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Cooperation Between Design and Neuroscience: Contributions to Current Project Methodologies Applied to Automotive Design

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Abstract. Currently, the project methodologies applied to Automotive Design indicate measurement limitations of car users' emotional responses, specifically in terms of correlating such responses to product project parameters. The purpose of this article lies in the mapping and elucidation of the neurophysiological data measurement techniques adopted by Automotive Design research, developed between the years 2000 and 2017, in order to identify relevancies to project development in this field. The main outcomes achieved in each investigation are discussed, as well as the main obstacles to the advancement of studies of this nature. Moreover, it reflects on the importance of Automotive Design and Neuroscience cooperation in the analysis and evaluation of products, mostly in regards to understanding the perceptive, cognitive and behavioral processes of human beings in this context; the obtention of relevant subsidies for the project parameter definition aligned to requirements of the human organism, addressing his well-being and quality of life.

Keywords: Automotive design · Neuroscience · Project methodologies · Neurophysiological data measurement

1 Introduction

In the automotive design field, as well as in the creation and development of any other product, there are limitations to the user's perception in regards to new proposals and design concepts. Specifically referring to their emotional response measurement, which aims to correlate between such responses to project parameters in relation to the product in question.

Such evidence is gathered through literature review [32], during the period between 1995 and 2017. It indicates the following project methodology applications in the automotive design field, hereby organized by decreasing order of recurrence: Kansei Engineering [1, 3, 5, 15, 22, 24, 29, 30, 34, 35, 41–45, 47, 48, 54], Semantic Differential Technique [23, 26, 49, 50], Environment Semantic Description [2, 25], Citarasa [16, 17, 28], Quality Function Deployment integrated to Fuzzy Kano Model

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[33, 53], Robust Design Methodology [31], MCDAC [10], Zaltman Elicitation Metaphor [13], Product Emotion Measure [8, 9], Fuzzy Set Theory [18, 19], and Quantification Analysis Type I [55]. In the methodological context, which employs questionnaires and interviews to gather data related to user perception, participants are asked to evaluate their emotions in a pre-defined numerical and semantical scale.

However, emotions consist of a complex set of chemical and neural reactions, primarily expressed through automatic reactions of physical and behavioral patterns, and after expressed in verbal responses [7, 38]. In addition, emotions are a complex feedback, generated by different brain systems, with variable timing, specific to each individual, culturally motivated, experience driven, and therefore, cannot be measured by just one technique [27].

From this perspective, this article aims to discuss the context of researches that employ neurophysiological data measurement, as a step in the process of automotive design development. This reinforces that the comprehension of the complex mechanism involved in the emotional process of individuals is able to bring significant contributions to project methodologies, specifically relevant information to designers' teams – responsible for the concept and development of a range of automobiles from a specific brand. The relevancy of this information lies in the analysis and interpretation of neurophysiological data delivered by the users' biological signals, through their experiences with product prototypes. Such responses may provide: (a) preview of emotional and behavioral reactions, by pattern mapping; (b) identification of wishes and/or corresponded or not expectations; (c) project guidelines in regards to consistent and affective interactions with the product; (d) extension of well-being and the identification to the product, as a result of the reduction in discrepancy between user emotional response and intentional project concept; among others, also capable of positively impacting individual habits and life quality in this context.

To broaden the knowledge of neurophysiological measurement techniques able to be applied to the automotive design field, consider the following table (Table 1).

2 Automotive Design and Neurophysiological Assessment Techniques: Scope Investigated [2000–2017]

The research is dedicated to identifying neurophysiological data assessment techniques applied in the automotive design field, between the years 2000–2017. Twelve researches express the totality of the available scope in international literature, in the referred period. It should be emphasized that, in this context, there were no studies dedicated to data measurement through: Heart Rate (HR); Magnetoencephalography (MEG) and Positron Emission Tomography (PET). From those, seven researches apply eye tracking (ET) technique [6, 11, 20, 21, 36, 39, 52]; one of them employs, simultaneously, the eye tracking technique, galvanic skin response (GSR) and facial electromyography (fEMG) [40]; three investigate the application of Functional Magnetic Resonance Imaging (fMRI) [12, 14, 46]; and one employs the Electroencefalography (EEG) [4].

Furthermore, only Normark et al. [36] study focuses on the collaboration of neurophysiological assessment technique and project methodology, specifically in the

Table 1. Neurophysiological measurement techniques.

Technology	Activity measured	Mapped state (in real time)
Eye Tracking (ET)	Time and trajectory of gaze, pupil diameter Alteration and blinking frequency	Attention, interest, complexity and visual memory
Galvanic Skin Response (GSR)	Electric skin conductivity	Arousal state and emotion intensity
Facial Electromyography (fEMG)	Facial muscle movements	Positive and negative emotions
Electroencephalography (EEG)	Brain wave frequency	Attention level, alert and relaxing states
Heart Rate (HR)	Cardiac frequency	Attention, positive and negative emotions
Magnetoencephalography (MEG)	Electromagnetic brain activity	Relates area and brain function
Positron Emission Tomography (PET)	Brain activity by radioactivity	Relates area and brain function

application of Eye Tracking associated to Environment Semantic Description methodology. It is also important to emphasize that, from the totality of researches mentioned, only 3 investigations involve authors from the automotive sector. This fact also indicates the interaction between the automotive industry and academic areas: Fiat Brazil and Colleges and Foundation of Minas Gerais, in Brazil [11]; Daimler-Chrysler Research Center and Ulm University, in Germany [12]; and Hyundai-Kia Motors and National Institute of Science and Technology ULSAN, in South Korea [4]. The table below summarizes the scope that will be discussed in sequence. It is organized by technology recurrence and presents each research in regards of neurophysiological data assessment applied in the automotive design sector (Table 2).

2.1 Eye Tracking and Semantic Environment Description

Normark et al. [36] employed the eye-tracking equipment Tobii x50, associated with two semantic evaluation methods, SMB – Semantic Environment Description and PSA – Product Semantic Analysis, in addition to interviews oriented by heat-maps reached through ocular assessment, to evaluate the visual appearance of eight instrumentation clusters, attached to the automotive panel. The categories "pleasantness", "complexity", "unit", "social status", "affection" and "originality" were classified in a 7-point Likert scale by 23 young participants, divided in four groups. Group 1 and 3 had access to left instrument panels, while groups 2 and 4 analyzed panels on the right. Two of the instrument panels, B and F are used as references in both scenarios.

We can infer that the participants follow a western reading trajectory, as they focus their attention from left to right, and from top to bottom, as showed in the following picture. However, it is not possible to correlate the gaze time and the attractiveness of the clusters, once the screen projection is downscaled and the visual perception of

Table 2. Researches in automotive design, which apply neurophysiological assessment techniques [2000–2017]

Technology	Researcher/Affiliation	Context of evaluation	Results
Eye Tracking (ET) and Semantic Environment Description (SMB)	Normark et al. [36] Lulea University, SWE	8 instrumentation clusters	ET as an interview support
Eye Tracking	Windhager et al. [52] EFS Company; Vienna University; Salzburg University, AT Bamberg University, DE	38 digital models, front view	Anthropomorphic perception; headlamp receives more attention
Eye Tracking	E Sousa et al. [11] Fiat Automobile, FAPEMIG University, USP University, BR	3 hatchback, front view	Preference order: Hyundai i30, Ford Focus and Fiat Bravo
Eye Tracking	Purucker et al. [39] Würzburg University, DE Washington University, USA St. Gallen University, SWZ	8 images, front view	Anthropomorphic perception
Eye Tracking	Chassy et al. [6] Liverpool Hope University, UK	50 mid-size cars, front view	visual complexity and gaze trajectory; aesthetic pleasure and dwelling time
Eye Tracking	Hyun et al. [20, 21] KAIST Advanced Institute of Science and Technology, KOR	119 cars from 23 brands, front, side and rear view	Front bumper and fender, side silhouette
Eye Tracking, Galvanic Skin Response, Facial Electromyography	Schmitt et al. [40] RWTH Aachen University; WZL Laboratory, DE Universitat Politècnica de València, ES	Production line SUV image and modified, ¾ view	Bumper and 'power'
Functional Magnetic Resonance Imaging	Gauthier et al. [14] Vanderbilt University; Yale University, USA	Cars, birds, familiar objects and human faces	Fusiform gyrus and facial recognition
Functional Magnetic Resonance Imaging	Erk et al. [12] Daimler-Chrysler Research Center; Ulm University, DE	Limousine, sporty and compact car images	Sporty cars activate reward brain area

(*continued*)

Table 2. (*continued*)

Technology	Researcher/Affiliation	Context of evaluation	Results
Functional Magnetic Resonance Imaging	Sylcott et al. [46] Carnegie Mellon University, USA	Car silhouette, side view	Anterior cingulate gyrus activated for form and function; insula activated for form
Electroencephalography	Chae et al. [4] Hyundai-Kia Motors; Ulsan National Institute of Science and Technology, KOR	HUD display	Information quantity activates central lobe; temporal lobe associated to concentration level

details may be affected, such as font variations in the text. The reduced number of subjects could compromise the studies validation. On the other hand, this investigation identifies eye tracking as a tool to guide interview discussions, by contrasting it with the user heat-map and its evaluation in regards to areas of interest and each element rating (Fig. 1).

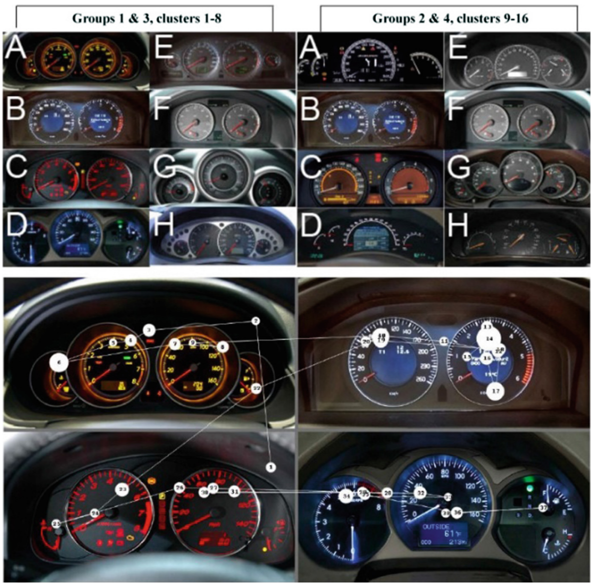

Fig. 1. Above: Cluster panels used in the study; bottom: visualization order of a participant. Font: adapted from Normark et al. [36]

2.2 Eye Tracking

The studies conducted by Windhager et al. [51, 52] aim to evaluate the human tendency of anthropomorphic perception. In other words, the investigation relies on identifying human face characteristics in front car view, through the following associations: 'headlamp and eyes', 'front grille and nose', 'air intake and mouth', and 'side view mirror and ears'.

In the study the IView X Hi-Speed tracking column camera is used to assess and analyze the eye-tracking data of 49 participants, while they evaluate 38 three-dimension digital car models from 26 different brands, related to existing cars on the market between the years 2004 and 2006. As a result, the tendency for anthropomorphic perception in visual interpretation is confirmed, through analogy identification between human faces and inanimate objects, such as the 'headlamp-eye'. Moreover, in human face perception, the eyes get more attention from the individuals (Fig. 2).

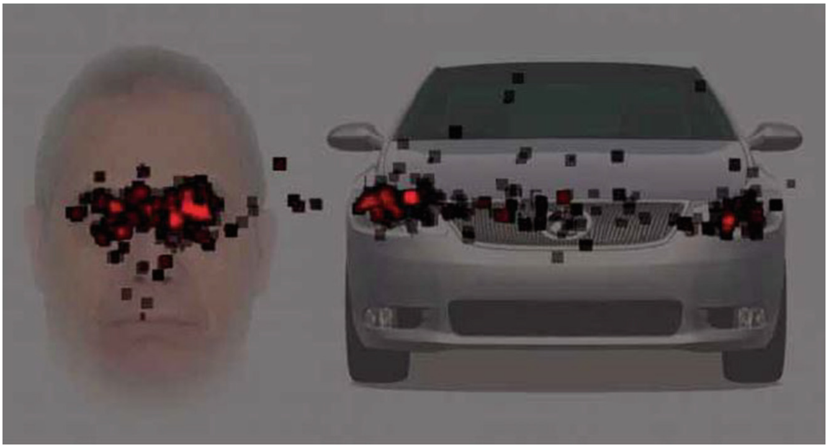

Fig. 2. Anthropomorphic perception: participants answer to the following question "Do the face and the car have the same eyes?" Font: Windhager et al. [52]

E Sousa et al. [11] investigates pupil diameter and heat-map from 30 participants, when in contact with three front view images from hatchback cars sold in Brazil: Fiat Bravo, Ford Focus and Hyundai i30.

The data gathering employs the Viewpoint of Arrington Tracker Research equipment, constituted by a pair of glasses with three cameras. Two of them are orientated to the participants' eyes, through two infrared Leds (invisible to the human eye) that read the pupil diameter, without distracting or disturbing the viewer. The third camera captures scenes analyzed by the individual in real time. The main goal is to examine the attention and interest area of each observer in relation to headlamps, brand logo, front bumper, front grill, hood and outside mirrors. And when measuring the pupil diameter, direction and gaze time of each individual, it is intended to identify elements of preference, with a view to future design solutions.

In the figure below, the red dots represent the left eye data assessment, and the yellow ones, the right eye. Next to it, there is data exported from the software. The results obtained from eye tracking equipment, associated to questionnaire answers with scale variation between ‘like’ and ‘do not like’, indicate the following participants preference order: (1) Hyundai i30; (2) Ford Focus; and (3) Fiat Bravo.

Only when each car was assessed individually, not side by side, it became possible to identify the relationship between the interest and preference points from viewers. According to the findings, the most preferred item in the Fiat Bravo was the headlamps, while the least one was the outside mirror. Such preference is measured from the correlation between the visualization of these items and the alterations caused in the pupil diameter (Fig. 3).

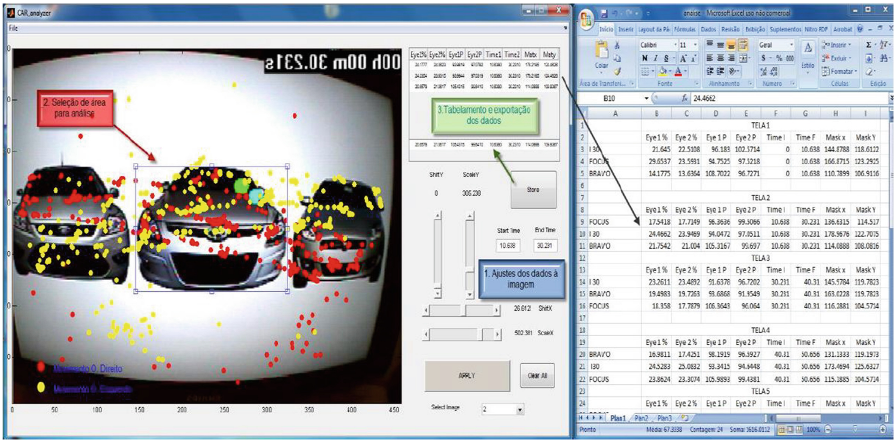

Fig. 3. Visual stimulus analysis by eye tracking (left): red – left eye; yellow – right eye. Data output (right). Font: adapted from E Sousa et al. [11] (Color figure online)

Purucker et al. [39] study investigated automatic responses in the observer evoked by car frontal views. Specifically, responses similar to those evoked by the human face and identified by anatomic structures of fusiform gyrus, according to the evolutionary mechanism of facial perception. The study seeks to comprehend if initial exposure to design characteristics qualified as ‘threatening’ attract observer attention, and if prolonged exposure to the same stimuli result in avoidance of those areas.

Modified frontal view images are used as stimuli for the participant to analyze. Eight combinations set the visual scope to be evaluated, in which there are variations in elements such as flipped headlamp, air intake and side air intake.

Tobii X120 eye tracking equipment is employed in the 8 images analyzed by 39 individuals. Primarily, it can be confirmed that subjects focus their attention on the ‘threatening’ elements. Besides that, participants prefer ‘threatening’ headlamps and ‘non-threatening’ air intake. In a second phase, it was found that 32 subjects avoided long periods of observation to design elements deemed as ‘threatening’.

According to evolutionary biological preparedness perspectives researchers [39] suggest that threatening facial expressions are processed faster and more accurately, if compared to friendly faces.

In conclusion, anthropomorphic car frontal design may attract attention and manifest specific behavior in the subject. In other words, the visual patterns associated to gaze activate the affective dimension and, thereby, are relevant in capturing the attention and reaching satisfactory evaluation from the user (Fig. 4).

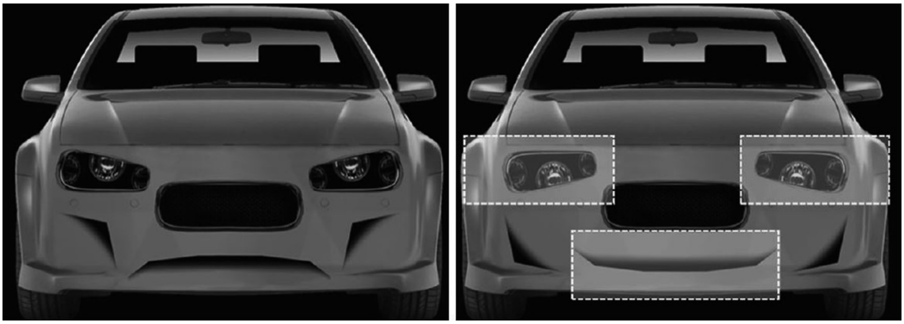

Fig. 4. 'Threatening' design (left); and 'non-threatening' (right), with headlamp, lower and side air vent variation. Font: Purucker et al. [39]

Chassy et al. [6] investigate the relationship between visual complexity and aesthetic pleasure, associated to two eye-tracking parameters: trajectory and gaze permanence. The device 'EyeLink1000' is attached to a head mounted feature to monitor and analyze left eye behavior, when visualizing 50 images of different mid-size car frontal views. Twenty-six students, 13 men and 13 women without art background or professional experience in automotive sector, evaluated the attraction degree of each image. A 9-point Likert scale was used with the following parameters: aesthetic appraisal – evaluated between −4 (ugly) and +4 (beautiful); and visual complexity – between 1 (simple) and 9 (complex). As a result: (a) the relationship between visual complexity and aesthetic pleasure are characterized by a U inverted curve calculated by a quadratic equation; (b) gaze is an objective behavior measure related to visual complexity; (c) dwelling time is correlated to aesthetic pleasure. Meaning, the observer spends more time exploring the image elements when the object is considered attractive (Fig. 5).

Hyun et al. [20, 21], via eye-tracking, identify the relationship between the visual observation patterns of 10 participants, familiar with automotive design, and the exterior design elements in 119 medium-sized sedans (on the market between 1999 and 2013) from 23 different brands.

Each car selected for the study is represented by 3 drawings: frontal, lateral and rear view. These drawings are used as a visual stimulus to the participants during the experiment with the Tobii X120. Nineteen design elements are analyzed, from the parameters: (a) duration of gaze on the area of interest; and (b) mapping of gaze

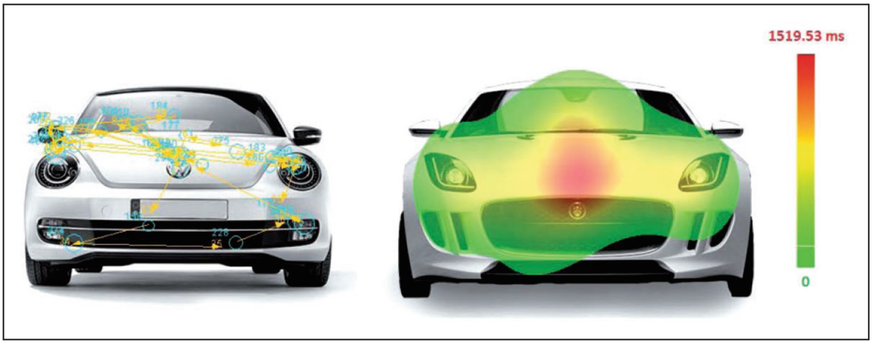

Fig. 5. Left – eye trajectories (visual complexity); right – eye tracking heat-map reflecting dwelling time (aesthetic pleasure). Font: Chassy et al. [6]

permanence. As a result, the most relevant exterior elements are the side silhouette, front fender and front bumper. Specifically, for luxury brands, participants focus attention on the silhouette, window and side taillamp (Fig. 6).

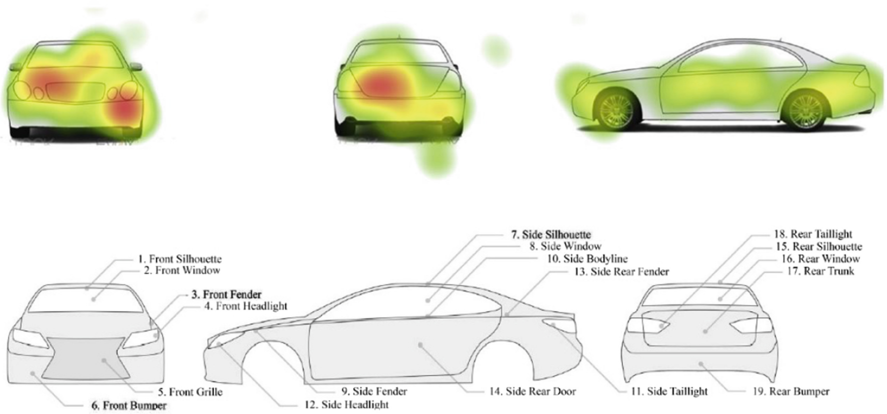

Fig. 6. At the top: red - long gaze time and green – short gaze time; at the bottom: most relevant elements in bold (3, 6, 7). Font: Hyun et al. [20, 21] (Color figure online)

2.3 Eye Tracking, Galvanic Skin Response, Facial Electromyography

The research of Schmitt et al. [40] seeks to identify the relevance of the external components of the sports utility vehicle (SUV), when assessing the emotions elicited by its elements. In addition, the study investigates the applicability of the screen-based eye-tracking system in the measurement of the degree of attention. Furthermore, they check the influence of the semantic concepts in the evaluation of the product mediated by the measurement of biological signals, in this case, through the association between facial electromyography (EMG) and galvanic skin response (GSR) techniques.

In the first phase, 25 participants holistically analyze the exterior image of two sports utility vehicles, one of which is the production model and the other a modified model. In this context, they evaluate their impression with the semantic concepts: “dynamic”, “powerful”, “sporty” and “modern”, in a 5-point scale. The explicit results were combined with the eye-tracking technique (ET), and it was concluded that the modified car is considered significantly more “potent” in terms of power when compared to the production model.

The second stage of the study focuses on the identification of quality attributes associated with certain concepts by users, either voluntarily or involuntary. To this end, areas of interest of the participants are mapped, via ET, during free visualization of the product image, and after presentation of the “dynamic” semantic concept. The figure below indicates relevant information regarding the attention, order and frequency of fixation of each individual’s gaze (Fig. 7).

Fig. 7. Individual gaze track for one user (free interaction vs. ‘dynamic’ concept). Font: Schmitt et al. [40]

Subsequently, the emotions are investigated via galvanic skin response (GSR) and facial electromyography (EMG), with the objective of verifying the quality of the users’ evaluation (positive or negative), in relation to specific design alternatives. In addition, they seek to identify the influence of the semantic concept on the behavior of neurophysiological signals. Fourteen students participate in this measurement (Fig. 8).

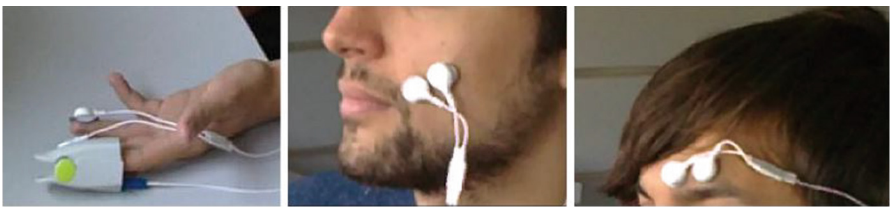

Fig. 8. Placement of sensors for detecting bio-signals. Left: Skin Galvanic Response (GSR); Center and right: Facial Electromyography (fEMG). Font: Schmitt et al. [40]

The results of the study suggest that semantic concepts affect eye-tracking and attention span over the relevant attributes of the product, as well as the signs of galvanic skin response and facial electromyography. The diagram below confirms the possibility of obtaining, for each attribute of the product in question, design recommendations regarding the attention evoked by the semantic concepts. In this case, the front bumper is mentioned as an example. The evaluation indicates it as a relevant attribute to the perception of the modified car as more "powerful" when compared to that of the production model (Fig. 9).

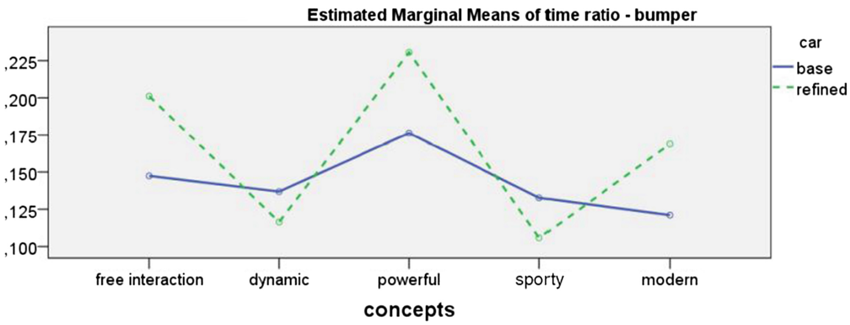

Fig. 9. Diagram representing semantic concept effect on the bumper perception. Font: Schmitt et al. [40]

2.4 Functional Magnetic Resonance Imaging

Gauthier et al. [14] confirm that the tasks of identifying and categorizing animals and cars, by specialists in these domains, activate the brain areas involved in facial recognition. With the use of the fMRI technique, they observe the brain activity of eight specialists in the identification of bird species and eleven professionals in the automotive sector, who are skilled at recognizing car models, when both groups are exposed to 4 categories of visual stimuli: human faces (Caucasian and without hair); familiar objects; cars (in models from years 1995 to 1998); and birds (from New England). All images are displayed in the chromatic scale of gray.

In conclusion, both categorization and identification, aside from experience, determine the specialization of fusiform gyrus, located in parts of the temporal and occipital lobes in area 37 of Broadmann, which is responsible for facial recognition (Fig. 10).

While the studies by Erk et al. [12] investigate the connection between the brain mechanism associated with reward and ownership of cars and the image of wealth and social dominance.

The fMRI technique is used through the 1.5 T Siemens Magnetom Symphony device to observe the brain activity of twelve male drivers, during the observation of 66 gray scale car images. The images are equally distributed in the following categories: sport; limousine; and compact. Associated with the fMRI technique, a 5-point scale

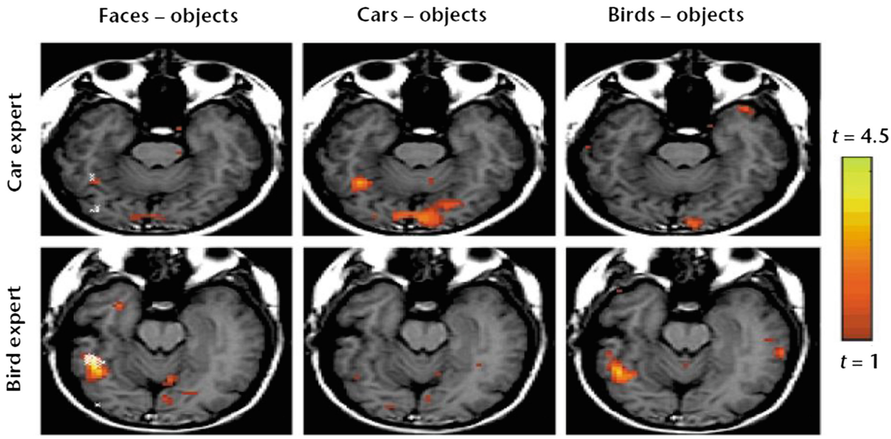

Fig. 10. Brain activation for cars and birds identification specialists, accessed by fMRI. Font: Gauthier et al. [14]

aims to assess the attractiveness of these models, based on the responses attributed by the drivers.

The rating obtained from the attractiveness scale indicates a better evaluation of sports cars, when compared to the other categories. In parallel, the results obtained through the fMRI technique express that cultural objects, associated with wealth and social dominance, modulate the reward dopaminergic circuit by stimulating brain-related areas: ventral striatum; orbitofrontal cortex; anterior cingulate gyrus; and occipital region. It is known that the reward mechanism induces subjective feelings of pleasure and contributes to trigger positive emotions (Fig. 11).

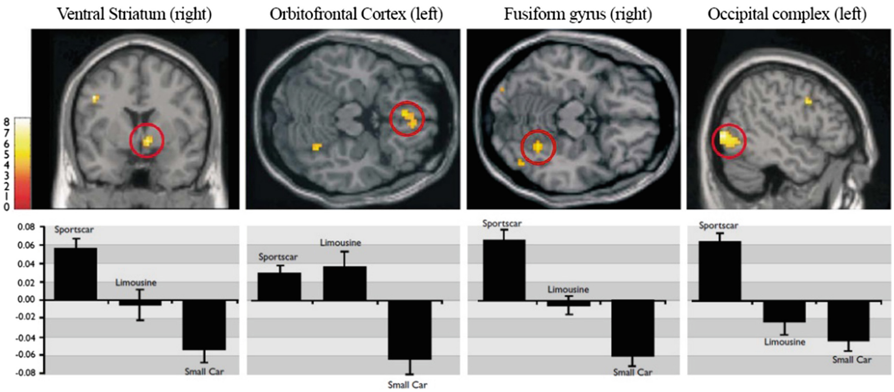

Fig. 11. Image of brain regions mapped for contrasting sports cars > small cars, accessed by fMRI. Font: Erk et al. [12]

The research of Sylcott et al. [46] investigates the preference and judgment processes, as well as consumer decision-making in regards to stimuli related to aesthetic (form) and automotive performance (function). The first phase employs the statistical technique of joint analysis and self-report, and the second adopts the fMRI technique.

The primary phase identifies the aesthetic preference of 14 participants considering 36 options of automobile silhouettes, with the following variations: shoulder, ramp angle, distance from the ground, body height, ceiling height, hood length, and trunk length. Of the total number of options, the distance between wheels and the wheel size remain constant. In this context, the functional preference is also identified, in which the performance specifications are observed, such as: acceleration, fuel consumption, power and braking. Subsequently, 25 combinations of preferences are observed, both aesthetic and functional, in order to evaluate the balance between decision-making and the above-mentioned attributes. The result of the first phase indicates the preference for the function, coming from the majority of participants.

In the second phase, validation of the first experiment occurs, through self-report, reading and interpretation of the brain activity of 7 individuals by fMRI. The collection of data is performed during the visualization of 24 stimuli, which focus on conflicts between form and function. Using the Siemens 3T Verio Scanner, the fMRI technique aims at highlighting the brain areas involved in the mechanisms associated with logic and emotion, and at the same time, relating the decision-making between form and function.

When analized individually, form and function activate the dorsal region of the anterior cingulate gyrus (involved in conflict monitoring, error detection in both domains, cognitive and emotional, and decision making) and the dorsolateral prefrontal cortex (cognitive reasoning). However, the insula (area of the limbic system associated with emotion derived from visceral experience) is exclusively activated during the analysis of the form. When evaluated simultaneously, form and function activate the dorsal region of the anterior cingulate gyrus; the limbic region, which includes part of the ventral striatum; and the area related to emotion and reward. In a situation of conflict between form and function in the process of decision making, the midbrain regions were activated, as well as the orbitofrontal cortex, the parahippocampal gyrus and the amygdala, which are associated with emotion and its regulation (Fig. 12).

2.5 Electroencephalography

Chae et al. [1] investigate the relationship between six basic emotional states (joy, sadness, anger, disgust, fear and neutral) and the brain signals evoked by different head-up display (HUD) configurations - technology that projects information on speed, fuel level, navigation, gear position, and others onto the windshield. Twenty participants are exposed to 18 HUD images performed in a laboratory-controlled environment and in a driving simulator. These images differ according to the type of content, color and source, according to (Fig. 13).

Sixteen localized channels in the participants' scalps are monitored through electroencephalography (EEG) technique. Three of them, associated with the indexes of mental activity, level of concentration and relaxation, are analyzed more in-depth from the PolyG-A equipment. In addition, participants report their emotions on a 7-point

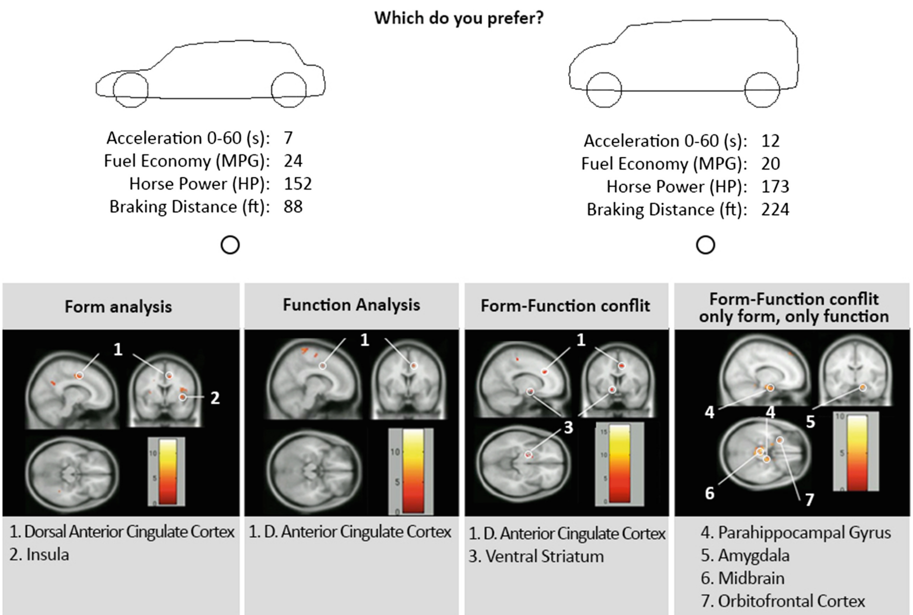

Fig. 12. Form vs. function: brain activity assessed by fMRI technique. Font: adapted from Sylcott et al. [46]

scale using the semantic differential technique, utilizing dichotomous adjectives such as "modern-old fashioned", "masculine-feminine", "comfortable-uncomfortable", "smooth-rough", "clear- ambiguous". The study shows that HUD images evoke different brain signals, concentration levels, and emotions. Moreover, color proves to be the main factor in determining the type of emotion evoked, while the amount of information determines the level of activation in the brain's central lobe. The brain activities in the temporal lobe are positively associated with the level of concentration. In this sense, it is possible to affirm that discoveries in the association between emotions and EEG signals can be used in the design of new driver-vehicle interfaces.

In order to clarify the understanding of the investigations that analyze human neural activity, through fMRI and EEG techniques, consider the following illustration of the brain areas and their correlation to perceptive, cognitive and behavioral processes (Fig. 14).

3 Conclusion

The mapping carried out by this research facilitates the formulation of inferences about the role and use of neurophysiological data verification techniques in the scope of Automotive Design and its association with design methodologies currently applied, specifically in the period between the years of 2000 to 2017.

Fig. 13. Top: 18 HUD images and brain activity induced by each image. Bottom: Electroencephalography experiment in laboratory and in simulator. Font: Chae et al. [1]

Although the twelve investigations covered here demonstrate the cooperation between the fields of Automotive Design and Neuroscience, and how promising and rich this research pathway proves to be, only two of them have professionals working in the automotive sector on their research team. This indicates an existing gap between the productive (automobile industry) and research (laboratories/universities) sectors, which endorses the reduced number of studies available in international literature.

Another factor that also corroborates this limitation lies in the main obstacles to the advancement found by research of this nature: (a) expressive sampling of participants to validate data collection; (b) limitations to the sampling of participants due to the use of technologies that require high investment of time and financial resources, and invasive radioactive material employment, such as PET; (c) limitations to the comparison of research results obtained through the same technology, caused by the adoption of different methods of induction, measurement and data processing, as cited by Phan et al. [37].

Despite the above mentioned adversities, the contributions of neurophysiological data assessment techniques are notorious when associated with design methodologies and, consequently, incorporated into product design and development stages. Such contributions emphasize, but are not limited to: (a) enable 'access' to brain areas related

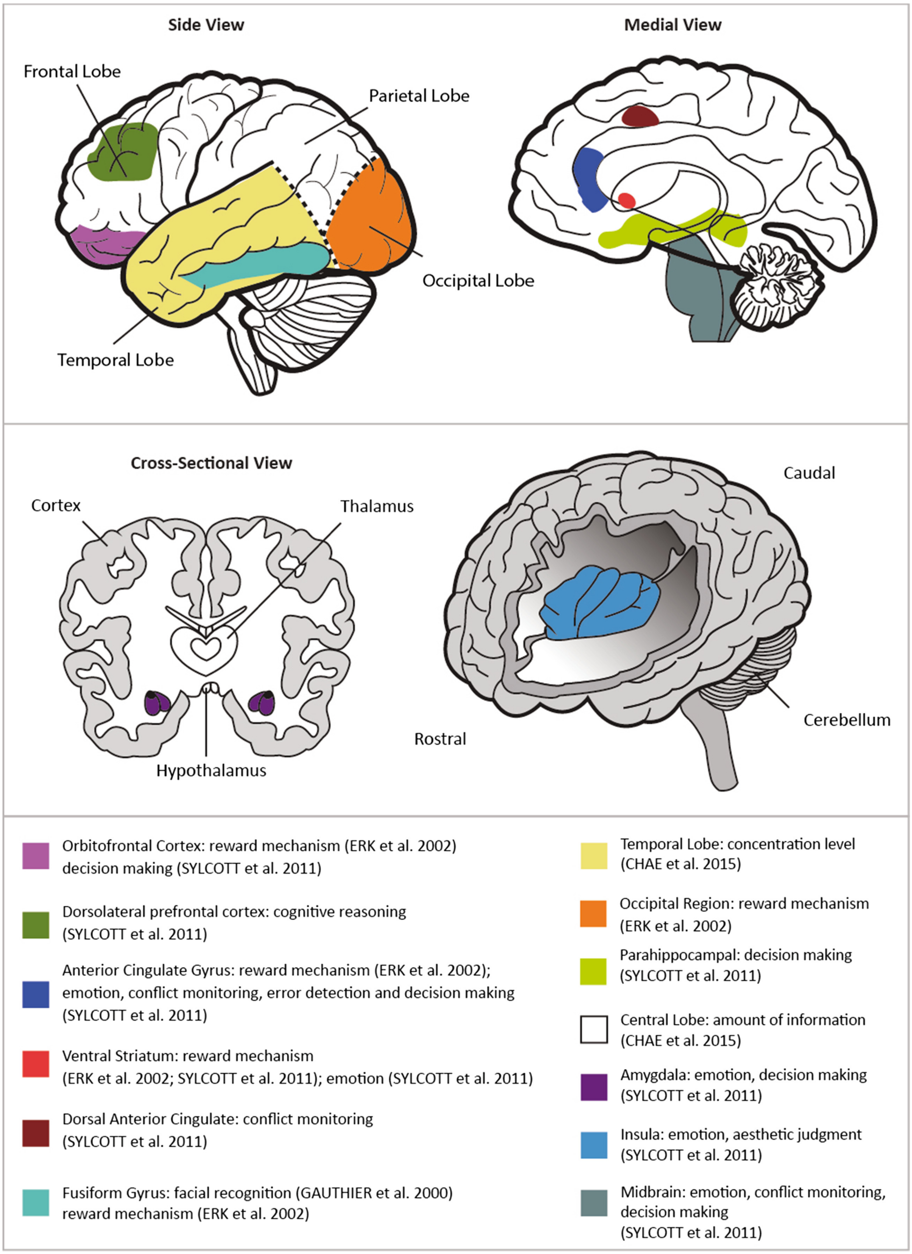

Fig. 14. Anatomy of brain areas and their respective functions, described in fMRI and EEG investigations. Font: the author (2018)

to visual memory and, thereby, providing information relevant to the perception of the product; (b) measure the degree of complexity and impacts coming from product stimuli on the brain; (c) highlight the brain mechanisms involved in the process of distinguishing between product design alternatives; (d) evaluate the neurophysiological behavior of the user in the preference and decision making processes, resulting from the selection between products; (e) facilitate the identification of design requirements demanded by the human organism itself.

For future development, this research focuses on the proposition and validation of automotive design parameters, seeking to formulate an integrated project methodology, which articulates the principles of Product Design and Neuroscience at its core. This articulation aims to broaden the spectrum of analysis and evaluation of the biological data of the potential user to the products elaborated in this context, through the combination between the different techniques of gauging neurophysiological data. The purpose is to ensure that the needs and preferences expressed by the emotional response of these users, integrate the vehicle design requirements and parameters in order to bring benefits to their well-being and quality of life in this environment.

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