.209 (.058)
ROC15	.168 (.049)	-.213 (.071)

Universal decoder of car styling analysis. In this analysis, one repeated measures ANOVA was performed considering the within-subject factor of universal decoder (3 categories: BO, P, and T), as well as time (ROC5, ROC10, ROC15).

In terms of main effect of universal decoder, Mauchly's test indicated that the assumption of sphericity was respected, χ^2 (2) = 2.93, *p* = .23. The main effect of universal decoder was statistically significant, *F* (2, 56) = 33.18, *p* < .001, η^2_p = .54, with all categories differing significantly from one another (see Table 22).

Table 22. Mean ROC *z* scores for the first 15 seconds of picture presentation regarding the universal decoder of car styling.

	Universal decoder of car styling		
	BO	P	T
ROC *z* scores	Mean (SD)	Mean (SD)	Mean (SD)
ROC5	.129 (.076)	.331 (.074)	-.432 (.069)
ROC10	.102 (.066)	.220 (.074)	-.321 (.077)
ROC15	.060 (.083)	.213 (.073)	-.326 (.080)

In terms of the main effect of time, Mauchly's test indicated that the assumption of sphericity was respected, χ^2 (2) = .75, p = .69, with no significant difference being found, F (2, 56) = 1.00, p = .37, η^2_p = .03. Finally, Mauchly's test for the interaction between time and the universal decoder indicated that the assumption of sphericity was respected, χ^2 (9) = 8.46, p = .49, with no interaction effect having occurred, F (4, 112) = .53, p = .71, η^2_p = .02.

The relevancy of specific features on the visual exploration of car exterior design.

In this analysis, we aimed at comparing gaze metrics among the cars regarding six car features: the logo, front wheel, back wheel, rear-view mirror, right headlight, and the right front handle. The nomenclature of *right* was defined according to the driver's perspective. It is also convenient to remember that all the cars were presented in the same position, *i.e.* front of the car facing the right direction, with visible front and side of the car. Repeated measures ANOVAs were performed for both sequence (*i.e.* order of gaze hits into the areas of interest based on entry time average, with the lowest entry time average meaning first in sequence), and fixation time (*i.e.* sum of all fixation durations for that area of interest; in milliseconds). The cars' features (logo, front wheel, back wheel, rear-view mirror, right headlight, right front handle) were considered as a within-subject factor, along with height (*i.e.* low and high), and outline (*i.e.* curved and angular), as well as the universal decoder of car styling (*i.e.* BO, P, and T categories). Regarding the sequence of fixations, missing data was treated by applying the maximum value of the sequence plus one (which in this case was seven). Concerning fixation time, since car features were established as free-hand areas of interest, they did not have the same size. Therefore, fixation time was divided by the area of the equivalent area of interest. The 30 seconds of picture presentation were considered for the present analysis. This analysis included 29 participants.

Results’ description focuses solely on the main effect of car features, and the interaction effects between car features and the car categorizations. Main effects of car height, outline, and universal decoder of car styling were disregarded, due to lack of pertinence.

Car shape analysis. As already explained, height and outline were treated independently in this study. In terms of the sequence and height analysis, when considering the main effect of car feature, Mauchly’s test showed that the assumption of sphericity was violated, χ^2 (14) = 37.45, p < .001, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .59). A main significant effect of car feature occurred, F (2.95, 82.58) = 15.06, p < .001, η^2_p = .35. Pairwise comparisons with Bonferroni corrections revealed that participants looked significantly first at the logo compared to the front handle (p = .001) and back wheel (p = .001). Participants also significantly faster to the right headlight in comparison with the front door handle (p < .001), and both the front (p = .001) and back wheels (p < .001). Participants also looked significantly faster towards the rear-view mirror compared to the front door handle (p < .001), and the back wheel (p < .001). Finally, participants also significantly looked first at the front wheel than at the front door handle (p = .05). Regarding the interaction effect, Mauchly’s test showed that the assumption of sphericity was respected, χ^2 (14) = 14.96, p = .38. There was no significant effect of interaction between car feature and car height, F (5, 140) = .31, p = .90, η^2_p = .01. See Table 23 for mean values.

Table 23. Descriptive statistics of fixation sequence for the considered specific car features for the 30s of picture presentation.

	Car height	
	Low	High
Car features	Mean (SD)	Mean (SD)
Logo	3.12 (.17)	3.32 (.22)
Front wheel	3.71 (.14)	3.79 (.14)
Back wheel	4.26 (.15)	4.15 (.10)
Rear-view mirror	3.06 (.20)	3.16 (.19)
Right headlight	2.83 (.21)	2.90 (.20)
Right front handle	4.54 (.19)	4.58 (.19)

In terms of fixation time and car height, regarding the main effect of car feature, Mauchly's test showed that the assumption of sphericity was violated, χ^2 (14) = 147.75, p < .001, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .33). A main significant effect of car feature occurred, F (1.64, 45.99) = 15.51, p < .001, η^2_p = .36. Pairwise comparisons with Bonferroni corrections revealed that participants spent significantly more time looking at the logo compared to the right headlight, front wheel, and back wheel (p < .001, in all cases). Participants also spent significantly more time looking at the rear-view mirror compared to the right headlight (p = .007), front door handle (p = .01), front wheel (p = .002) and back wheel (p = .004). Lastly, participants also significantly looked longer at the front door handle compared to both front (p = .005) and back wheels (p = .02). In the interaction effect between car features and car height, Mauchly's test showed that the assumption of sphericity was violated, χ^2 (14) = 89.62, p < .001, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .54), with the interaction effect not being statistically significant, F (2.72, 76.06) = 2.42, p = .08, η^2_p = .08. See descriptive statistics in Table 24.

Table 24. Descriptive statistics of fixation duration for the considered specific car features for the 30s of picture presentation.

	Car height	
	Low	High
Car features	Mean (SD)	Mean (SD)
Logo	.0119 (.0014)	.0115 (.0013)
Front wheel	.0039 (.0005)	.0034 (.0005)
Back wheel	.0043 (.0005)	.0045 (.0004)
Rear-view mirror	.0164 (.0028)	.0135 (.0021)
Right headlight	.0049 (.0006)	.0052 (.0007)
Right front handle	.0070 (.0009)	.0076 (.0008)

Regarding car outline and the sequence of fixations analysis, in the main effect of car feature, Mauchly's test showed that the assumption of sphericity was violated, χ^2 (14) = 38.47, p < .001, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .60). The main effect was significant, F (3.01, 84.19) = 14.20, p < .001, η^2_p = .34, with pairwise comparisons with Bonferroni corrections showing the same significant differences already described in the car height analysis. In terms of the interaction effect between car feature and car outline, Mauchly's test showed that the assumption of sphericity was respected, χ^2 (14) = 16.77, p = .27. There was no significant interaction effect, F (5, 140) = 1.84, p = .11, η^2_p = .06. See Table 25 for mean values.

Table 25. Descriptive statistics of fixation sequence for the considered specific car features for the 30s of picture presentation.

	Car outline	
	Curved	Angular
Car features	Mean (SD)	Mean (SD)
Logo	3.20 (.19)	3.21 (.19)
Front wheel	3.85 (.12)	3.62 (.16)
Back wheel	4.31 (.13)	4.04 (.14)
Rear-view mirror	3.04 (.21)	3.23 (.21)
Right headlight	2.69 (.18)	3.13 (.26)
Right front handle	4.51 (.18)	4.63 (.21)

Concerning car outline and fixation time analysis, in terms of main effect of car features, Mauchly's test showed that the assumption of sphericity was violated, χ^2 (14) = 138.96, $p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .35$). A statistical significant main effect occurred, F (1.73, 48.52) = 15.69, $p < .001$, $\eta^2_p = .36$, with pairwise comparisons with Bonferroni comparisons showing the same significant differences as in the height analysis. In terms of the interaction between car features and car outline, Mauchly's test showed that the assumption of sphericity was violated, χ^2 (14) = 112.88, $p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .36$), with no occurrence of statistical significance, F (1.78, 49.79) = 1.53, $p = .23$, $\eta^2_p = .05$. Check Table 26 for mean values.

Table 26. Descriptive statistics of fixation duration for the considered specific car features for the 30s of picture presentation.

	Car outline	
	Curved	Angular
Car features	Mean (SD)	Mean (SD)
Logo	.0119 (.0013)	.0113 (.0013)
Front wheel	.0038 (.0004)	.0035 (.0004)
Back wheel	.0044 (.0005)	.0045 (.0004)
Rear-view mirror	.0160 (.0028)	.0129 (.0019)
Right headlight	.0052 (.0006)	.0050 (.0008)
Right front handle	.0074 (.0008)	.0073 (.0010)

Universal decoder of car styling analysis. In terms of sequence of fixations and universal decoder of car styling analysis, when considering the main effect of car feature, Mauchly's test showed that the assumption of sphericity was violated, χ^2 (14) = 39.68, $p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .58$). This main effect was statistically significant, F (2.91, 81.62) = 15.14, $p < .001$, η^2_p = .35, with pairwise comparisons with Bonferroni corrections showing the same statistically significant differences as described in the car height analysis. Regarding the interaction effect of car feature and universal decoder of car styling, Mauchly's test showed that the assumption of sphericity was respected, χ^2 (54) = 64.66, $p = .17$. This interaction effect was statistically significant, F (10, 280) = 1.85, $p = .05$, $\eta^2_p = .06$. Besides seeing the replication of the overall car feature effect, more interestingly participants looked significantly faster to the front wheel in the P category than to the front wheel in the BO category ($p = .04$; for the mean values see Table 27).

Table 27. Descriptive statistics of fixation sequence for the considered specific car features for the 30s of picture presentation.

	Universal decoder of car styling		
	BO	P	T
Car features	Mean (SD)	Mean (SD)	Mean (SD)
Logo	2.86 (.19)	3.42 (.24)	3.42 (.24)
Front wheel	4.03 (.15)	3.54 (.17)	3.70 (.18)
Back wheel	4.34 (.14)	4.24 (.17)	4.02 (.15)
Rear-view mirror	2.97 (.21)	3.14 (.22)	3.25 (.22)
Right headlight	2.88 (.21)	2.61 (.21)	3.12 (.27)
Right front handle	4.63 (.21)	4.49 (.24)	4.57 (.22)

Regarding the analysis of fixation time, and more specifically the main effect of car features, Mauchly's test showed that the assumption of sphericity was violated, χ^2 (14) = 144.22, p < .001, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .33). A main significant effect of car features occurred, F (1.67, 46.67) = 15.65, p < .001, η^2_p = .36, with pairwise comparisons with Bonferroni corrections showing the same statistical differences as firstly stated in the height analysis. Regarding the interaction effect of car features and universal decoder of car styling, Mauchly's test showed that the assumption of sphericity was violated, χ^2 (54) = 285.07, p < .001, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .27). No significant interaction effect occurred, F (2.71, 75.76) = 2.44, p = .08, η^2_p = .08. See descriptive statistics in Table 28.

Table 28. Descriptive statistics of fixation duration for the considered specific car features for the 30s of picture presentation.

	Universal decoder of car styling		
	BO	P	T
Car features	Mean (SD)	Mean (SD)	Mean (SD)
Logo	.0101 (.0012)	.0141 (.0018)	.0108 (.0013)
Front wheel	.0036 (.0004)	.0040 (.0005)	.0034 (.0004)
Back wheel	.0047 (.0005)	.0041 (.0004)	.0045 (.0005)
Rear-view mirror	.0167 (.0030)	.0153 (.0029)	.0122 (.0019)
Right headlight	.0045 (.0006)	.0058 (.0006)	.0050 (.0008)
Right front handle	.0068 (.0009)	.0079 (.0008)	.0076 (.0011)

Ambient/focal visual attention towards car exterior design.

As previously stated, with this analysis, we were interested in studying the dynamic of the participants' visual attention towards car exterior design. In order to do so, we applied the coefficient *K* methodology (Krejtz et al., 2016, 2017). According to the values of *K*, we can associate a certain time frame to a certain type of visual attention being at play. While positive values of *K* are associated to the occurrence of longer fixations followed by shorter saccade amplitudes, meaning *focal* attention, negative values of *K* are associated to shorter fixations followed by relatively longer saccades, meaning *ambient* attention. The coefficient *K* was calculated per participant, and per car picture, by "subtracting the standardized fixation duration from the standardized amplitude of the subsequent saccade" (Krejtz et al., 2017).

Car shape analysis. In the shape analysis, two repeated measures ANOVAs were done, one with the within-subject factor of height (low, high), and other with the within-subject factor of outline (curved, angular). In both analyses of variance, time was considered as a within-subjects factor (5s, 10s, 15s, 20s, 25s). In terms of the height analysis, and more specifically regarding the main effect of time, Mauchly's test showed that the assumption of sphericity was violated, χ^2 (9) = 29.05, p < .001, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .69). A main significant effect of time occurred, F (2.77, 77.46) = 31.28, p < .001, η^2_p = .53, with pairwise comparisons with Bonferroni corrections showing a significant difference regarding the first block of 5s compared to all the other time blocks (p < .001 in all cases), and a significant difference also between the 10s block and the 20s block (p = .04). The main effect of height was not statistically significant, F (1, 28) = .007, p = .80, η^2_p = .002. Finally, in terms of the interaction effect between height and time, Mauchly's test showed that the assumption of sphericity was respected, χ^2 (9) = 11.38, p = .25. The interaction effect lacked of statistical significance, F (4, 112) = 1.72, p = .15, η^2_p = .06. See Table 29 for mean values.

Table 29. Mean coefficient *K* data for each of block of 5 seconds of picture presentation regarding car height.

	Car Height	
	Low	High
Time block	Mean (SD)	Mean (SD)
5 seconds	-.472 (.055)	-.353 (.044)
10 seconds	-.096 (.042)	-.103 (.048)
15 seconds	-.055 (.043)	-.024 (.049)
20 seconds	.057 (.048)	-.011 (.075)
25 seconds	.065 (.058)	.038 (.042)

In terms of the outline analysis, the main effect of time also occurred, as in stated in the height analysis. The main effect of outline did not reach statistical significance, F (1, 28) = .19, p = .66, η^2_p = .007. Finally, regarding the interaction effect between outline and time, Mauchly's test showed that the assumption of sphericity was respected, χ^2 (9) = 12.30, p = .20. This interaction effect was not statistically significant, F (4, 112) = 1.24, p = .29, η^2_p = .04. Check Table 30 for mean values.

Table 30. Mean coefficient ***K*** data for each of block of 5 seconds of picture presentation regarding car outline.

	Car Outline	
	Curved	Angular
Time block	Mean (SD)	Mean (SD)
5 seconds	-.423 (.040)	-.373 (.051)
10 seconds	-.091 (.034)	-.113 (.056)
15 seconds	-.019 (.040)	-.062 (.052)
20 seconds	.009 (.050)	.030 (.074)
25 seconds	.084 (.052)	.001 (.047)

Universal decoder of car styling analysis. In this analysis, one repeated measures ANOVA was performed considering the within-subject factor of universal decoder (3 categories: BO, P, T), as well as time (5s, 10s, 15s, 20s, 25s). Regarding the effect of time, it was also statistically significant, as stated in the height analysis. In terms of the universal decoder of car styling main effect, Mauchly's test showed that the assumption of sphericity was violated, χ^2 (2) = 25.23, p < .001, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .62). This main effect was not statistically significant, F (1.24, 34.84) = .59, p = .48, η^2_p = .02. Finally, in terms of the interaction effect of universal decoder of car styling and time, Mauchly's test showed that the assumption of sphericity was respected, χ^2 (35) = 38.09, p = .34. This interaction effect was statistically significant, F (8, 224) = 1.98, p = .05, η^2_p = .07. Pairwise comparisons with Bonferroni corrections showed how for each car category, the first block of 5s was significantly different than all the other time blocks (p = .001, for all). In the P category, the 10s block also differed statistically from the 20s block (p = .008). In the 5s block, there was a significant difference between the BO and T categories (p = .05), whereas in the 10s block there was a statistically significant difference between the BO and P categories (p = .03). Check Table 31 for mean values.

Table 31. Mean coefficient ***K*** data for each of block of 5 seconds of picture presentation regarding the universal decoder of car styling.

	Universal decoder of car styling		
	BO	P	T
Time block	Mean (SD)	Mean (SD)	Mean (SD)
5 seconds	-.462 (.057)	-.426 (.057)	-.319 (.067)
10 seconds	-.043 (.044)	-.186 (.047)	-.072 (.075)
15 seconds	.011 (.058)	-.056 (.039)	-.067 (.066)
20 seconds	.006 (.056)	.024 (.056)	.023 (.094)
25 seconds	.129 (.058)	.005 (.070)	.015 (.042)

5.4. Discussion.

In this final study, we wanted to study the potential impact of contextual factors on the visual perception of car exterior design, namely the potential impact of stimuli size on the participants' experience. By using car photographs especially taken to be displayed in a 4x2m

4k screen, we were hoping to provide participants a closer-to-reality experience, as well as to unveil more fine-grained details about each car exterior design that would otherwise not be perceptible if displayed on a common computer screen. Could these contextual changes have an impact on the participants' perception of car exterior design? Firstly, in order to understand the participants' core affect and subjective experiences, we measured skin conductance responses, mean heart rate and pupil size, and provided participants with an Osgood' semantic differential questionnaire. Secondly, we focused on gaze behaviour analyses. By studying the impact of visual saliency, we hoped to understand the role of bottom-up and top-down influences on the visual perception of different car exterior designs. By studying the amount of attention given to different car features, we hoped to gain useful easy-to-use information to designers. Finally, by comparing scanpath sequences among participants per car picture, we hoped to gain insight on the dynamics of the visual exploration, and the type of attentional engagement elicited by car exterior design. In all of these analyses, we were interested in comparing perception in terms of car shape (height, and outline), and universal decoder of car styling (BO, P, T).

In terms of *psychophysiological and subjective responses*, there were no differences in terms of skin conductance response, nor heart rate response regarding both car shape and the universal decoder of car styling. In terms of pupil size, only curved designs evoked a bigger pupil dilation than angular designs. Finally, the statistical analysis of the semantic differential showed how discriminant this methodology can be. Low shapes were considered more beautiful, softer, and more pleasant compared to high designs (*i.e.* uglier, more aggressive, and more unpleasant). Curved shapes were also considered more beautiful, softer, more pleasant, more modern, and more sophisticated compared to angular designs (*i.e.* uglier, more aggressive, more unpleasant, more classic, and more basic). In terms of universal decoder of car styling, BO designs were overall considered more beautiful, softer, and more pleasant compared to P and T designs. Moreover, BO designs were considered more classic and more basic than P, but more modern and more sophisticated than T designs.

Contrary to former findings on the manipulation of stimuli size (Codispoti & De Cesarei, 2007; Reeves et al., 1999), no differences were found among psychophysiological data regarding car shape nor universal decoder of car styling. However, these contradictory findings may be explained by the simple fact that in the present study we focused in comparing car shapes and categories shown in the same display (4k screen of 4x2m). Furthermore, whereas these other studies focusing on stimulus size used extremely emotional visual stimuli, we focused on showing car pictures, which – as shown in Study 1 –, can be thought of stimuli rich in meaning and hedonic valence, but with no biological significance. This is further justified by Byron Reeves and colleagues' work (1999), who found that bigger screens will increase ANS activation when the pictures themselves are extremely activating. Moreover, in these other experiments, participants were asked to rate the content right after its exposure, which meant there was some level of motor activation happening. This joins the discussion of Study 2, with the proposition that the fact that the present task was a passive one could explain the lack of enough ANS activation to reach statistical significance (Mendes, 2009). The posture of participants was also different in the present study: participants were standing up during picture presentation. The lack of peripheral activation may be explained by the simple fact that peripheral physiological activity varies as a function of the somatic involvement and following metabolic support (Bradley & Lang, 2007). Finally, Osgood's differential scale (*vs.* Likert-scale questionnaires in Studies 1 and 2) allowed us to gain more detailed information about what participants thought of different car exterior designs, and hence seems to us a good option to use for future studies.

In terms of the *impact of saliency* in the visual exploration of car exterior design, high designs, and angular designs were more prone to top-down influences whereas low designs, and curved designs were more prone to bottom-up influences. In terms of the universal decoder of car styling categories, the T category elicited the most top-down processing from all the considered categories, whereas the P category was the most prone to bottom-up influences, with the BO category in the middle. Moreover, these processing influences were stable in time. In Study 2, we saw how low shapes, and angular shapes, and specifically the low and angular shape evoked strong bottom-up influences in its visual processing. At the time we justified this by the perceived exacerbation of the acute angles due to the size of the stimuli, and wondered if the size of the stimuli could have contributed to the occurrence of bottom-up processing. And indeed, by taking into consideration the results of the present study, it seems that it does. In the present study, low shapes continued to evoke bottom-up influences, but angular shapes evoked top-down influences. We posit that, by augmenting the size of the stimuli, the perception of more acute angles became more "diluted", hence giving space for more top-down influences to occur. Moreover, low shapes, along with angular shapes, and the T category were considered overall uglier and more unpleasant, and they also evoked more top-down influences, which goes in line with literature on the importance of the interest-factor (*vs.* pleasantness factor) in the aesthetic experience (Berlyne, 1972, 1973). The fact that in the present study curved designs elicited more bottom-up influences was surprising. As previously discussed in Study 2, curved designs would be the ones evoking an experience that would be the most similar to an aesthetic one. Then why do they seem to evoke more bottom-up processing in the current study? Looking at the saliency maps (Appendix 12), overall the pictures of curved shaped cars had more and stronger salient characteristics (e.g.: BMW i3) than the angular shaped cars (e.g.: Skoda Yeti), which may have had an impact on the participants' visual processing. Moreover, when looking back at the saliency maps of Study 2 (Appendix 5), we see that indeed the saliency maps were more homogeneous among car models, thus supporting our hypothesis. Even though this discussion is valid, one should keep in mind that Study 2 and the present study are not directly comparable due to methodological differences, and hence further studies should be considered in order to really understand whether visual processing influences may change according to context characteristics such as stimuli size, participants' posture, the pictures used as stimuli, and mode of display.

In terms of the *importance of car features*, this was the analysis with the most potential influence on the automotive industry and designers, since it can have a direct impact of production costs (Du & MacDonald, 2014). In the current analysis, we were interested in understanding whether some car features captured more attention than others, and we were hoping to discern potential differences among car shape and categories. Regarding the latter, only one result was statistical significant, in which participants looked consistently first at the front wheel of cars of the BO category than at the front wheel of cars of the P category. Overall, participants looked at the front headlight first, but paradoxically did not spend a lot of time looking at that car feature. The two prominent features being looked at earlier, and spending more time being explored (*i.e.* fixation duration) were the logo and the rear-view mirror. Again, we attribute the attention given to the logo due to its undeniable role in the identification of the object (*i.e.* checking which brand the car is, in order to give information about which car the viewer is looking at). The attention given to the rear-view mirror may be justified by the fact that it is the feature spatially located closer to the centre of the screen.

In terms of the *ambient/focal visual attention* analysis, we focused on understanding whether different car shapes or categories could elicit a particular phenomenon of visual attention when taking into consideration comparisons of gaze behaviour. Our experiment showed that even though in the universal decoder of car styling there were some statistical differences among car categories and time blocks, the type of visual attention engaged stayed the same. Overall, a common pattern of gaze behaviour among participants occurred: at first, there was a more ambient processing at play, which started to fade with time, until after the first 15 seconds of picture presentation, where participants toppled over a more focal processing that developed with time. This goes in line with the expected results, since viewers commonly tend to strategically take upon a more ambient processing in the beginning in order to understand the main idea or gist of the content, and only afterwards focus on the details of the content being presented to them (Hafri et al., 2013; Potter, 1975; Rasche & Koch, 2002).

Due to the number of participants and number of stimuli used, it was not possible to expose participants to the cars in real life. However, since changing the size of the stimuli had consequences on the visual perception of car exterior design, one could hypothesize – in future studies – about the potential impact of actually seeing the car designs in real life. This approach seems relevant when considering how the neural mechanisms involved in processing real objects and pictures of those objects may be different (Snow et al., 2011), and how our preference to look at real objects instead of their equivalent in pictures occurs even as infants (Gerhard et al., 2016). If presenting cars in real life is still not a viable option due to methodological choices, a worthy halfway proposal would be the use of 3D display. Due to the fact that head-mounted displays visually isolate the subject from their surroundings, a more natural approach to 3D display of car exterior design would be the use of more complex and large devices, such automatic virtual environments (Mestre, 2017), or even a structure like the 4k screen used in the present study. However, since there is not a "one size fits all" formula, the adequacy of which system to use still depends on the task that the subject will have to perform (Mestre, 2018). Moreover, the use of more immersive systems would allow us to bring other factors to the study of the consumer experience, such as distance perception and spatial categorisation (Coello & Delevoye-Turrell, 2007; Iachini et al., 2014).

Another relevant aspect to keep in mind is the notion of movement. Here, we tried to provide an experience to participants as close to reality as possible. However, in the end, cars are not made just to be looked at in a static way, they are made to move. Indeed, stimuli motion seems to have an impact on the activation level of participants, capturing their attention (Simons et al., 1999). Another notion to keep in mind is the effect of reading action-words on the perception of motion (Bidet-Ildei, Sparrow, & Coello, 2011), which may also be interesting as a follow-up question, especially when considering hybrid procedures (*i.e.* intercalating objective and subjective measures), and the creation of questionnaires. Therefore, it would also be interesting to see whether consumers' cognitive and attentional processes, as well as preferences may change when taking car motion into consideration.

In summary, in the present study, by augmenting the size of the stimuli to almost real-size in a 4k screen, we were able to make available details in the car design that were not perceivable in pictures of smaller scale. This choice, as well as other adaptations to the methodology (*i.e.* posture of the participants, and photographs used), brought out the importance of taking into consideration contextual factors when measuring the affective and cognitive mechanisms involved in the consumer experience.

IV General Discussion

With this thesis, we shed some light about the affective and cognitive dynamics in play in regard to the visual perception of car exterior design. The chosen experimental approach (*i.e.* psychophysiological and behavioural) has proven to provide a new and useful kind of information to be applied to the conception of car exterior design, as well as to be taken into consideration by experts in several domains, from design to aesthetics, from consumer behaviour research to cognitive sciences.

By measuring core affect responses and gaze behaviour in relation to design, we established a parallel between the visual perception of car exterior design and what outlines an aesthetic experience. In the present thesis, there were some methodological choices that also helped to allow this parallel, specifically in Studies 2 and 3, where: participants were asked to solely focus on the designs *per se* they were going to see, not considering aspects such as car brand or model, perceived quality, or purchase intentions; also, participants were asked to perform a free-viewing task. This may have encouraged them to take up on a more contemplative role during the task.

Still in relation to the methodological choices that provided participants the opportunity to enrol on a more aesthetic experience, by proposing a free-viewing task, along with a highly controlled environment, instructions (*i.e.* instructing participants to solely focus on the design being presented to them), and stimuli set (*i.e.* grey-scaled car pictures with no background or other context), we were focusing more on the potential bottom-up influences that could arise from the visual exploration of car exterior design.

With these considerations in mind, here are the most relevant findings of this thesis. When actively engaged in a task, participants were more attentive and preferred more familiar designs. There seems to be a cost regarding the perception of very innovative designs, which confirms the importance of taking into consideration the car-related *affordances* whenever creating a new design. Moreover, low shapes, as well as angular ones evoked higher arousal (Study 1), which can be attributed to the fact that these designs – such as presented in Study 1 – suppose the existence of more accentuated angles, which is associated to a sense of threat and can hence be associated to specific brain region activation, such as the amygdala (Bar & Neta, 2007). This reasoning was further supported by the findings in Study 2, where low and angular designs evoked a clear bottom-up processing, despite lack of particular sympathetic activation. Indeed, research has shown how exposure to highly negative (and positive) arousing pictures may impair top-down attention (Sutherland et al., 2017). We hypothesize that low and angular shapes were only able to evoke an emotional reaction when presented in the smallest form (*i.e.* perception of very acute angles; Study 1), whereas, in Study 2. even though the perceived angles were accentuated enough to evoke a bottom-up processing, they were not acute enough to provoke sympathetic activation (allied to a passive task). Hence, in Study 3, because we augmented stimuli size, there was a "dilution" of the perceived acuteness of the angles, which made these shapes more prone for top-down influences to occur. This last occurrence allied to the change of type of processing that occurred for curved shapes (from top-down processing in Study 2 to bottom-up processing in Study 3) highlight how sensitive viewers are to the physical characteristics of the pictures being presented to them.

There was a surprising finding still related to the analysis of the potential impact of saliency on the visual perception of car exterior design. In both Studies 2 and 3, top-down and bottom-up influences remained stable in time, and only differed according to the car shape or category. Indeed, research on visual perception (Itti & Borji, 2014; Koch & Ullman, 1985; Treisman & Gelade, 1980) sustains how in the first moments of picture presentation, viewers are more susceptible to, and visual exploration is more guided by, the most salient characteristics of the picture. However, recent research has debated this idea and shown how top-down and bottom-up influences continuously influence each other in order to orient attention (Clark, 2013; Shariatmadar & Faez, 2019), with this phenomenon also occurring when viewing artworks (Cupchik et al., 2009). Considering our current results, and the current findings on visual perception research, it is clear how top-down and bottom-up influences will have a very important impact on the visual experience of viewers, justifying thus the need to further explore this matter in the future.

As also seen in other studies (e.g.: Gómez-Puerto et al., 2018; Palumbo & Bertamini, 2016; Westerman et al., 2012), we found a consistent preference for curved designs and dislike for more angular shapes. Additionally, we were able to gain a more detailed insight on the participants' subjective experience with the Osgood differential scale compared to Likert scale questionnaires, which allowed us to better understand the affective and attentional mechanisms at play.

In this thesis, we also reiterated the major role the logo plays on the visual exploration of car exterior design, and how this car feature draws more attention than the most salient area of said picture, even at the beginning of picture presentation. Viewers are strongly drawn to looking at the logo, since it is the car feature that contains the most direct information about which car they are looking at, gaining access to all the notions related to brand heritage (Pecot et al., 2018). Even though this may seem like a trivial finding, almost like a common fact, it illustrates in a very simple way the intricacy and complexity of the interplay between top-down and bottom-up influences in visual perception. In the present work, we were also interested in finding whether specific features were paid more attention to in regard to certain car shapes or categories. This seems not to be the case: overall, the importance of certain features stayed the same independently of car shape or universal decoder of car styling.

Another result that seems to take place independently of car shape or category relates to the strategy used during picture visualization. Similarly to other studies (Hafri et al., 2013; Potter, 1975; Rasche & Koch, 2002), participants engaged firstly on a mode of ambient attention, in order to understand the main idea or "gist" of the content being presented to them, and only afterwards (in this case, 15s), did they switch to a more focal attentional mode, looking at the car designs in more detail. The overall results of the universal decoder of car styling show how this type of experimental approach may be a useful tool in order to test new or other existing forms of design categorizations.

With this thesis, we wanted to see whether it was possible to establish a parallel between looking at a car exterior design and an aesthetic experience. And indeed, in Study 2, when combining the physiological and subjective responses to the occurrence of a robust top-down processing for curved shapes, we were able to compare this overall experience to an aesthetic one for curved designs. Surprisingly, changing the form of the display of the car designs had a direct impact on how these designs were perceived, as already discussed in Study 3. In the last experiment, we saw how high shapes, and angular shapes, which were considered uglier, more aggressive and unpleasant than their counterpart ones, elicited a top-down processing. This may be explained by research on aesthetics, where viewers can not only be engaged in a visual content because they find it beautiful or pleasant, but also (and in some cases mostly) because they find it interesting (Berlyne, 1972, 1973).

It is important to place the present findings in light of the current theories of aesthetic experience. Even though research and discussions on how to define, study, and experimentally frame this experience can be traced to almost fifty years ago (Berlyne, 1972), only more recently did this topic gain a new momentum, with researchers trying to establish a comprehensive theory in order to break down all the processes and stages involved in aesthetic processing (e.g.: Chatterjee, 2003; Leder et al., 2004; Marković, 2012; Nadal et al., 2008). Even though most studies focus on the viewers’ reactions towards paintings and visual art in general, there is no doubt that the same type of mechanisms and responses can be applicable to other objects (Leder et al., 2004; Leder & Nadal, 2014; Pelowski et al., 2017), as hopefully also demonstrated in this thesis. Moreover, when considering these models, one should be aware of the suggested definitions and conceptualizations, especially when using the same terminology.

For example, some researchers place arousal as playing a crucial role in the aesthetic experience. However, different theories conceive arousal in a different way: whereas on focusing on psychophysiological arousal (as discussed by Berlyne, 1972), or focusing on ratings in subjective scales of arousal (as conceptualized in Marković, 2012; Marković & Radonjić, 2008).

In the literature review (section 1.4. Introducing aesthetics), we presented two current very comprehensive theories about the aesthetic process, one taking up on a more neuroscience approach (Chatterjee, 2003; Chatterjee & Vartanian, 2014), and the other taking up on a more psychological approach (Leder et al., 2004; Leder & Nadal, 2014) on the study of the aesthetic experience. Due to its broad integration of intermediate visual and cognitive processing in the aesthetic experience, the latter model is more relevant for the present thesis.

As suggested by this model, the aesthetic experience occurs in five main processing stages: perception, implicit memory integration, explicit classification, cognitive mastering and evaluation, and a continuing emotional evaluation. Overall, the way this model is conceptualized allows the study of the aesthetic experience in terms of the time-course and temporal order, whether stimuli presentation is masked and/or very briefly presented, or when taking into consideration the overall time of exposure to the visual content. Moreover, it allows to make a distinction and to see to what extent the aesthetic experience may change depending on the knowledge the viewer has beforehand (*i.e.* information about the painting, the artist, etc.). Because this theory delineates a series of cognitive and affective processing stages, it allows researchers to consider the role potential contextual factors may have on the aesthetic experience, which differs from the conventional approach to aesthetics where this experience is viewed as mostly unchangeable (Leder & Nadal, 2014).

Due to the cognitive and affective integration framework this model offers, it is possible to establish some parallels with our overall results. Firstly, the chosen methodology and following results allowed us to gain a perspective on the overall duration of the aesthetic experience, with participants not having access to any contextual information about the designs they were about to see. Also, by manipulating the posture of the participant and size of the stimuli, we also corroborated notion of Helmut Leder and colleagues (2004) that the aesthetic experience may indeed be highly influenced by contextual factors. Moreover, this model also predicts certain occurrences to have an impact on the aesthetic experience, such as the level of the familiarity or the prototypicality of the stimuli, both phenomena having occurred and been discussed in our first study. In the future, and following the trend in aesthetics research, brain imaging studies may be useful for a better understanding of how perception of car exterior design occurs as an aesthetic experience, as well as to provide more information that could further corroborate the current theories of aesthetics.

Hopefully the present work also highlights the importance of the researchers' or designers' positioning regarding the creation and evaluation of car exterior design. As the choice of language and terminology can automatically direct reasoning towards certain paths, maybe by proposing a different way of studying consumers' reactions to car exterior design may help researchers and professionals to explore new grounds. More specifically, perhaps by conceptualizing the perception of car exterior design as an aesthetic experience – rather than focusing on its functional purpose, or focusing on the specific role of emotion – may open new fields and ways of thinking for designing car exteriors. This seems particularly pertinent when considering how highly aesthetic products have an impact on the consumers' perceived sense of self (Townsend & Sood, 2012). Furthermore, when we think of studying the *experience* of a consumer with a product, we tend to associate this to the *use* of that product. However, as hopefully demonstrated with this work, *how* consumers *look* at products can give us a lot of pertinent information that will be also useful to understand the follow-up experience when using that product. Overall, in this thesis we uncovered practical information that can easily be taken into consideration and integrated in a more applied setting, such as: electrodermal activity may not be the most useful psychophysiological indicator to consider in a static visual task; the logo is a determinant feature of the car exterior design, but changing some contextual factors may have an impact on the importance of the logo; be aware of the saliency of the picture playing a determinant role on the visual exploration of the consumer, and therefore influence their experience; studying contextual factors need to be accounted for; affective and cognitive processes are not independent from one another. Moreover, by taking into consideration the study of top-down and bottom-up influences on the visual exploration of car exterior design, we uncovered a way to objectively evaluate to what extent changes in the overall car exterior design may alter the consumer's visual experience. This may be particularly useful for the automotive industry, when making smaller design changes in the same car model (which usually happens every couple of years).

Some follow-up questions may be evoked when considering the present results. For example, in this thesis, we excluded colour from the study of visual perception of car exterior design. However, this should be an interesting variable to study, as research has shown how colour may have an impact on attentional mechanisms (see Adaval et al., 2019), and subjective experience of the participant (e.g.: Barkat et al., 2003; Lee et al., 2014).

Furthermore, as previously mentioned, participants were told to disregard all the information they might know beforehand about the presented car pictures, and to just focus on the design of the presented car, exploring it as they wished. Even though our methodology implicitly invited participants to adopt a more aesthetic approach when visually exploring the designs, this notion was not directly presented nor instructed to participants. This does not go in line with what Leder and colleagues' (2004) posit by suggesting to explicitly explain to participants that they are taking part in an aesthetics' experiment, when in a laboratory setting. Would one observe differences in core affect responses and attentional mechanisms towards car design by introducing a more aesthetic context when in a laboratory setting? What about if one adds the instruction of adopting an *intention to purchase* when looking at different car designs? This seems to be a relevant follow-up question to this study since research on purchase intention shows how consumers' intentions may be modulated by various factors, that include individual characteristics, the product's characteristics, and contextual factors (e.g.: Bian & Forsythe, 2012; Paul & Rana, 2012; Yeon Kim & Chung, 2011). One may hypothesize about participants taking up on a more active role during the task, which may have repercussions on their physiology and attention.

On one hand, the present experiments highlighted the importance of taking into consideration how the demanded task may have an influence on the peripheral activation of the participant that is independent of the stimuli to be shown. On the other hand, viewers seem to be very sensitive to the characteristics of the visual content being presented to them, displaying attentional strategies accordingly. It is therefore particularly encouraged to take these contextual factors into consideration when creating new content. In practical terms, this is relevant for when creating advertising content, for example.

The Literature Review presented a comprehensive view on emotion research. Taking into consideration this review along with the presented Experimental Framework, we will have hopefully made clear how there are a multitude of possibilities in terms of the conceptualization and methodologies to use and apply in aesthetics research in order to better comprehend a person's experience.

With this thesis, we hopefully offer a sound step into the affect and cognitive mechanisms involved in product experience, namely on the visual discovery of the product, applied to car exterior design. We consider this first contact with a car design to be the first step on how consumers will later form their purchase choices, hence the importance of understanding their experience. The chosen psychophysiological and behavioural approach is even more relevant when considering the change of shift in consumer research, from focusing on the product itself to focus on the study of the experience that the product evokes on the consumer. Hopefully these findings will shed some light on visual attention and emotion research, by taking up on more complex visual stimuli. Finally, even though this thesis focuses on design from a consumers' point of view, we hope these findings may be of use to various concerned experts, including designers in the automotive industry, whether by providing them with new methodological options to test other forms of design categorizations or specific car designs, as well as reiterating the importance of taking contextual factors into consideration, or by making available information that may be useful to their daily work.

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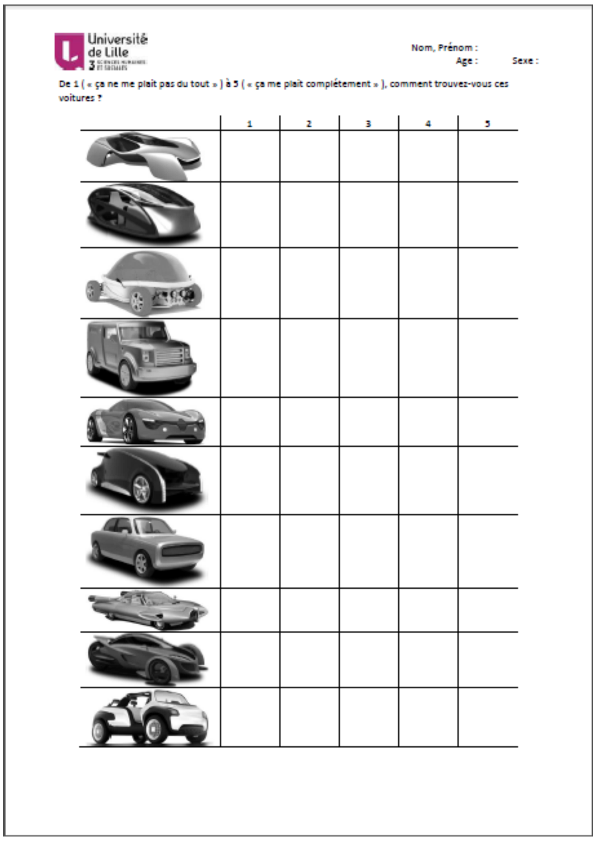
Appendices

Appendix 1. Stimuli list of Study 1.

Pairs	Concept cars	Non-Concept cars	Pairs	Concept cars	Non-Concept cars
Audi Avatar – Dodge Viper			Lancia Stratos – Lamborghini Aventador		
Audi e-Tron – Infinity			Lexus LF-NX – Cadillac SRX		
Coffre – Nissan Cube			Manga – Renault Espace 5		
Courrèges Zooop – Citröen C4 Picasso			Peugeot LiiON – Chevrolet Camaro		
Ford 021C – Chrysler PT Cruiser			Peugeot Metromorph – Renault Zoe		
Ford X2000 – Alpha Romeo 159			Renault DeZir – Aston Martin Rapide S		
Holden Efijy – BMW Serie 4 Gran Coupé			Renault Ondelios – BMW X6		
Honda Puyo – Fiat 500			Savon – Maserati Granturismo		
Kia Pop – Nissan Juke			Toyota Fun VII – Rolls-Royce Phantom		

Appendix 2. Liking questionnaire of Study 1.



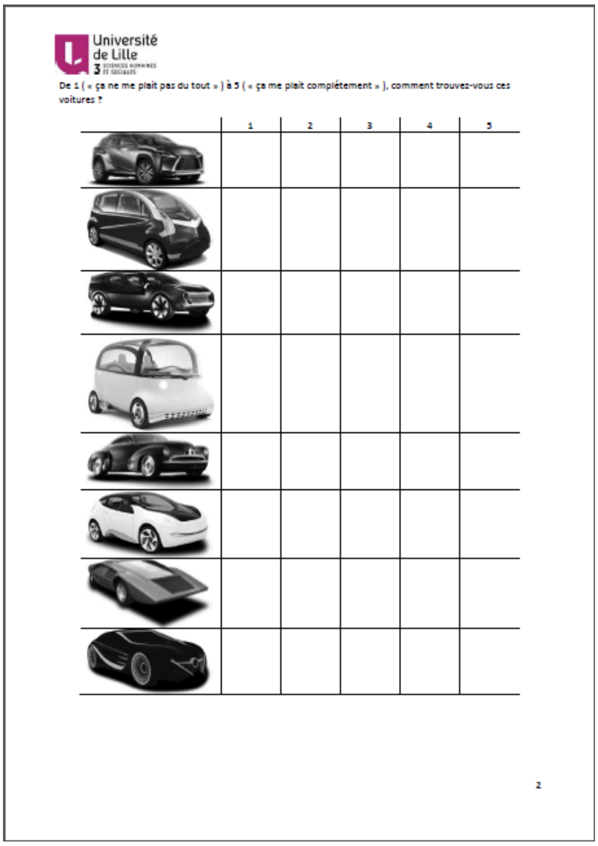
Université de Lille 3

Nom, Prénom :

Age : Sexe :

De 1 (« ça ne me plait pas du tout ») à 5 (« ça me plait complètement »), comment trouvez-vous ces voitures ?

	1	2	3	4	5

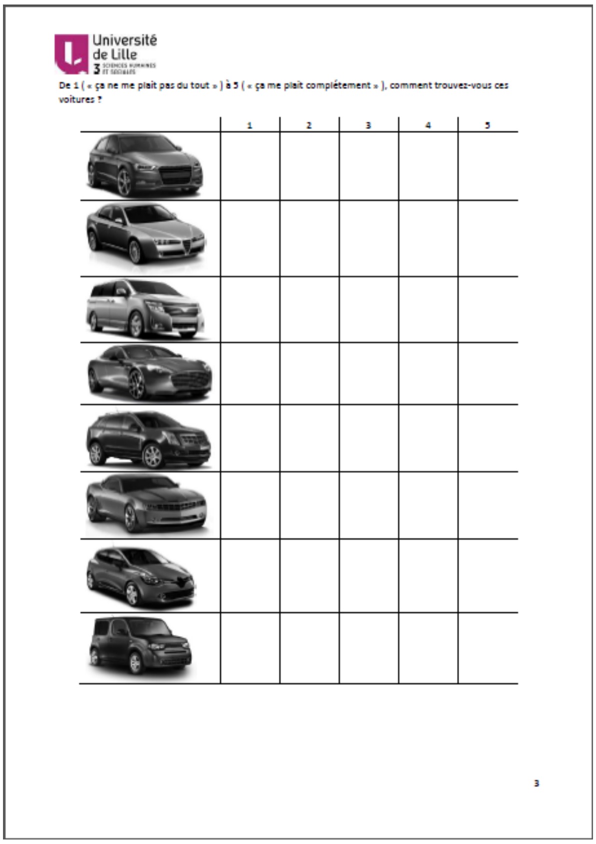


Université de Lille 3

De 1 (« ça ne me plait pas du tout ») à 5 (« ça me plait complètement »), comment trouvez-vous ces voitures ?

	1	2	3	4	5

2

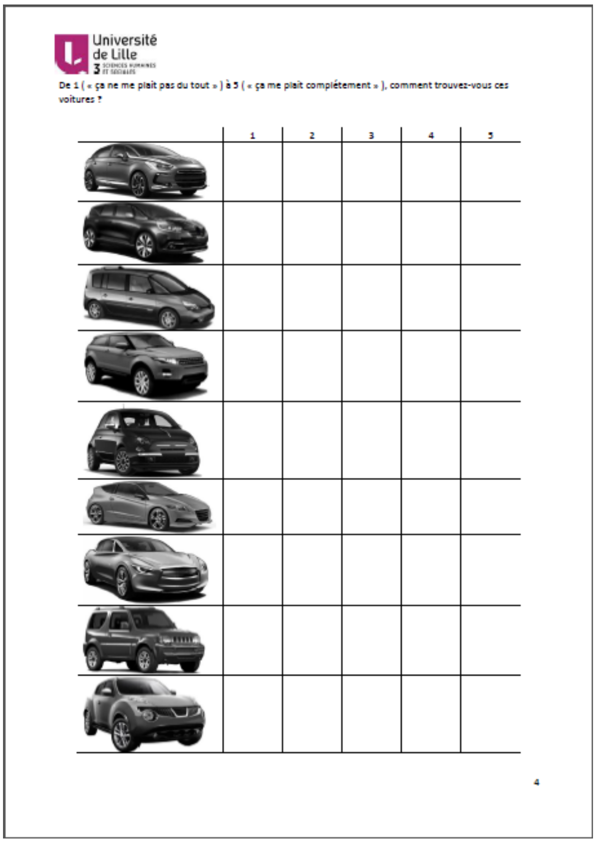


Université de Lille 3

De 1 (« ça ne me plait pas du tout ») à 5 (« ça me plait complètement »), comment trouvez-vous ces voitures ?

	1	2	3	4	5

3

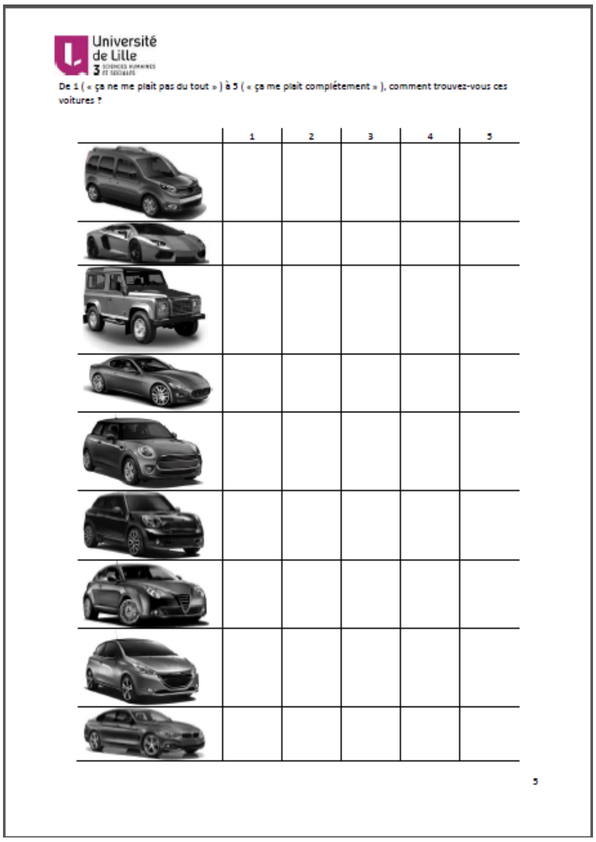


Université de Lille 3

De 1 (« ça ne me plait pas du tout ») à 5 (« ça me plait complètement »), comment trouvez-vous ces voitures ?

	1	2	3	4	5

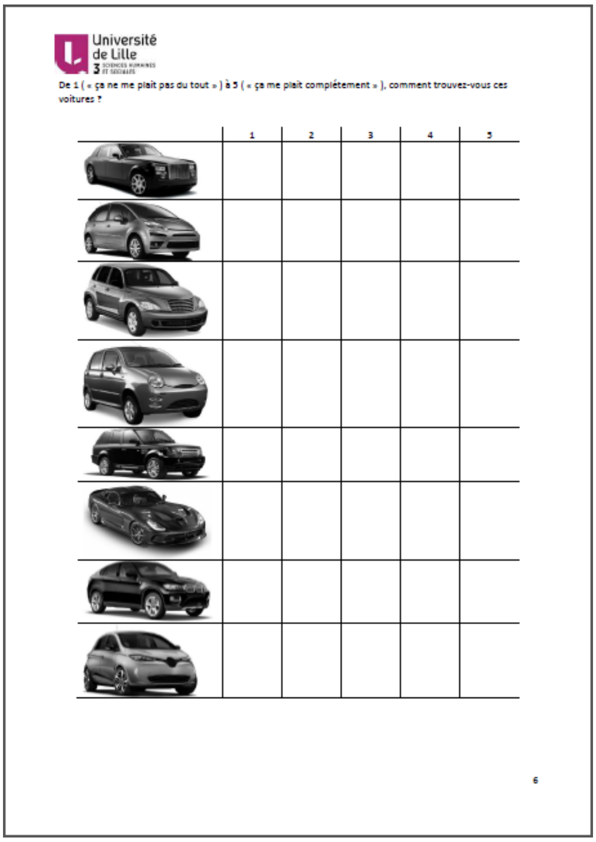
4


Université de Lille 3 Sciences humaines et sociales

De 1 (« ça ne me plait pas du tout ») à 5 (« ça me plait complètement »), comment trouvez-vous ces voitures ?

	1	2	3	4	5

5


Université de Lille 3 Sciences humaines et sociales

De 1 (« ça ne me plait pas du tout ») à 5 (« ça me plait complètement »), comment trouvez-vous ces voitures ?

	1	2	3	4	5

6

Appendix 3. Familiarity online questionnaire for stimuli selection in Study 2.

Avez-vous déjà vu cette voiture (dans une publicité ou autre média ou dans la rue) ? Pour vous aider, une échelle à 7 niveaux a été établie de « Je n'ai jamais vu cette voiture » à « Je vois cette voiture tous les jours ou presque tous les jours.

1 : Je n'ai jamais vu cette voiture

2 : Je ne crois pas avoir déjà vu cette voiture

3 : Je pense avoir déjà vu cette voiture au moins une fois dans ma vie

4 : J'ai déjà vu cette voiture au moins une fois dans ma vie

5 : Je vois occasionnellement cette voiture

6 : Je vois régulièrement cette voiture

7 : Je vois cette voiture tous les jours ou presque tous les jours

Appendix 4. Stimuli list of Study 2.

Acura ILX

Alfa Romeo 159

Audi A3

Bentley Mulsanne

BMW P-4 series

BMW X6

Cadillac SRX

Chery QQ

Chevrolet Camaro

Chrysler PT Cruiser

Citröen Picasso

Dacia Duster

Dodge Challenger

Fiat 500

Ford EcoSport

Ford Fiesta

Ford Galaxy

Ford Mustang

Honda CRZ

Jeep Renegade

Jeep Wrangler

Kia Picanto

Kia Rio SLI

Kia Soul

Lamborghini Aventador

Mazda 2

Mercedes-Benz CLA

Mini One

Nissan March

Opel Corsa

Peugeot 2008

Range Rover Sport


Renault Clio


Renault Espace


Renault Kangoo


Rolls-Royce Ghost

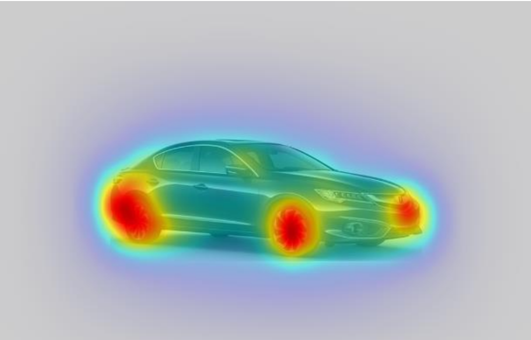
Rolls-Royce Phantom

Skoda Yeti

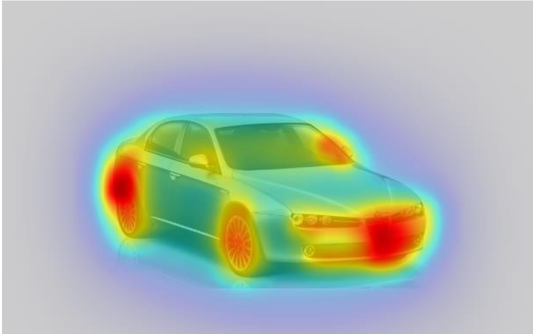
Suzuki SX4

Toyota Alphard

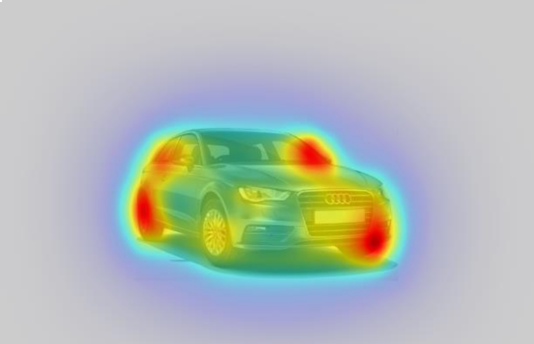
Appendix 5. The obtained saliency maps in Study 2.



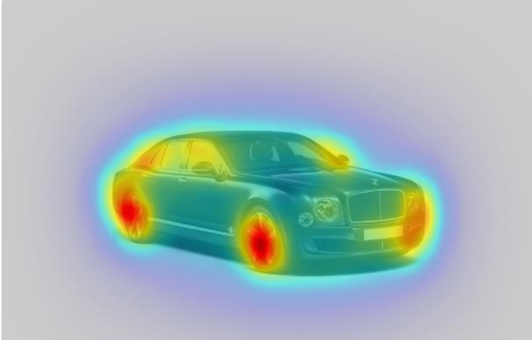
Acura ILX



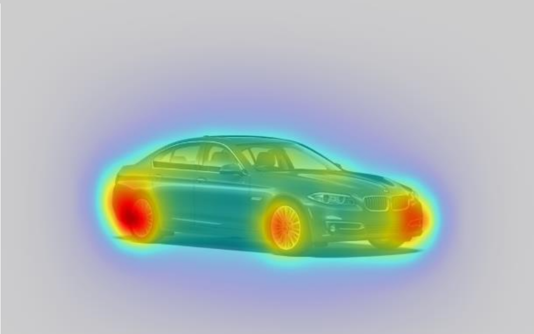
Alfa Romeo 159



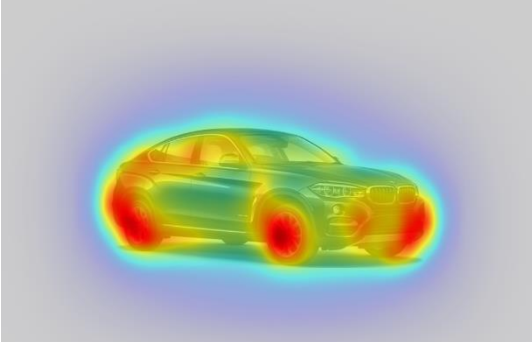
Audi A3



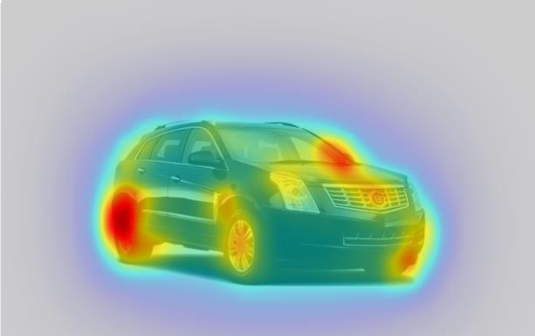
Bentley Mulsanne



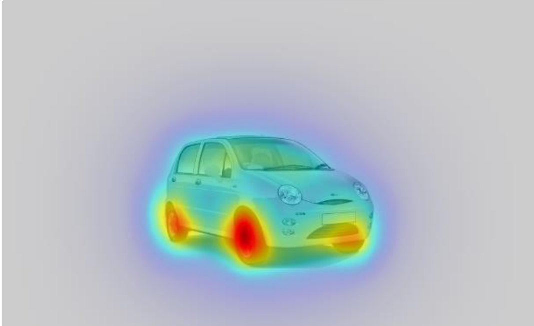
BMW P-4 series



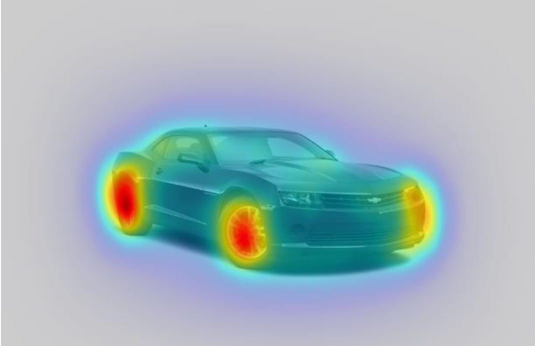
BMW X6



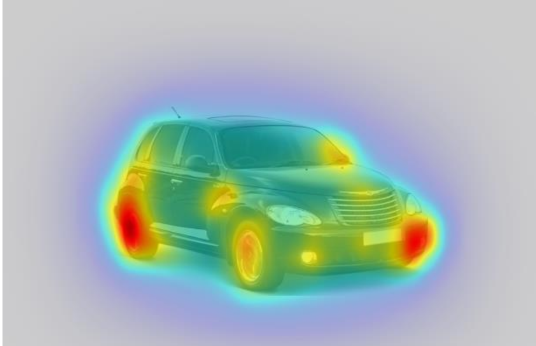
Cadillac SRX



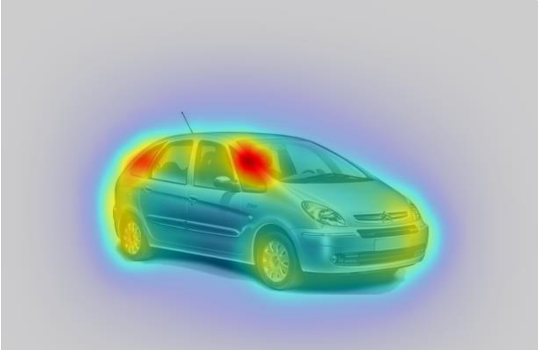
Chery QQ



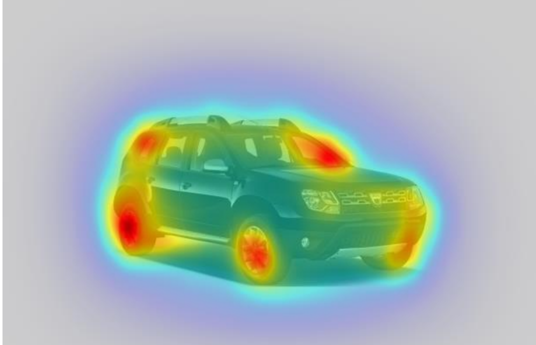
Chevrolet Camaro



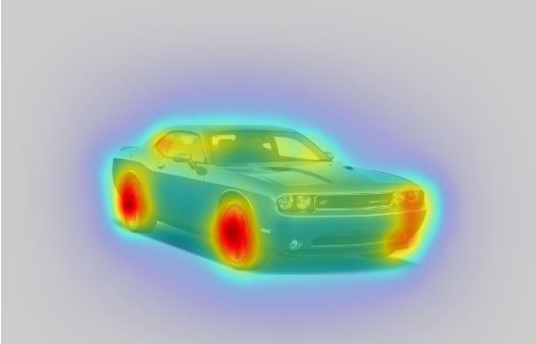
Chrysler PT Cruiser



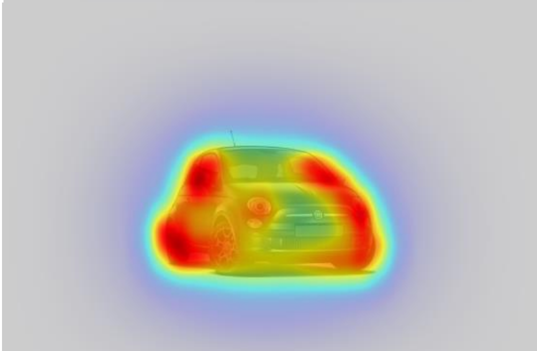
Citröen Picasso



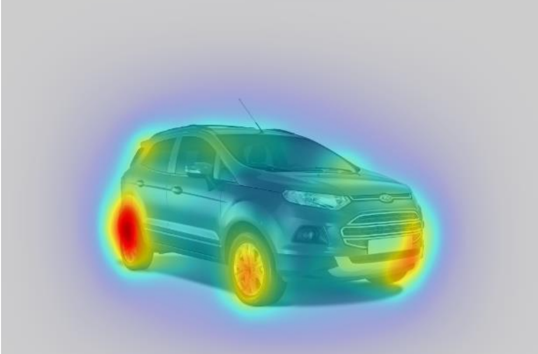
Dacia Duster



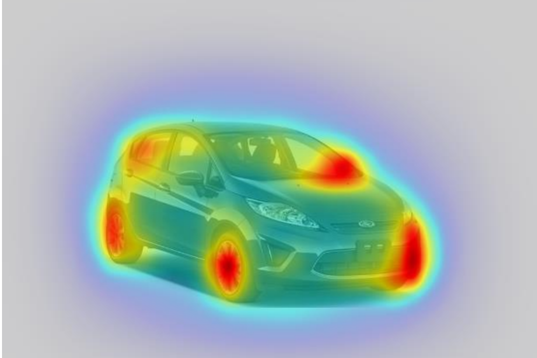
Dodge Challenger



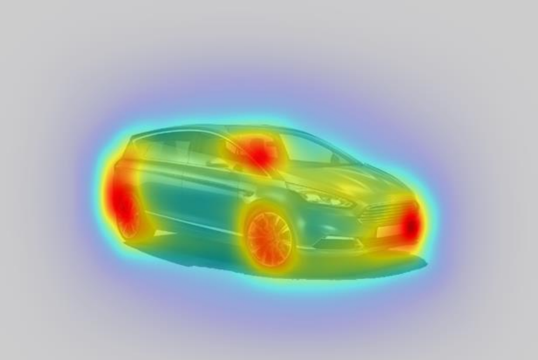
Fiat 500



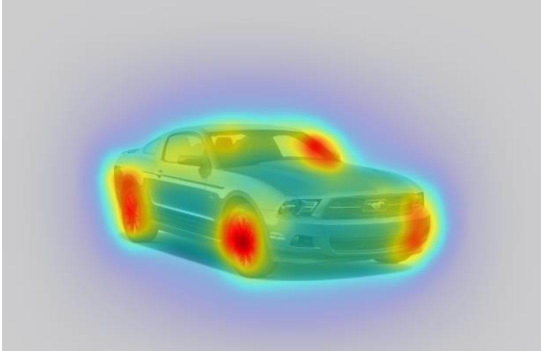
Ford EcoSport



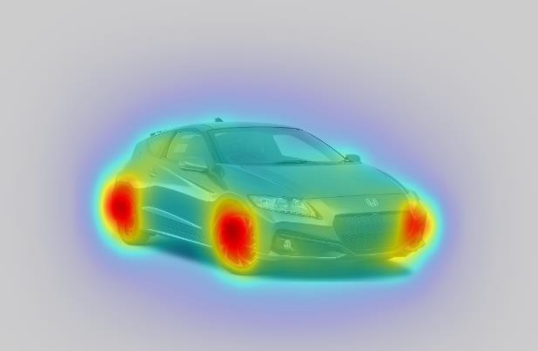
Ford Fiesta



Ford Galaxy

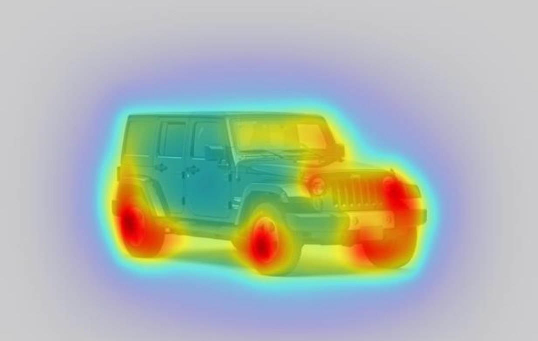


Ford Mustang

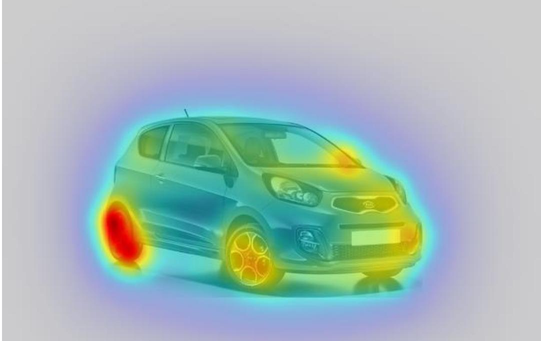


Honda CRZ

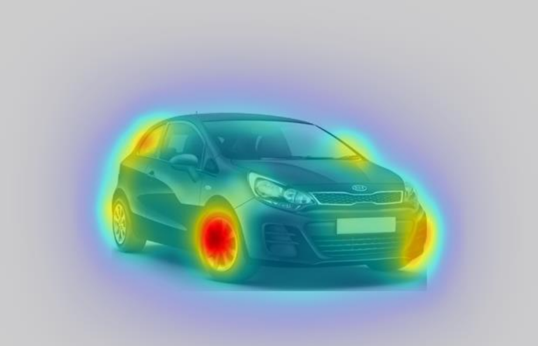
Jeep Renegade



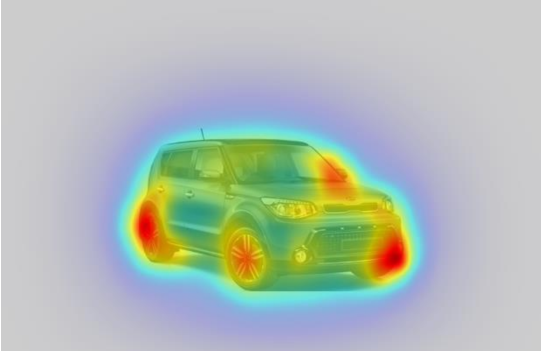
Jeep Wrangler



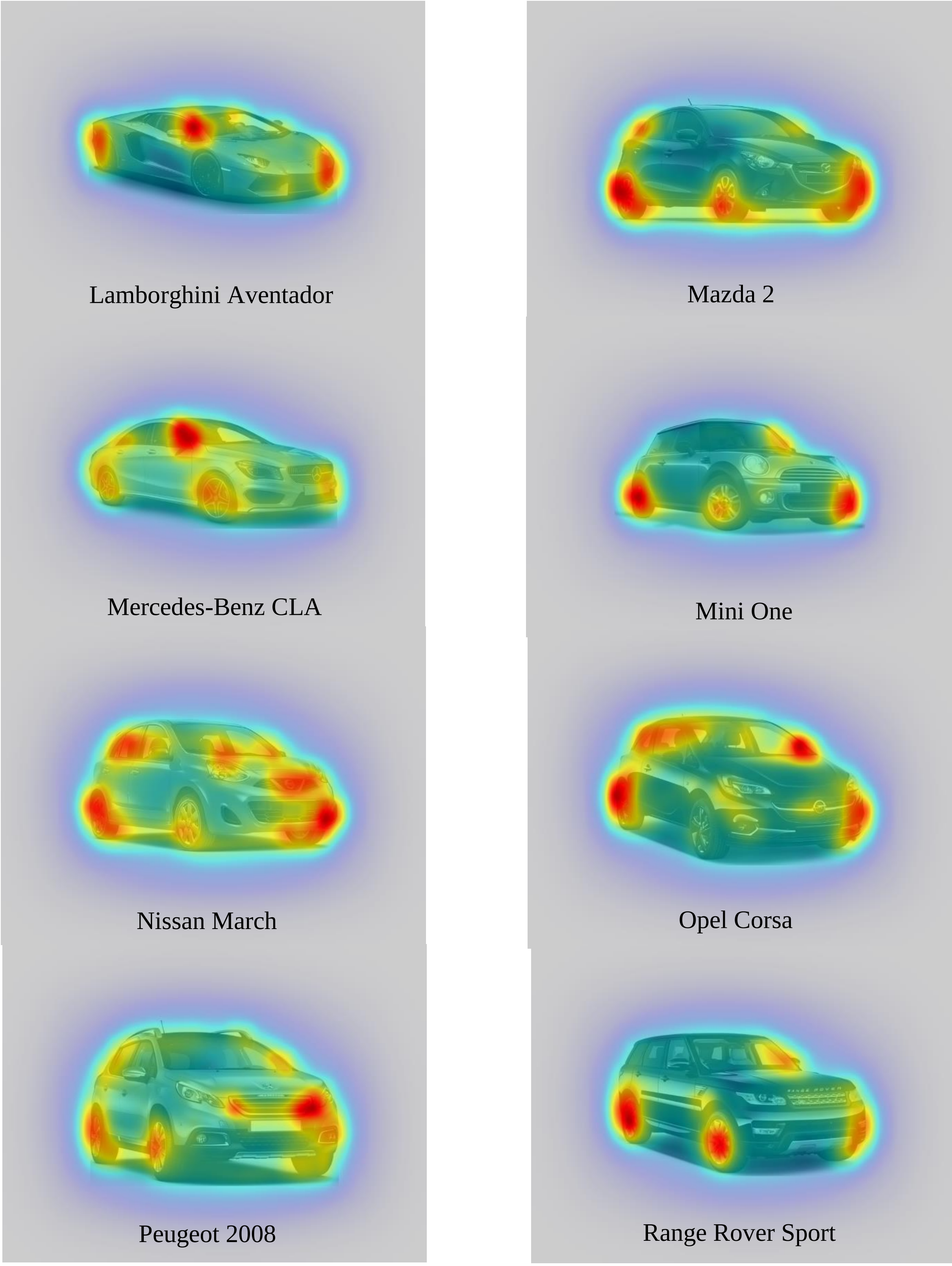
Kia Picanto

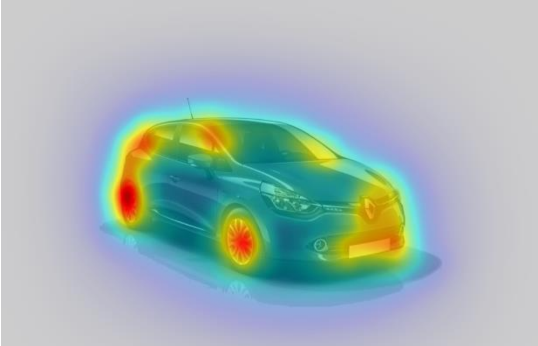


Kia Rio SLI

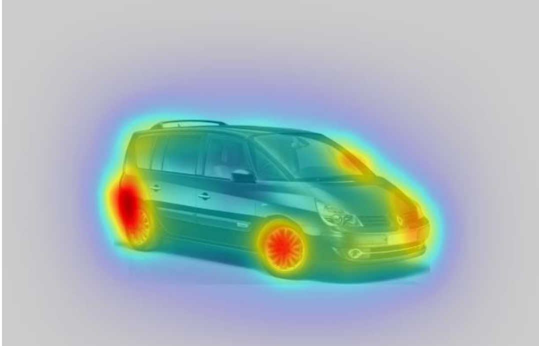


Kia Soul


Lamborghini Aventador
Mazda 2
Mercedes-Benz CLA
Mini One
Nissan March
Opel Corsa
Peugeot 2008
Range Rover Sport

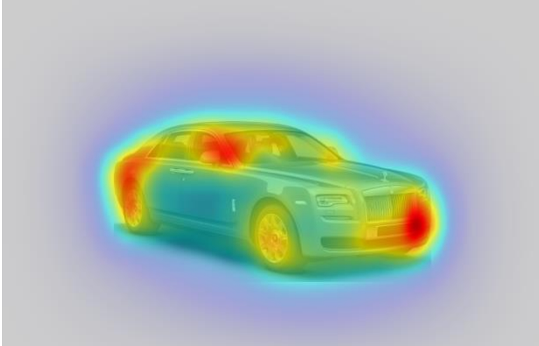


Renault Clio

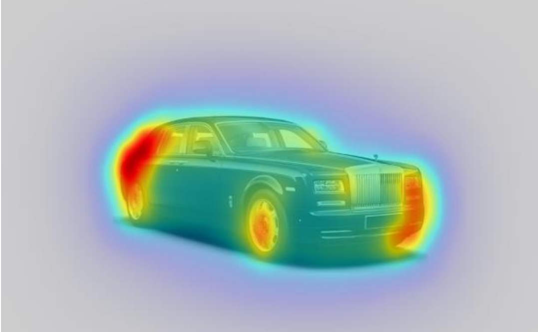


Renault Espace

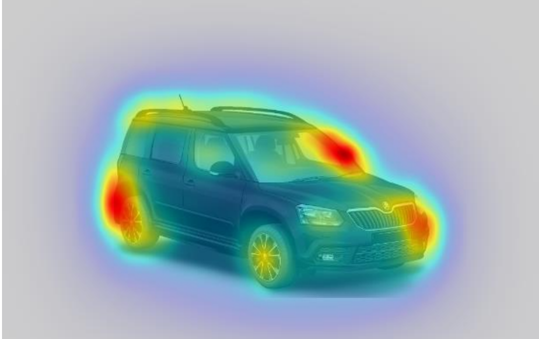
Renault Kangoo



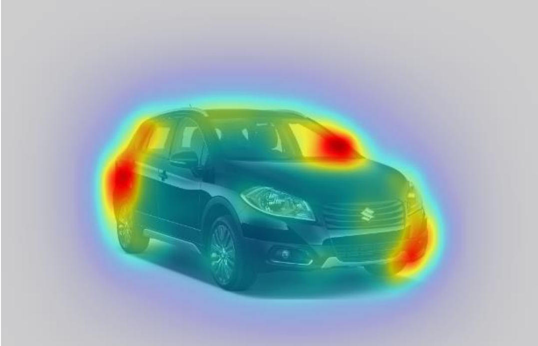
Rolls-Royce Ghost



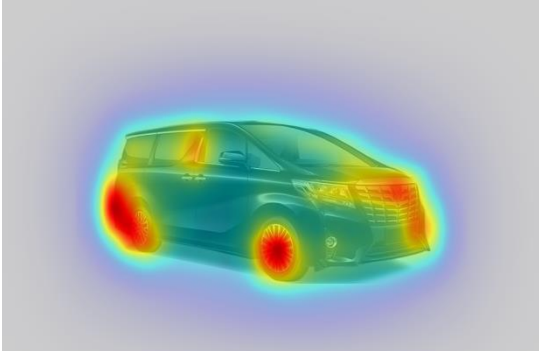
Rolls-Royce Phantom



Skoda Yeti

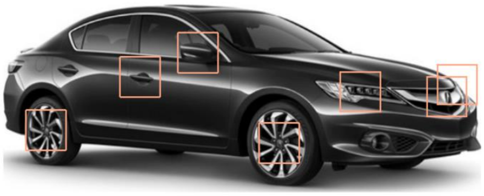


Suzuki SX4

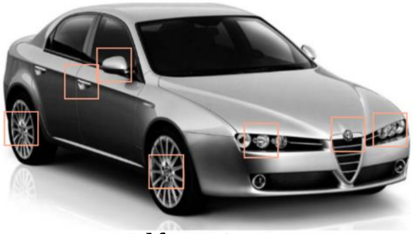


Toyota Alphard

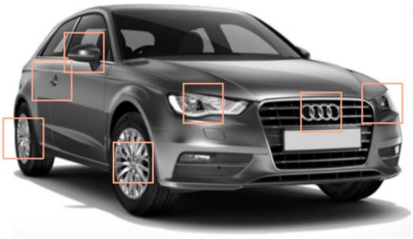
Appendix 6. Pictures of the considered car features in Study 2.



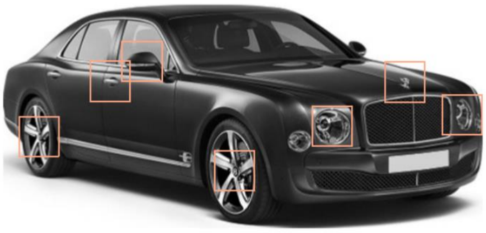
Acura ILX



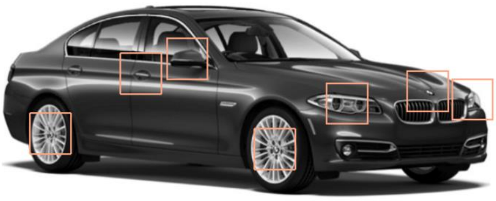
Alfa 159



Audi A3

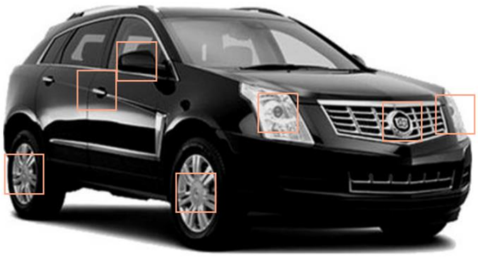


Bentley Mulsanne

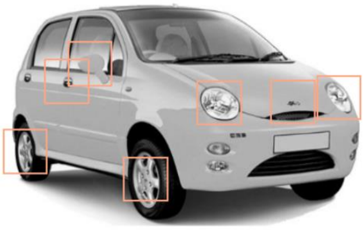


BMW P4 series

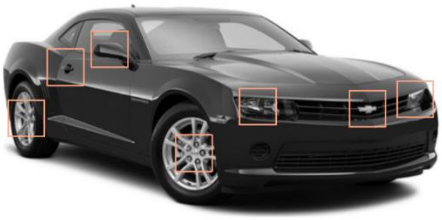
BMW X6



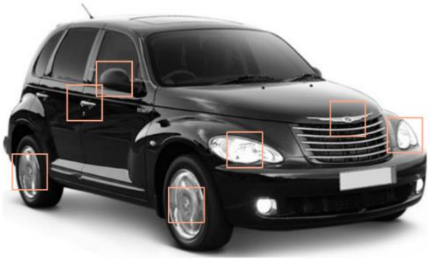
Cadillac SRX



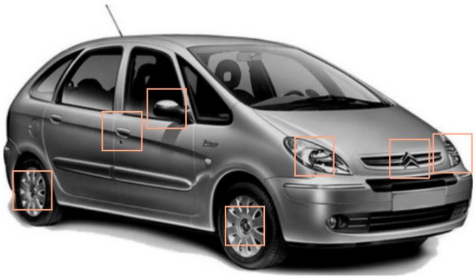
Chery QQ



Chevrolet Camaro



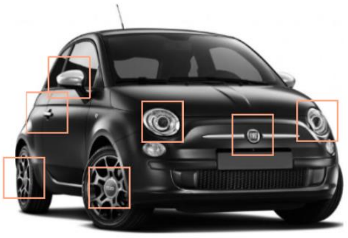
Chrysler PT Cruiser



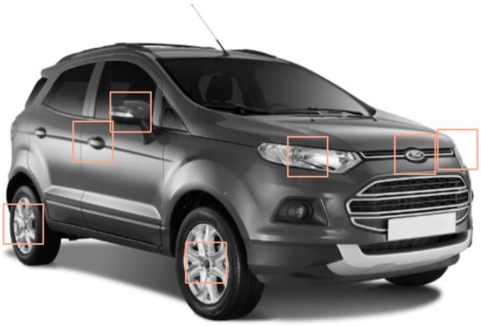
Citröen Picasso

Dacia Duster

Dodge Challenger

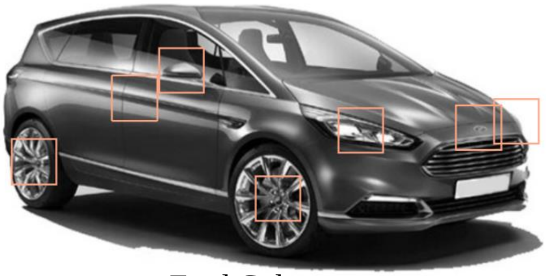


Fiat 500

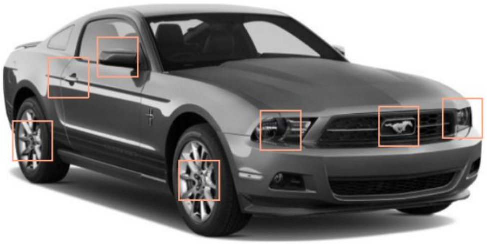


Ford EcoSport

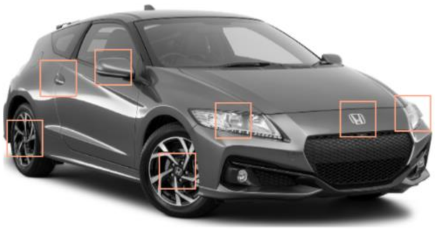
Ford Fiesta



Ford Galaxy



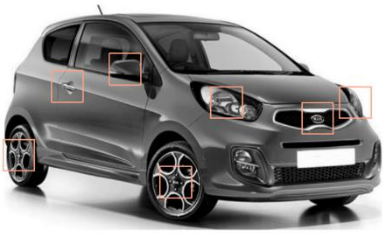
Ford Mustang



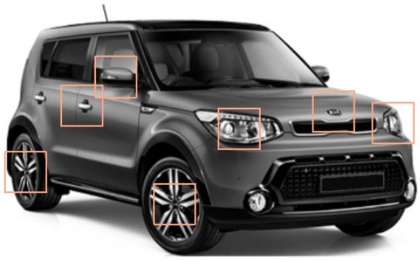
Honda CRZ

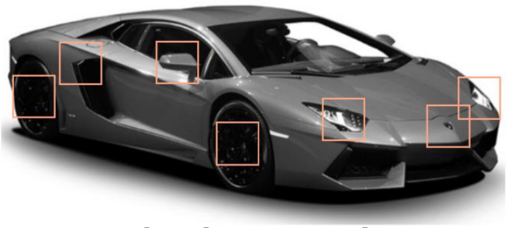
Jeep Renegade


Jeep Wrangler

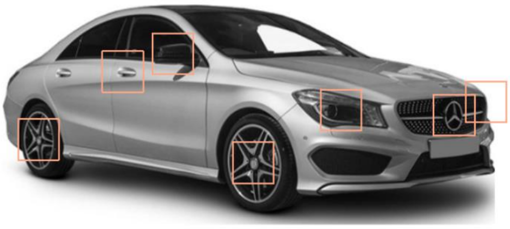

Kia Picanto


Kia Rio SLI


Kia Soul


Lamborghini Aventador


Mazda 2

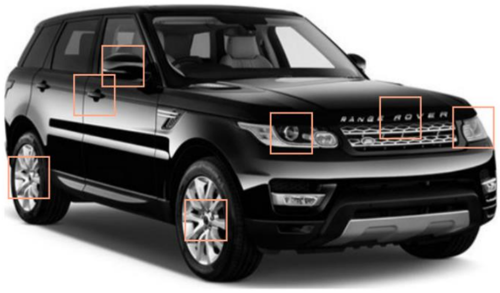

Mercedes-Benz CLA


Mini One

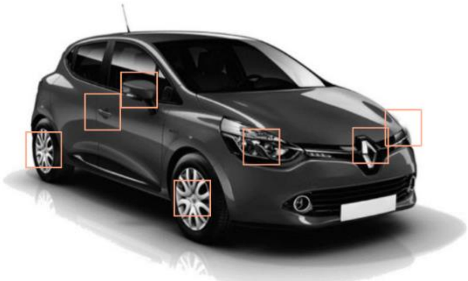

Nissan March


Opel Corsa

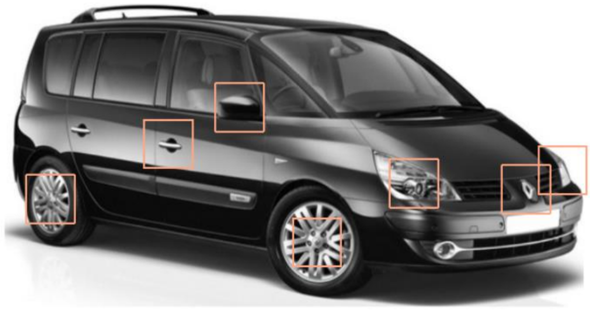
Peugeot 2008



Range Rover Sport

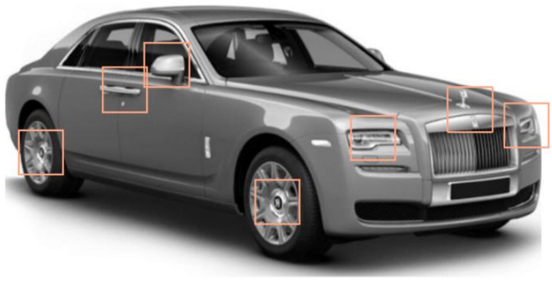


Renault Clio

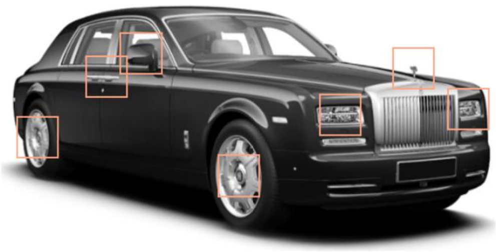


Renault Espace

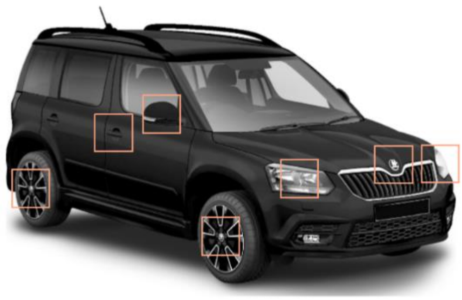
Renault Kangoo



Rolls-Royce Ghost

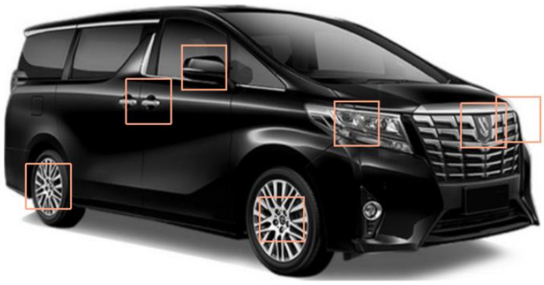


Rolls-Royce Phantom



Skoda Yeti

Suzuki SX4



Toyota Alphard

Appendix 7. Car profile questionnaire of Study 2 and 3.

1) Vous lisez des magazines de voitures :
   a. Régulièrement …..
   b. De temps en temps …..
   c. Jamais …..

2) Vous regardez des émissions de télévision concernant les voitures :
   a. Régulièrement …..
   b. De temps en temps …..
   c. Jamais …..

3) Lorsque vous croisez une voiture qui vous plait dans la rue, vous arrive-t-il de la photographier ?
   a. Systématiquement …..
   b. Parfois …..
   c. Jamais

4) Pour moi une voiture est :
   a. Un « objet d'art/bel objet » ?

Pas du tout d'accord	Pas d'accord	Ni en accord, ni en désaccord	D'accord	Tout à fait d'accord

   b. Un « moyen de déplacement » ?

Pas du tout d'accord	Pas d'accord	Ni en accord, ni en désaccord	D'accord	Tout à fait d'accord

c. Un « merveille technologique » ?

Pas du tout d’accord	Pas d’accord	Ni en accord, ni en désaccord	D’accord	Tout à fait d’accord

5) Je pense avoir un bon niveau de connaissances en automobile (connaissance des modèles et de leurs spécificités) :

Pas du tout d’accord	Pas d’accord	Ni en accord, ni en désaccord	D’accord	Tout à fait d’accord

Appendix 8. Liking questionnaire of Study 2.

J'aime bien le design extérieur de cette voiture.

En désaccord			Neutre	En accord		
1 Complètement	2 Moyennement	3 Faiblement	4	5 Faiblement	6 Moyennement	7 Complètement

Appendix 9. 4k screen setup, and experimental setup.

Screen specifications:

- Glass screen dimensions: 4x2m
- 4K Display resolution: 4096x2160 pixels (display of 1mm per pixel)
- Video projector suitable for stereoscopy (*i.e.* 3D display)
- Frequency: 120Hz
- Power: 25 000 lumens
- Multi-touch system (up to 10 simultaneous touches), with a precision of ~1.5cm

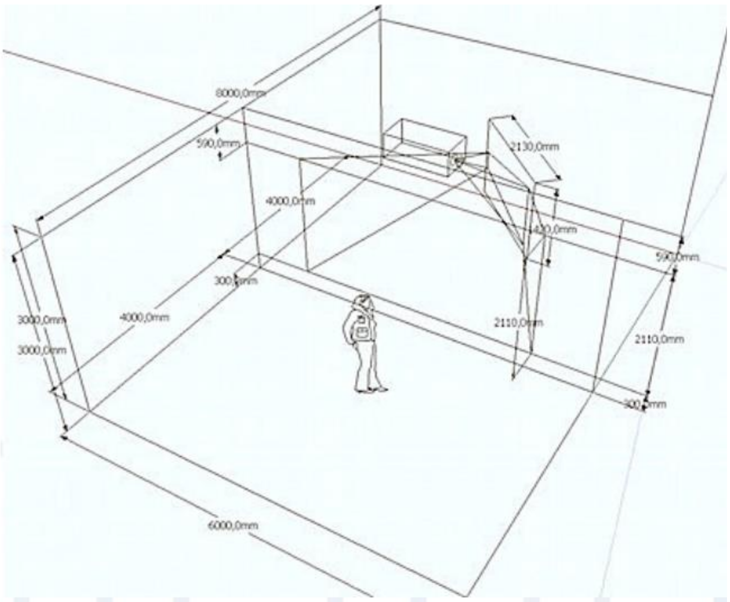


Figure 20. Setup of the 4k screen.

Figure 21. Experimental setup.

Appendix 10. Stimuli list of Study 3.

BMW i3

Citroën DS3

Dacia Duster

Jeep Renegade

Jeep Wrangler

Mazda 2

Peugeot 2008

Peugeot 208

Renault Captur

Renault Clio

Skoda Yeti

Volvo v40

Appendix 11. Liking questionnaire of Study 3.

Each question was presented along with a car picture, in a pseudo-randomized order.

Evaluez chaque extérieur de voiture par rapport à chaque paire d'antonymes :

Agressif : 1 2 3 4 5 6 7 : Doux

1) Extrêmement agressif

2) Assez agressif

3) Légèrement agressif

4) Ni agressif ni doux ; Équitablement agressif et doux

5) Légèrement doux

6) Assez doux

7) Extrêmement doux

Beau : 1 2 3 4 5 6 7 : Laid

1) Extrêmement beau

2) Assez beau

3) Légèrement beau

4) Ni beau ni laid; Équitablement beau et laid

5) Légèrement laid

6) Assez laid

7) Extrêmement laid

Désagréable : 1 2 3 4 5 6 7 : Agréable

1) Extrêmement désagréable
2) Assez désagréable
3) Légèrement désagréable
4) Ni désagréable ni agréable; Équitablement désagréable et agréable
5) Légèrement agréable
6) Assez agréable
7) Extrêmement agréable

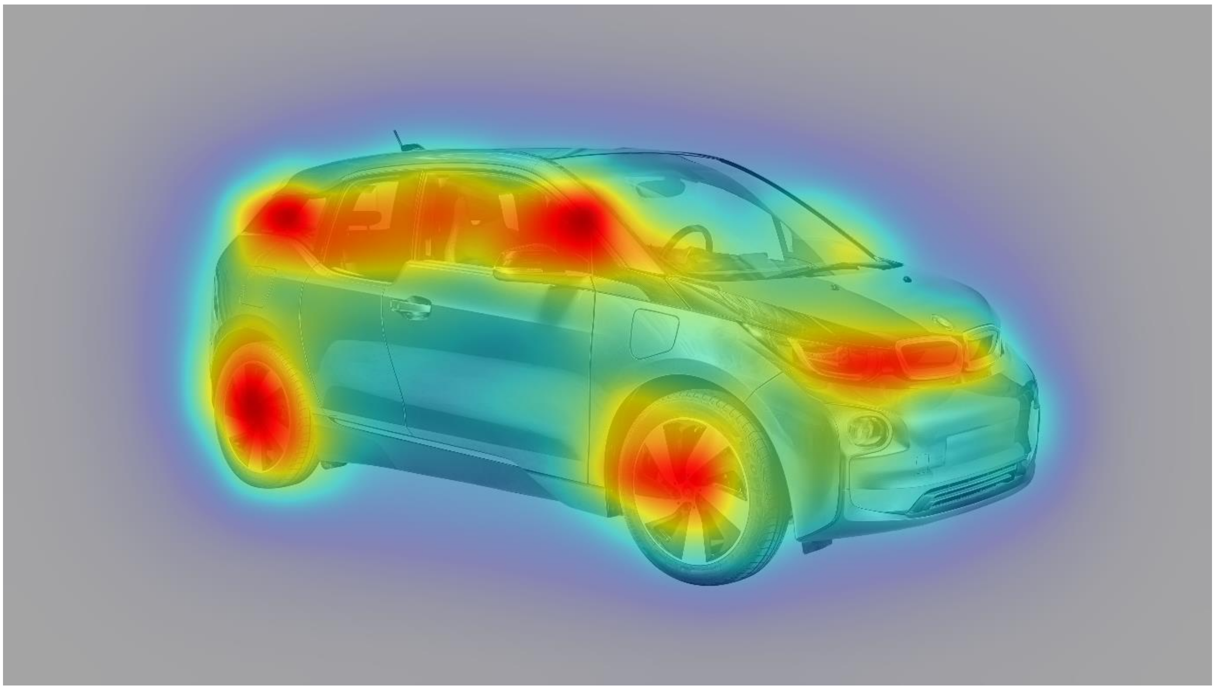
Élaboré : 1 2 3 4 5 6 7 : Basique

1) Extrêmement élaboré
2) Assez élaboré
3) Légèrement élaboré
4) Ni élaboré ni basique; Équitablement élaboré et basique
5) Légèrement basique
6) Assez basique
7) Extrêmement basique

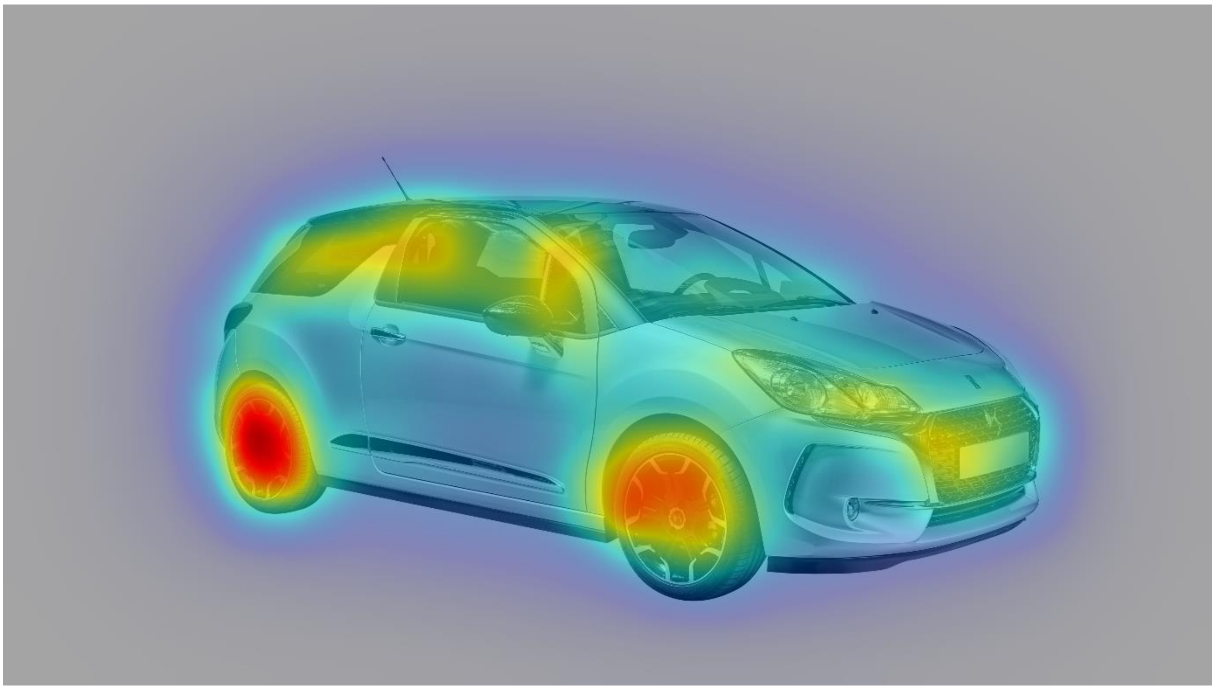
Moderne : 1 2 3 4 5 6 7 : Classique

1) Extrêmement moderne
2) Assez moderne
3) Légèrement moderne
4) Ni moderne ni classique; Équitablement moderne et classique
5) Légèrement classique
6) Assez classique
7) Extrêmement classique

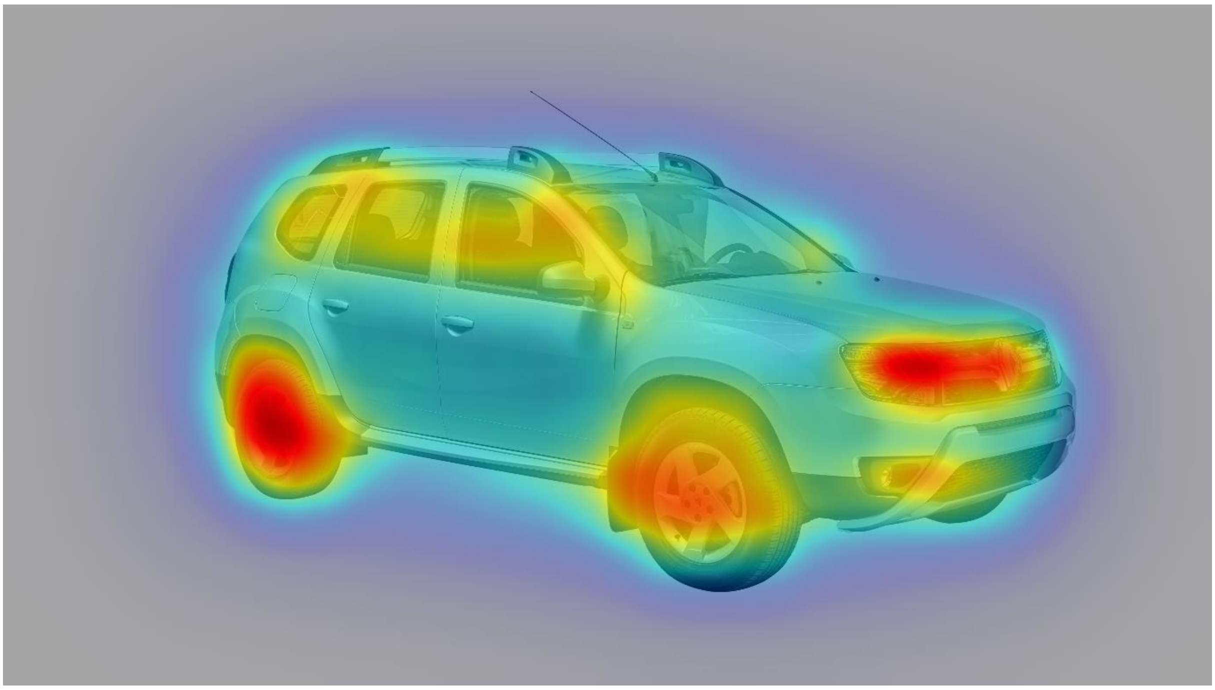
Appendix 12. The obtained saliency maps in Study 3.



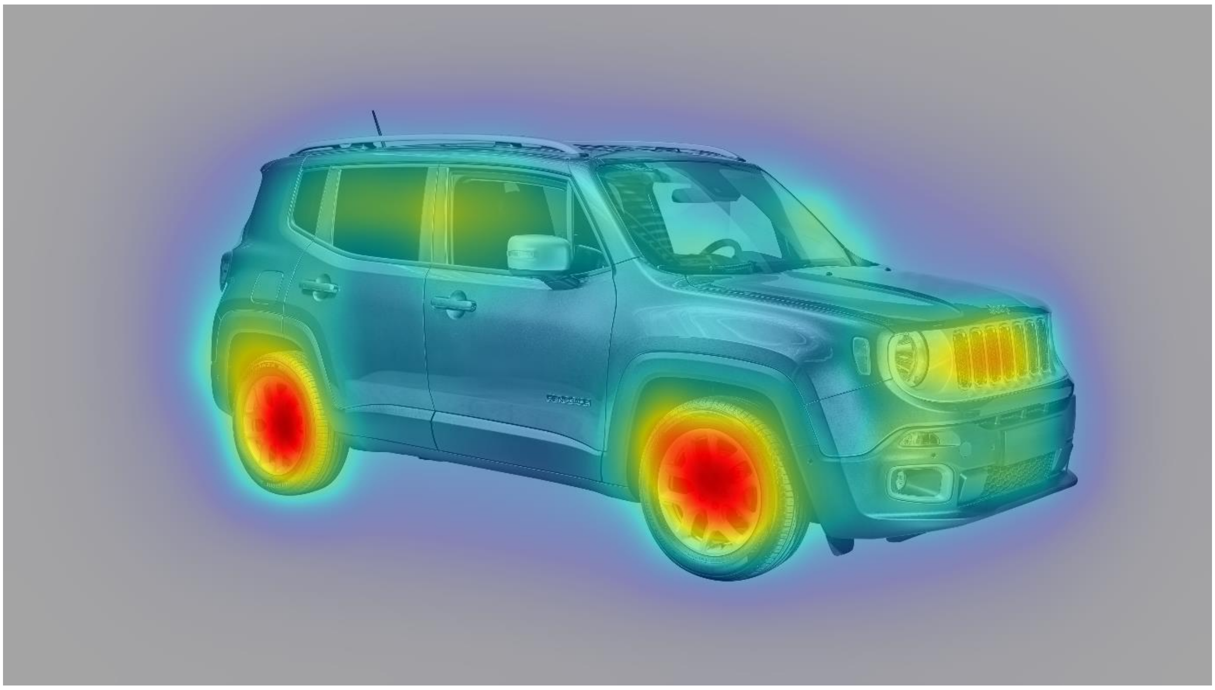
BMW i3



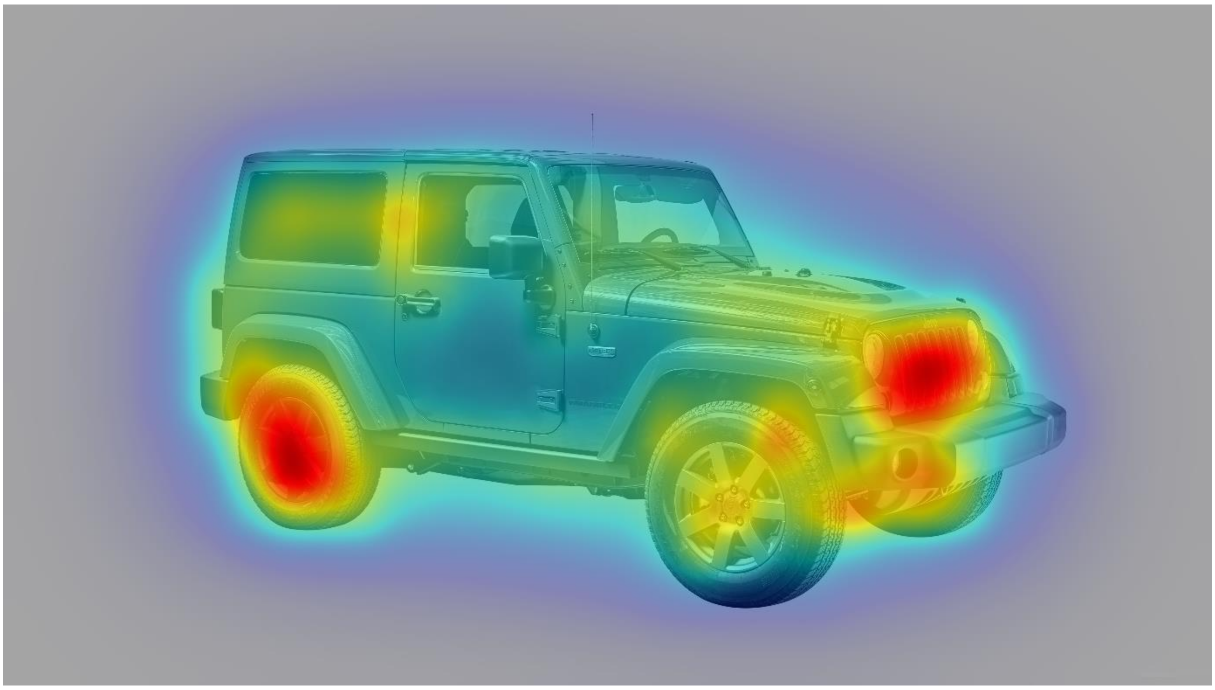
Citroën DS3



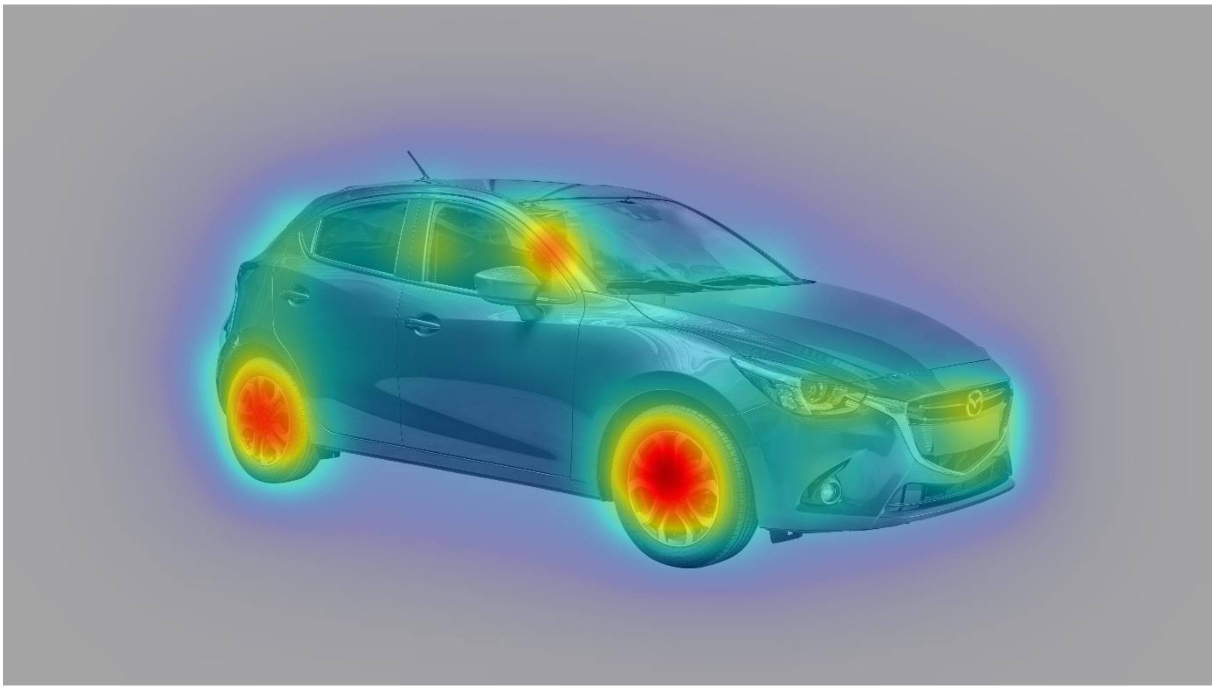
Dacia Duster



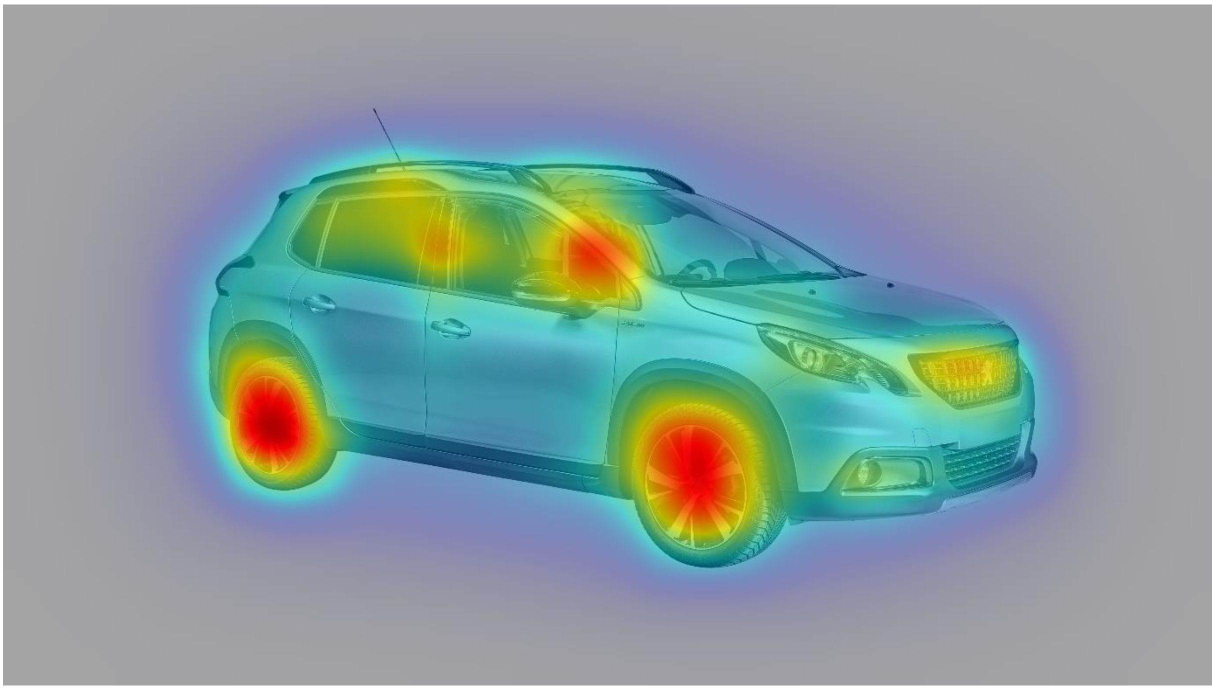
Jeep Renegade



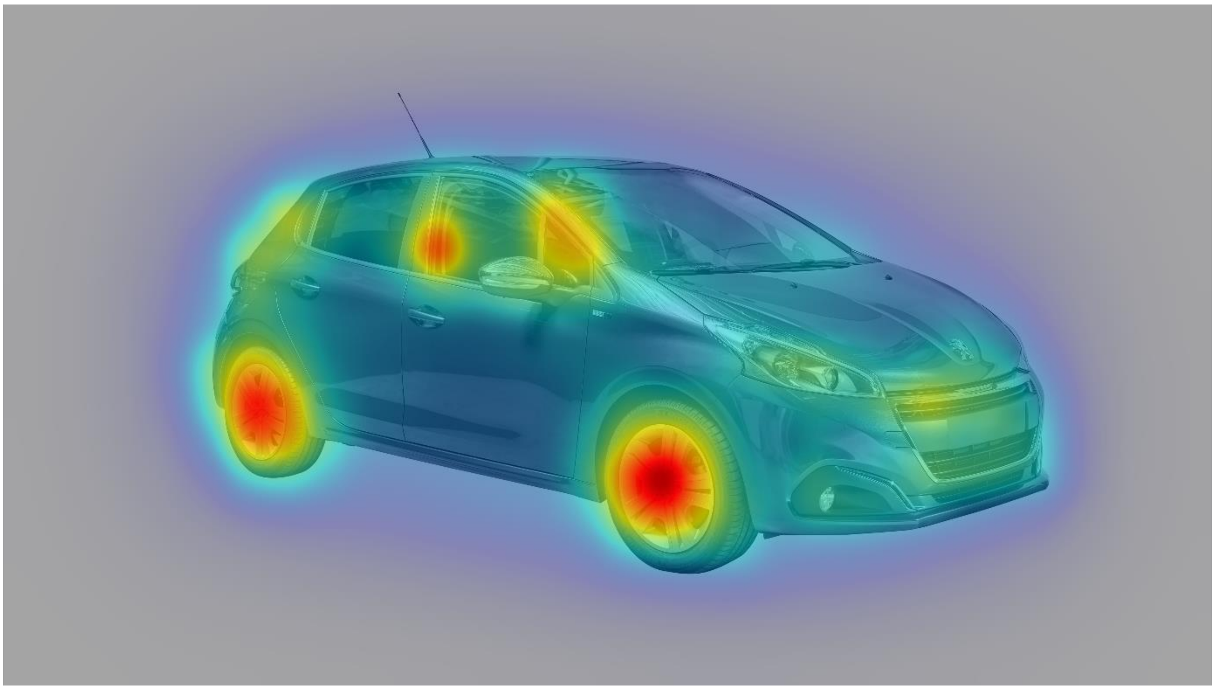
Jeep Wrangler



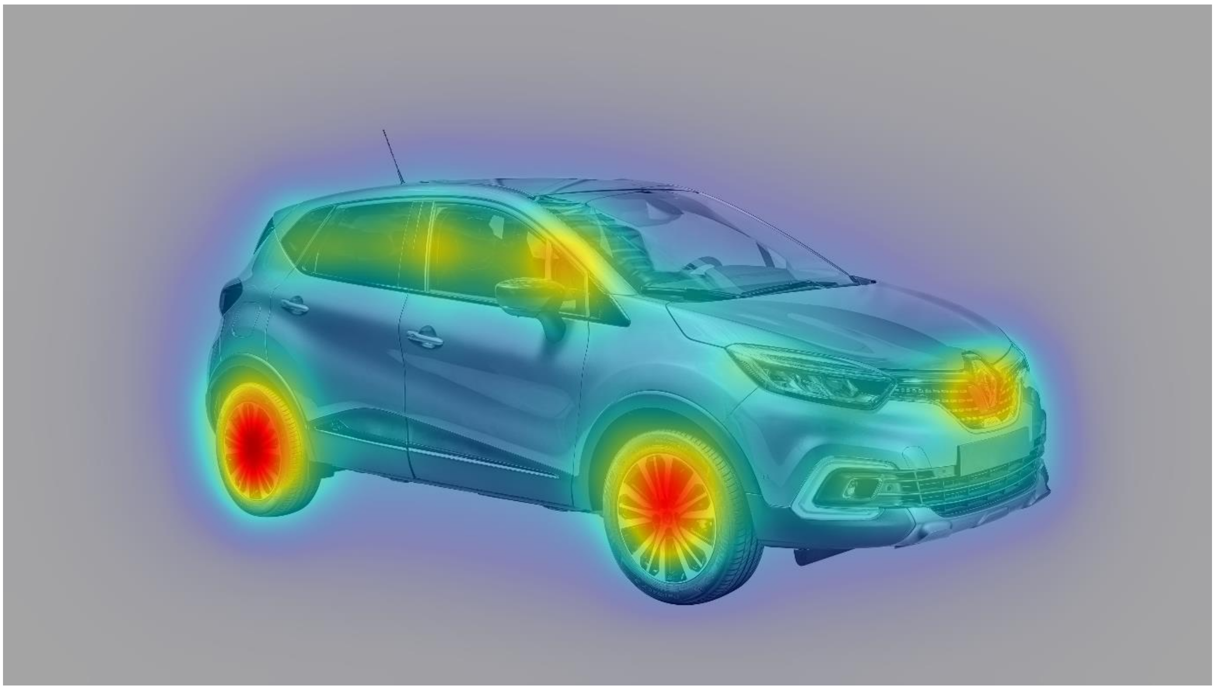
Mazda 2



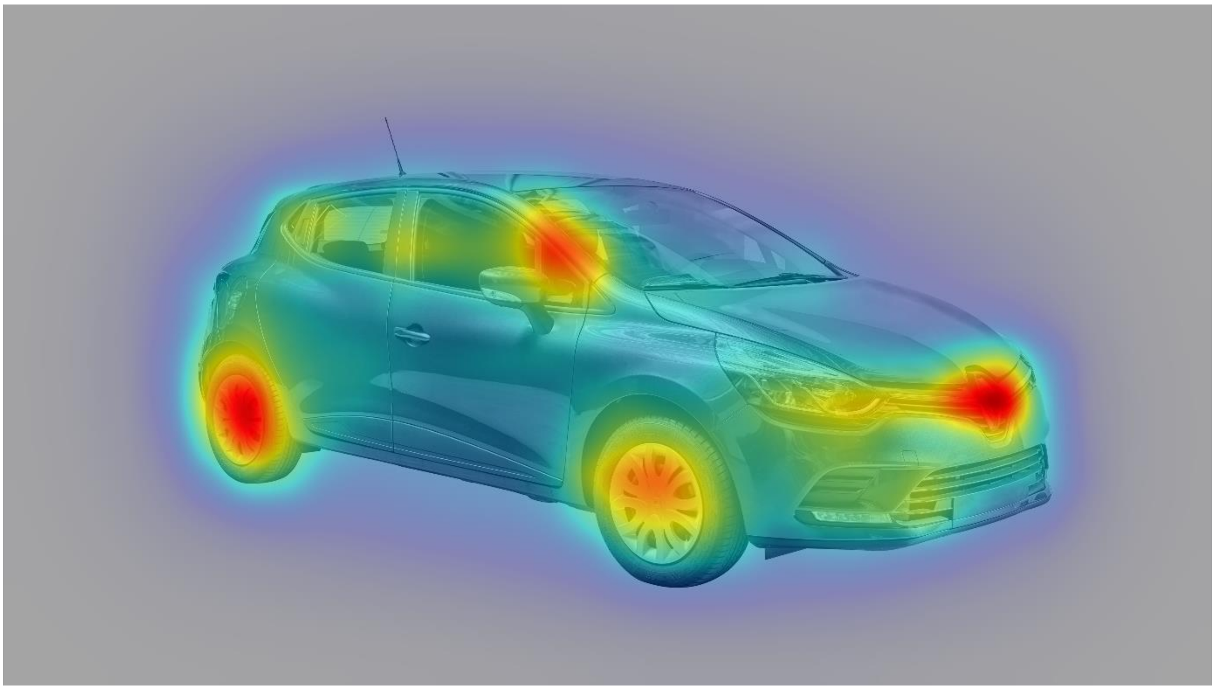
Peugeot 2008



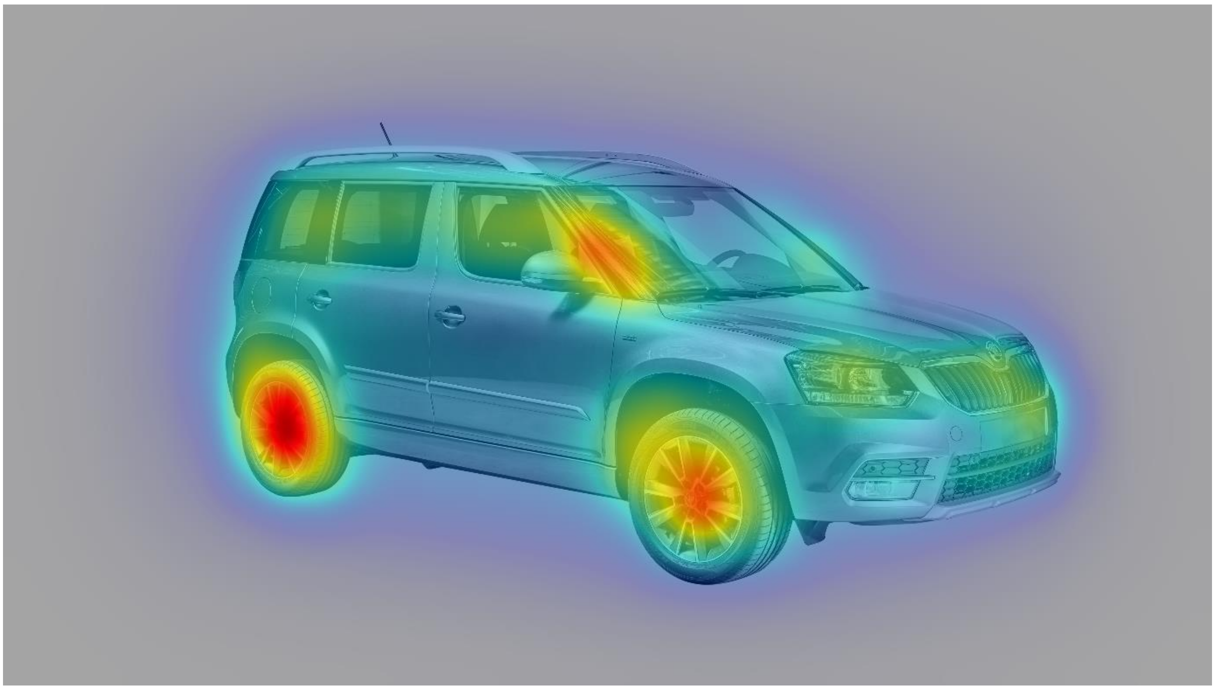
Peugeot 208



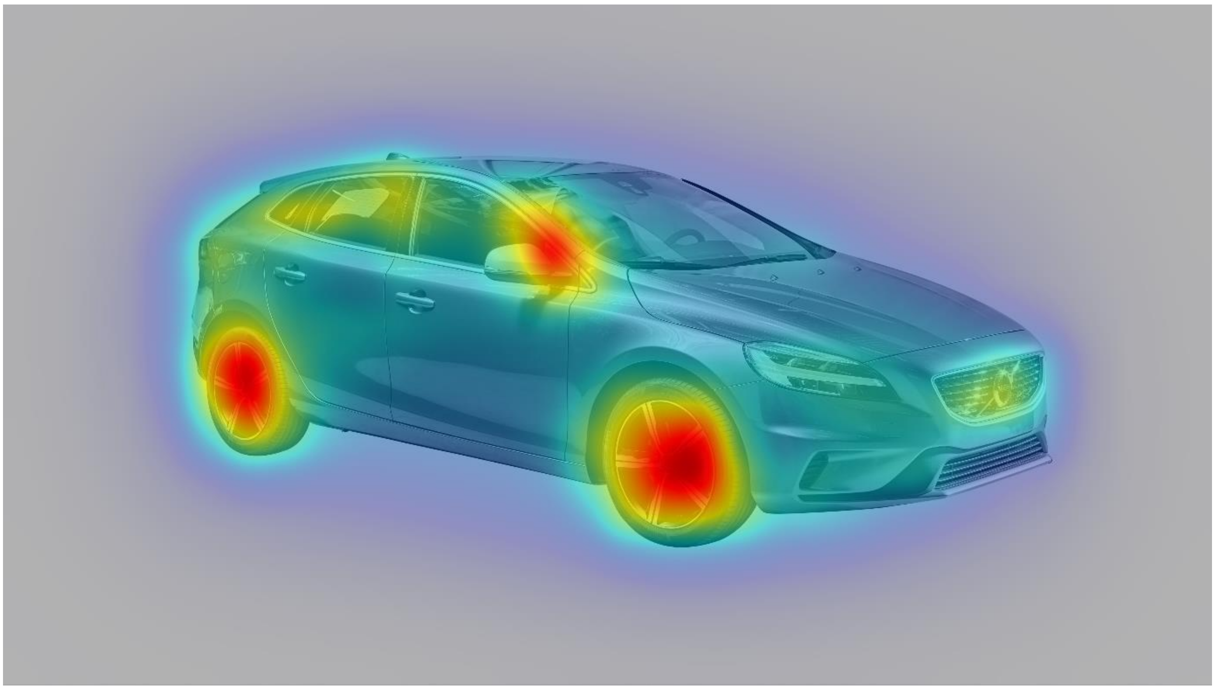
Renault Captur



Renault Clio

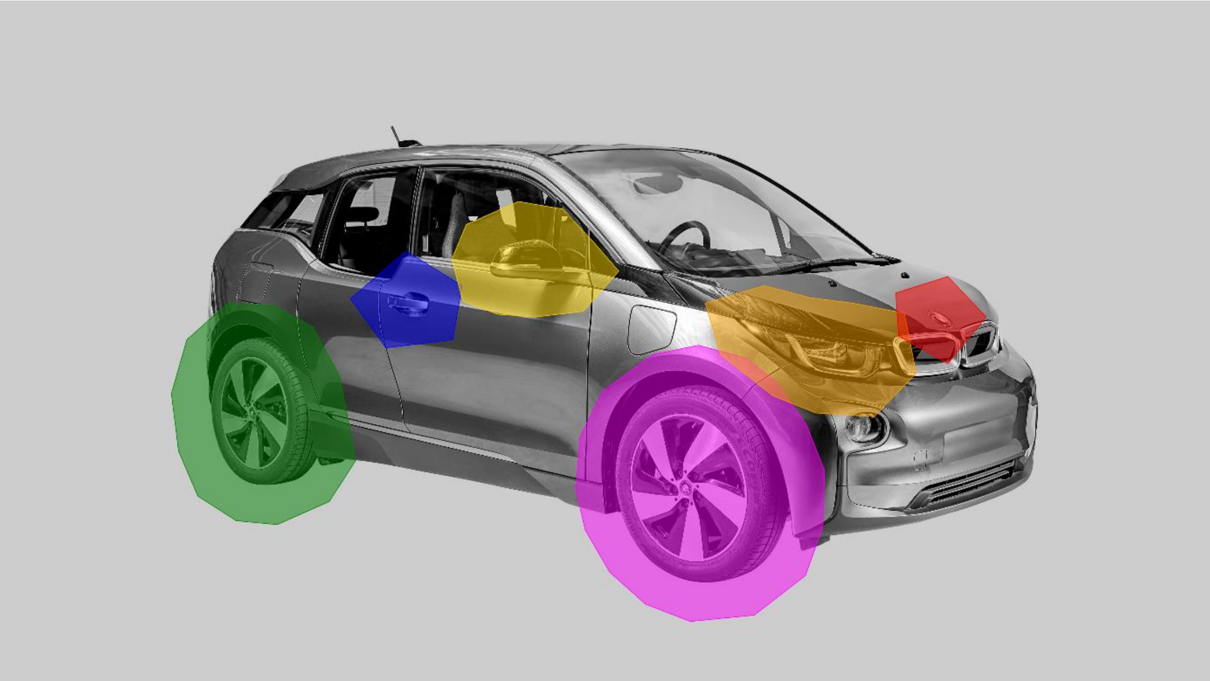


Skoda Yeti

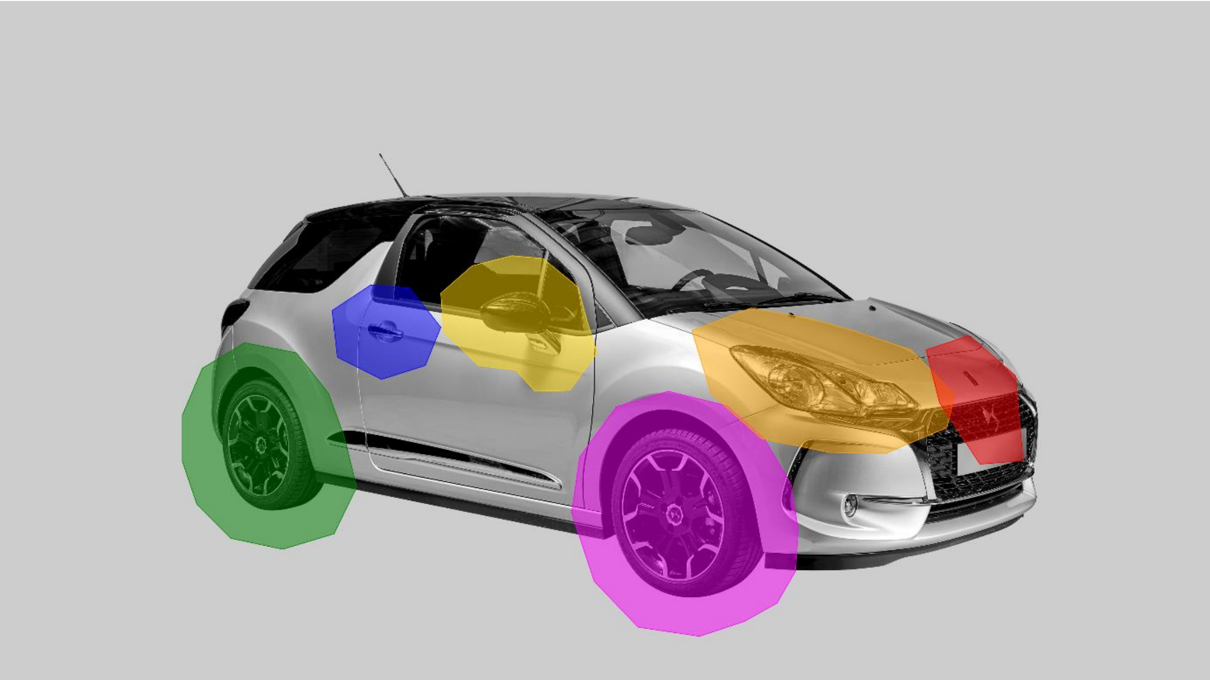


Volvo v40

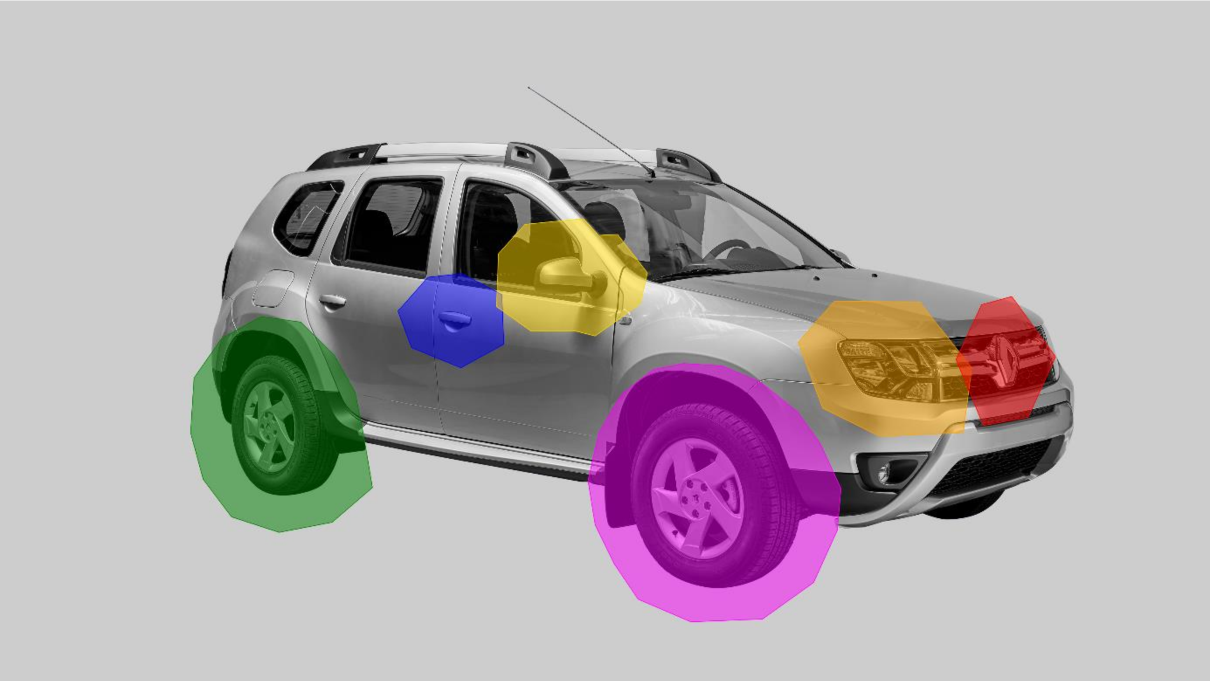
Appendix 13. Pictures of the considered car features in Study 3.



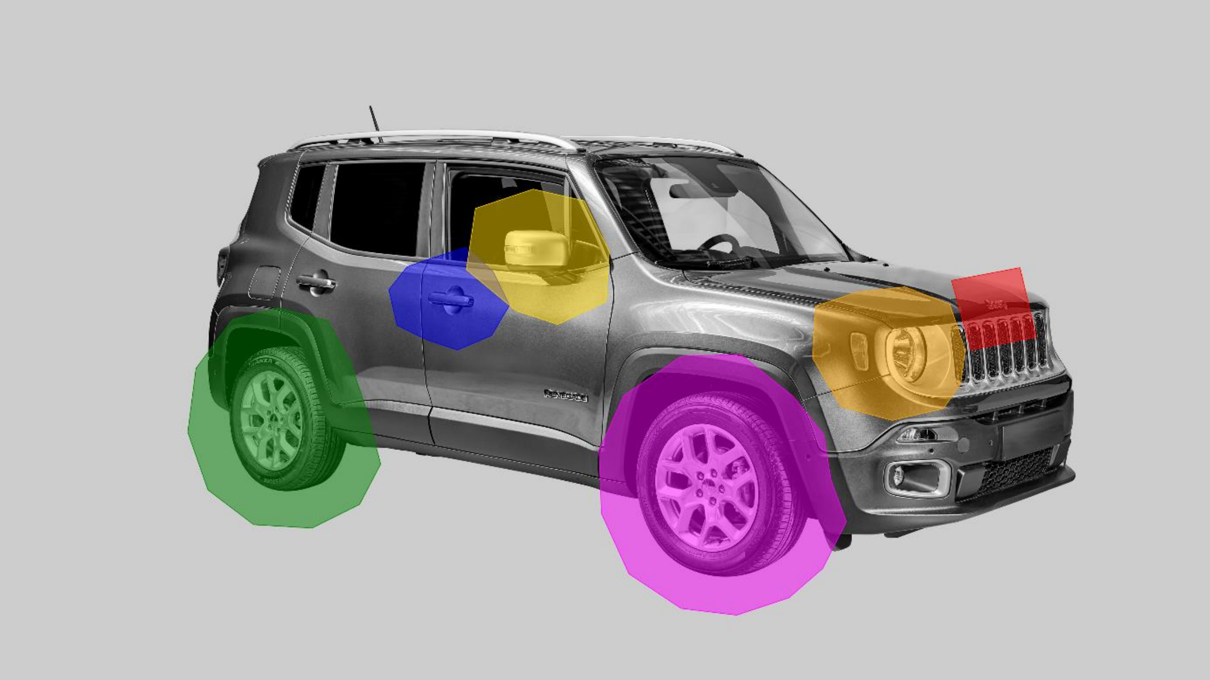
BMW i3



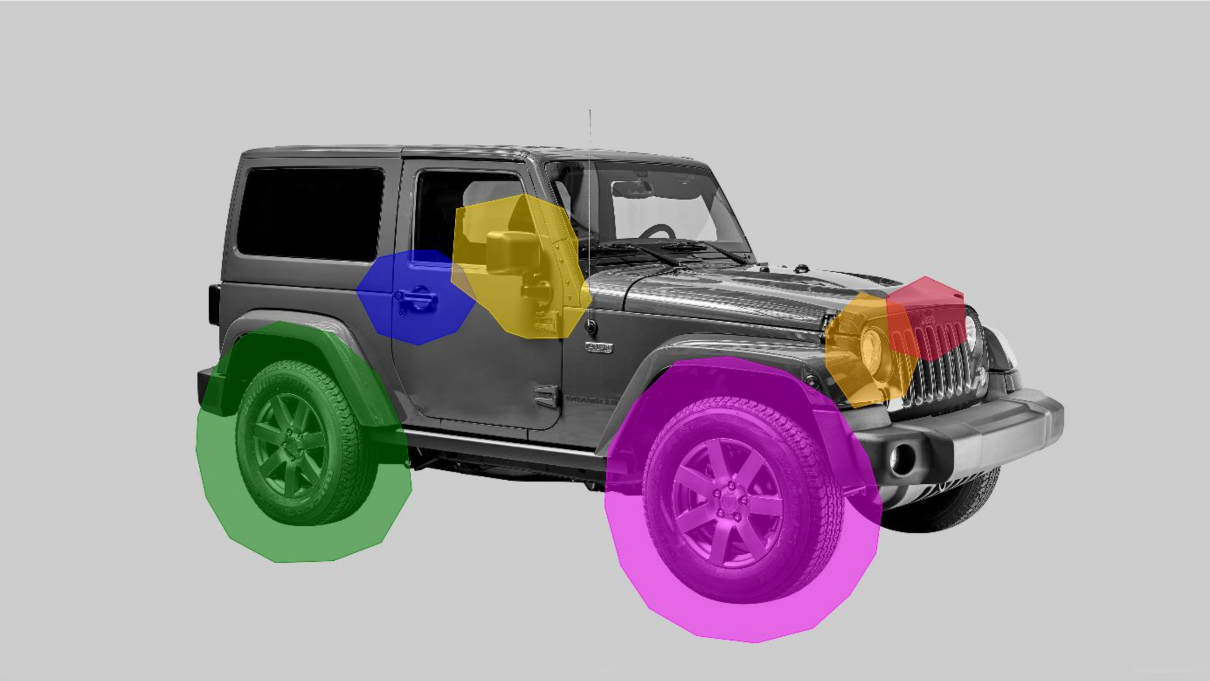
Citroën DS3



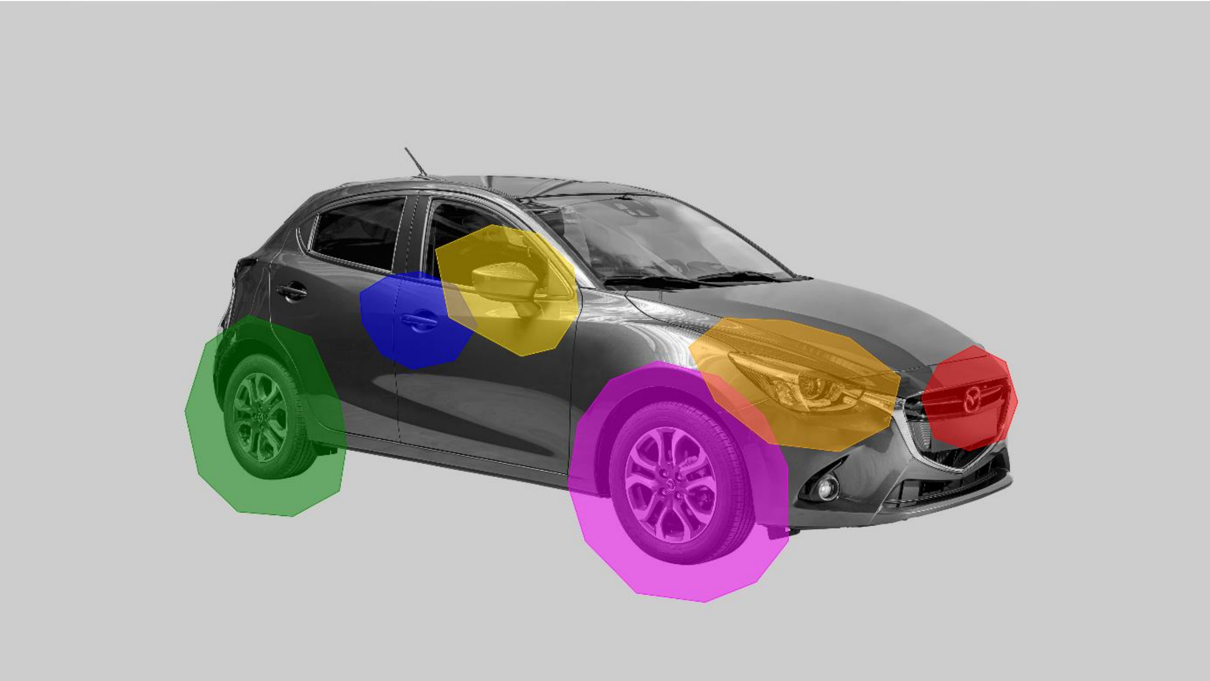
Dacia Duster



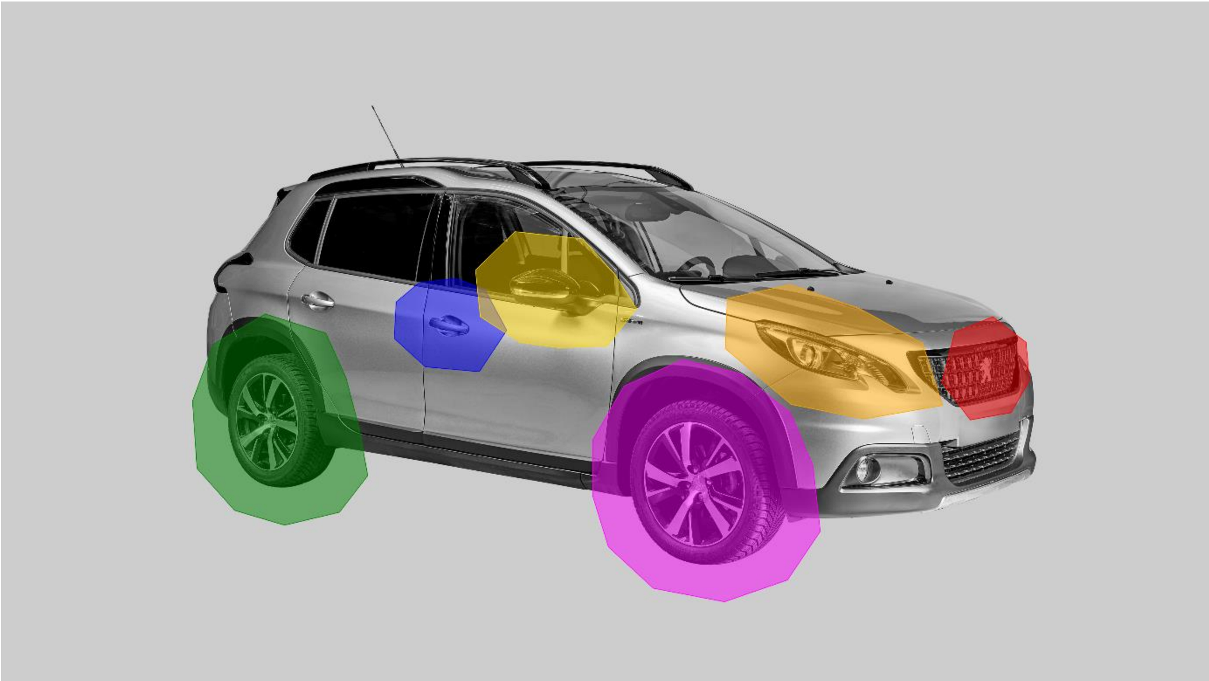
Jeep Renegade



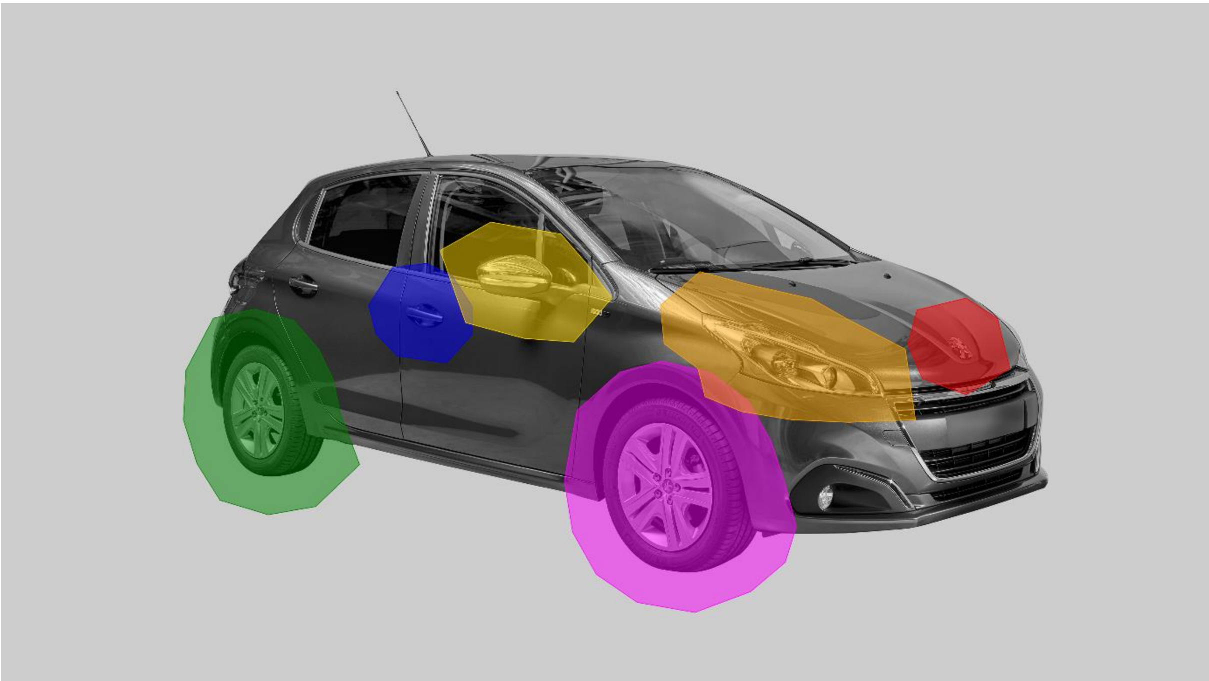
Jeep Wrangler



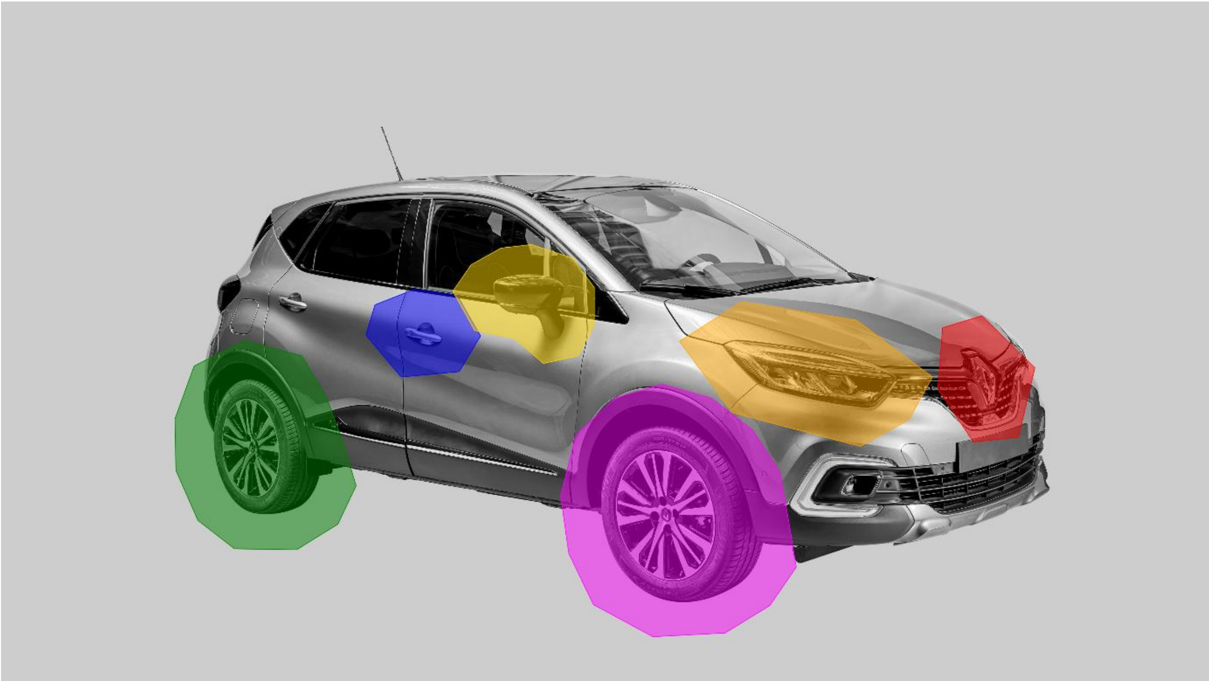
Mazda 2



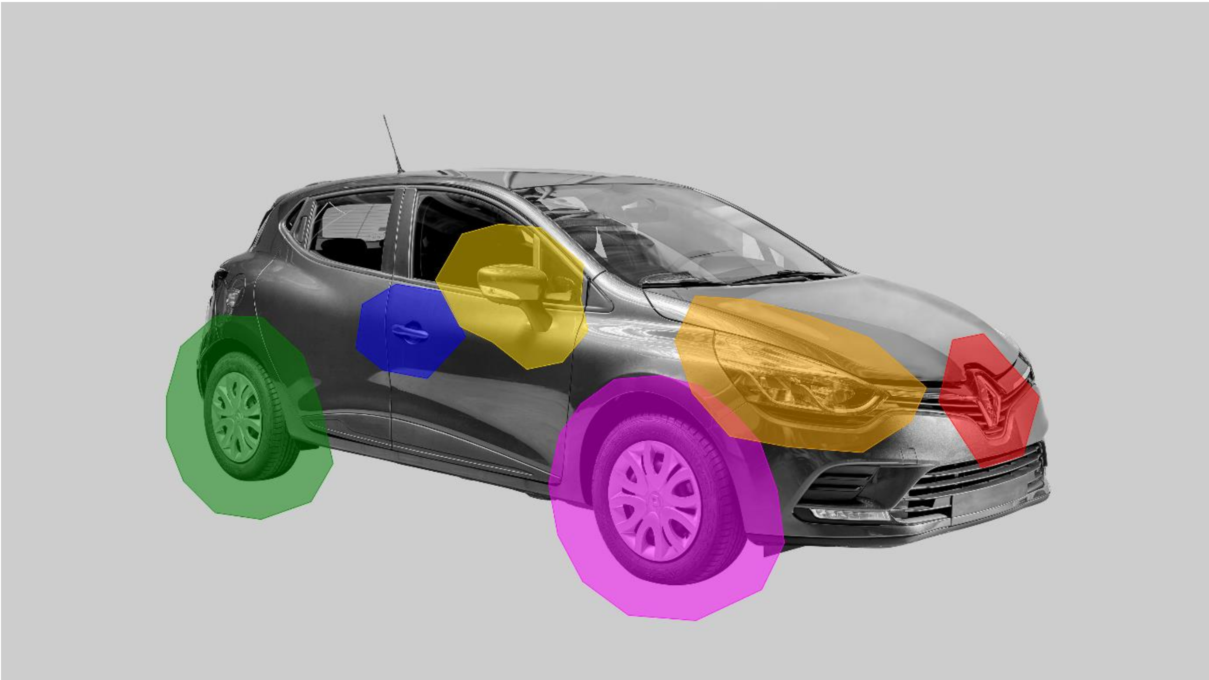
Peugeot 2008



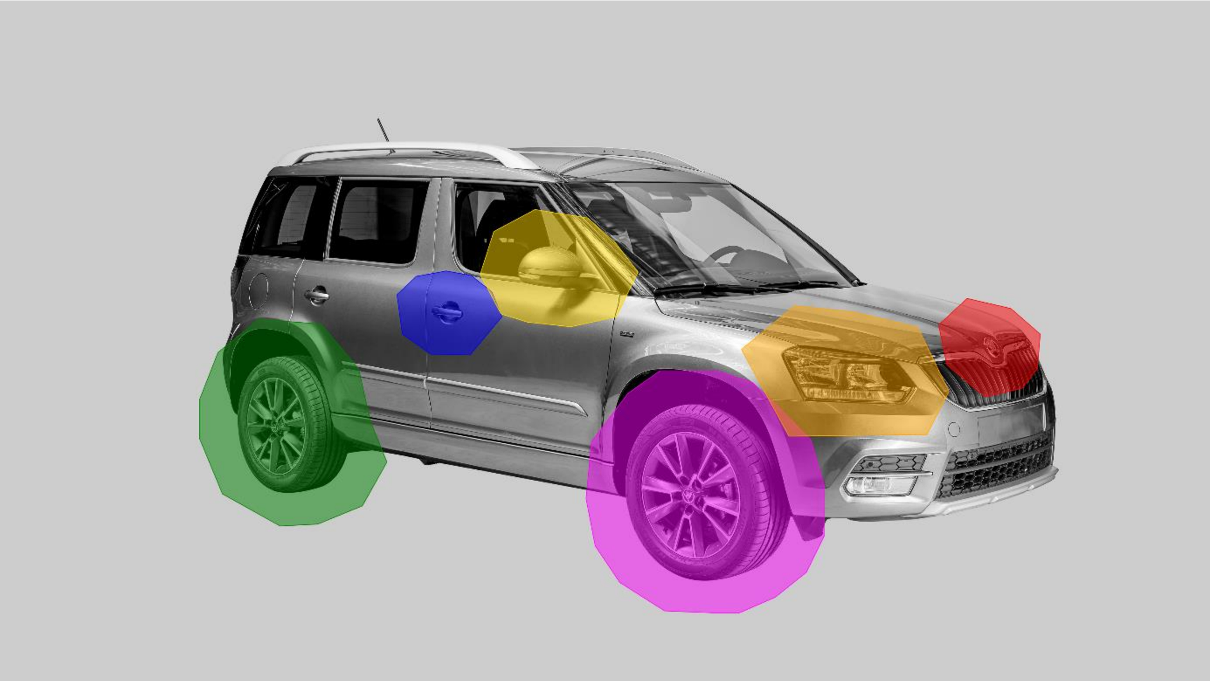
Peugeot 208



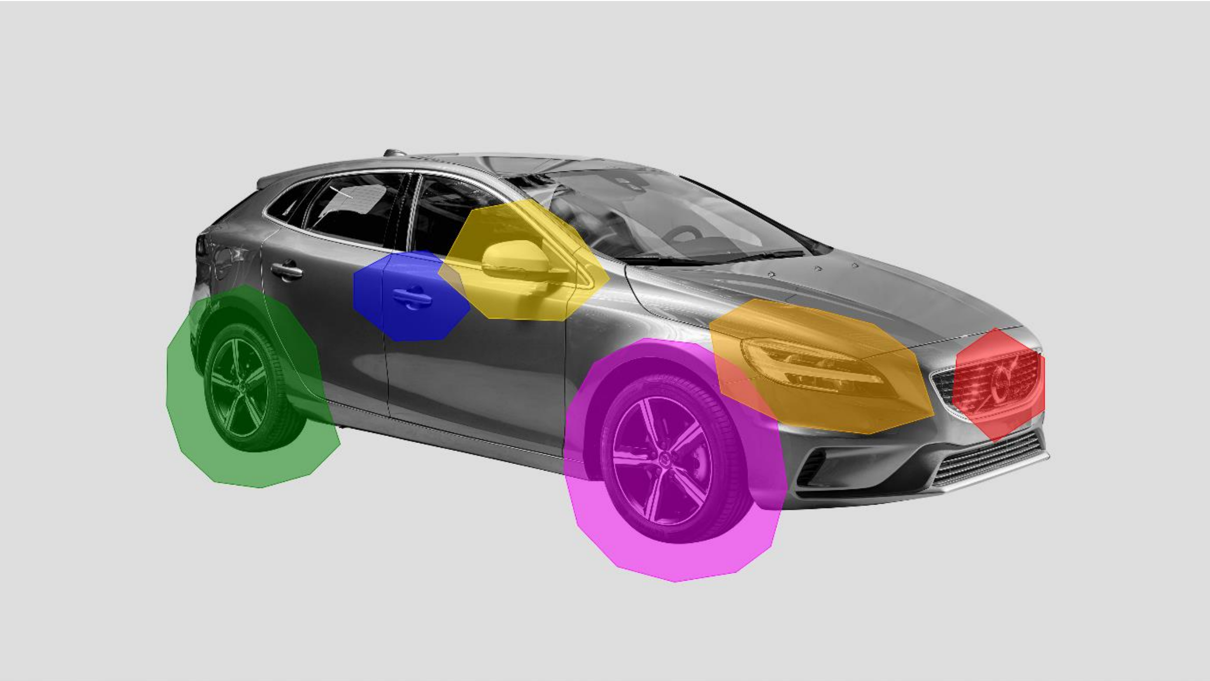
Renault Captur



Renault Clio



Skoda Yeti



Volvo v40