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USING BRAIN IMAGING TO MEASURE EMOTIONAL RESPONSE TO PRODUCT APPEARANCE

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ABSTRACT
Brain imaging systems are a set of techniques that allow visualizing the regions of the brain that are activated when (emotional) stimuli are presented. Their advantage over traditional methods of measuring emotion, like self-reports is that they leave out response biases. This paper presents what brain imaging measurement can do for emotional design. It also reviews the brain imaging studies that have been performed in the field of emotional design. Very few such studies were found, and they were dispersed among different disciplines: design, marketing, advertising, human-computer interaction. One of the results of that investigation is that the complexity of brain imaging systems and of designing adequate experimental setups imply that brain imaging be reserved for some very specific purposes, like obtaining the very first impression of a product design.

Keywords: emotional design, emotion measurement, brain imaging, physiological measurement

1 INTRODUCTION
Ten years ago, Desmet et al. [1] wrote: "Psychophysiological instruments measure typical physiological reactions that come along with emotions, such as changes in heart rate or pupil dilatation. These measures cannot be used to distinguish emotions since they only indicate the amount of arousal that is part of the emotion. Moreover, emotions of low intensity are difficult to assess with these measures. Therefore, psychophysiological instruments are not suitable for the present purpose of measuring emotions elicited by product design." Psychophysiological measurement techniques permit the immediate and continuous measurement of the bodily reaction to an emotional stimulus. They bypass the subjectivity and ambiguities of self-reports and allow for a precise matching between the emotional trigger and the emotional reaction. These last ten years, the importance of the emotional factor in product experience made it the focus of a growing number of studies, and psychophysiological measurement techniques have known a vivid renewal of interest. The expression *neuromarketing* has appeared, promulgating immense enthusiasm and enormous controversy. In the meantime, however, more articles have been written about this subject than studies have been actually performed. So, ten years later, does this statement still hold?
This paper aims at presenting what brain imaging techniques can do for the field of emotional design, and what studies concerned with product design (tangible products and not interfaces) have been performed in that area. We will establish that psychophysiological measurement techniques can do more than measuring arousal but will never fully replace classical methods of investigation. Brain imaging was chosen over other psychophysiological measurement techniques because it is the domain that has received most attention. *Brain imaging* is a term that encompasses a set of techniques that allows for visualization of the regions of the brain that are activated in response to a certain stimulus. Other psychophysiological measurement techniques are mentioned but are not reviewed. Likewise, the studies reviewed are strictly limited to the emotional experience of product appearance. Relaxation and stress monitoring is a well-covered area in usability, ergonomics and human-computer interactions (HCI). Engagement (involvement, interest, frustration) is extensively studied in advertising [2] and also HCI [3].
The literature search method was a "loosely structured method", similar to that used by Krishnan and Ulrich [4]. First, a set of papers on *neuromarketing* was gathered. This gave orientation towards the search of other references in the field of marketing and advertising. A systematic search in databases on neuroscience was also performed. The main journals and conferences of the design field were also

covered. The studies were distributed among many different research disciplines: design, marketing, advertising, affective neuroscience, HCI. The following reviews on psychophysiological measurement techniques in different fields were found: Poels and Dewitte [5] in advertising, Wang & Minor [6] in marketing, Picard and Daily [7] in HCI. None took up the subject of product design. Finally, the reading of each paper led to other referenced articles that seemed to be of importance for the domain study. The studies in emotional design using brain imaging are surprisingly few, compared to the interest expressed in that area. Only fifteen or so studies could be found, so that even if this paper aims at exhaustiveness, one cannot speak of a comprehensive review. The number of studies involving other psychophysiological measurement techniques (not reviewed here) was not much larger. One possible reason is that many such studies are performed for companies, meaning that the results and the experimental protocol cannot be revealed.

This paper is organized as follows. First the field of *neuromarketing* and its implications are presented the next section. Using these techniques that aim at tracking down emotional response from product designs implies adopting some specific views on what an emotion is. Emotional models and measurements are briefly presented in section 3. In section 4, the main psychophysiological measurement techniques are described, and the studies applying them in the measurement of emotional experience of product appearance are described and discussed.

2 NEUROMARKETING

The term *neuromarketing* first appeared in 2002 (according to [8]), after a series of brain imaging studies on consumer behavior were performed for some large companies. Brain imaging is the most spectacular psychophysiological technique, as it permits directly visualizing precisely which region has been activated by a certain stimulus (see Figure 2 below). This was also what triggered early controversy: many popular articles (see [9]) developed the argument that a fine knowledge of the pleasure and motivation centers of the brain (the 'buy button' in the head [10]) could be used to eventually control consumer behavior and preferences. Ethical discussions have followed [11,12] of what is actually a use of methods that have the same goals as classical marketing ones.

Hubert and Kenning [13] distinguish *consumer neuroscience* as the scientific development of explanatory models for consumer behaviors, from *neuromarketing* as being "the application of these findings within the scope of managerial practice." Neuromarketing is clearly related to the measurement of affect in product experience, as it is interested in consumer behavior, but is not limited to it: studies concern for example brand research (e.g. [14-16]), which also concerns inter- and intra-organizational research [11,17].

Studies in *neuroeconomics* [18], in which *neuromarketing* and *consumer neuroscience* are subsumed, are also of interest for the area of product experience, as it deals largely with decision making. It is important to point out that *neuromarketing* deals with methods and *insights* from brain research [13], which means that many studies performed by neuromarketing companies do not involve actual tests but are rather a compilation of results obtained in basic research in cognitive and affective neuroscience [19]. For example "BrightHouse does not scan people while showing them specific products or campaign ideas, but bases its work on the results of more general fMRI-based research into consumer preferences and decision-making carried out at Emory University in Atlanta" [19]. In 2005, it was estimated that there were 90 neuromarketing companies in the US [20]. Both *neuroeconomics* and *neuromarketing* have been the object of special issues in the *Journal of Consumer Behavior* and the *Brain Research Bulletin* [21,22].

3 EMOTION: MODELS AND MEASUREMENTS

3.1 Emotion models

There are numerous models of emotion, not least in the emotional design and product experience field (see e.g. [23-25]). Hiort [26] presents a review of most of them. Using psychophysiological measurement techniques basically limits the field to only a few models. The standpoint in affective (neuro)science is that affects (emotions, engagement, stress, thirst, hunger…) exist to make the person more reactive to its environment. Affect disrupts the current functioning state of the organism to make it ready for subsequent action. So an emotion can be defined as "a relatively brief episode of coordinated brain, autonomic, and behavioral changes that facilitate a response to an external or internal event of significance for the organism." [27, p. xiii] As such, most of this emotional reaction is completely unconscious, and/or is not under the control of the subject, at least under an initial stimulus onset. Of course, the emotional reaction can quite rapidly be modulated consciously —having a *feeling* is becoming conscious of the emotion. The emotional process and the physiological emotional responses are presented in a very simplified way in Figure 1. A stimulus goes through two pathways: 1) A low-level pathway where the information is quickly processed at the expense of accuracy and a first emotional response is produced; 2) the emotional stimulus information also goes through the higher-level cortical areas where more accurate emotional responses can be elaborated; the emotional event eventually becomes conscious. A more complete description of the emotional mechanisms and a discussion of their implications for emotional design can be found in Christoforidou and Motte [28].

Although only the central nervous system (the brain) process is investigated by brain imaging, other body responses can be investigated [29] (not presented here):

- the somatic response: reflex, startle (very specific to fearful stimuli)
- the endocrine and immune system: the organism starts the release of hormones and antibodies if necessary (no study found in neuromarketing or related areas exploited this phenomenon)
- autonomic responses:
  - cardiovascular activity: variations of heart rate and blood pressure
  - electrodermal activity: sweat
  - body temperature
  - respiration
  - pupillary activities
- expressive displays (to communicate one's emotion to others):
  - facial expressions
  - vocal expressions
  - gestures
  - postures

If the organism is preparing for some response given some stimuli, that means that there is a physiological pattern for each emotions. The categorical emotion paradigm (basic emotions, see e.g.[30]) is dominant in that context. However, this does not completely exclude the valence-arousal model (see Russel [31] for valence as positive-negative emotion dimension, and see Lang [32] for valence as a motivational dimension) as both models overlap partially. A discussion on this point can be found in [29]. So the psychophysiological measurement techniques can theoretically be used when searching for a particular emotion, or an emotional valence or arousal.

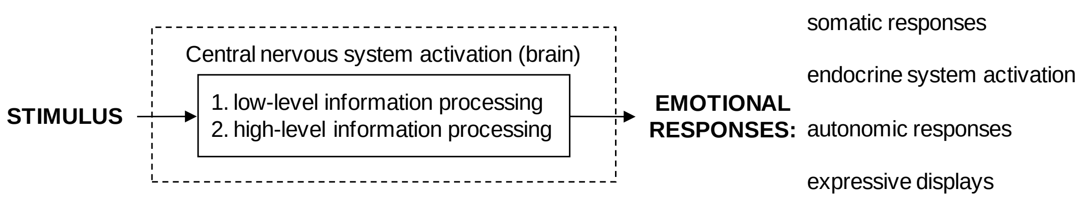

Figure 1. The emotional pathway

3.2 Measuring emotions

The advantage of psychophysiological measurement techniques is that they are able to directly access the primary response to an emotional stimulus (revealed in the bodily response). The other methods are more indirect: the verbal self-reports (questionnaires, emotion rating scales) or non-verbal self-reports [1,33] are reflected, subjective emotion descriptions. The scaling can also be ambiguous.

The downside of physiological measurements is that they need to be taken in a very controlled environment. Physiological and neuronal responses are responses to all external or internal stimuli present during the experiment (light intensity changes, sudden unrelated thoughts, gross movements…). Consequently, in many cases repeated experiments are necessary to eliminate all this noise. Finally, the psychophysiological measurement techniques are not adapted for investigating mixed emotions (research has been scarce in that area). The specificities of the brain imaging measurement techniques are described next.

4 MEASURING CHANGES IN THE CENTRAL NERVOUS SYSTEM RESPONSE

There are several brain imaging techniques: functional Magnetic Resonance Imagery (fMRI), Positron Emission Tomography (PET), Electroencephalography (EEG), Magnetoencephalography (MEG). PET is an imaging similar to fMRI, but older, and less used nowadays. No study of emotional response to product appearance used PET, so this system is not presented here. The fMRI system is the object of subsection 4.1. First the technique, its advantages and limitations are presented. Second, the way the emotions can be measured with it is described. Third, the studies related to emotional experience of product appearance using fMRI are introduced. Finally, the system and its use for emotional design are discussed. The second subsection concerns the EEG and MEG systems, and will follow the same structure.

4.1 Functional Magnetic Resonance Imagery (fMRI)

The technique, advantages and limitations

Functional Magnetic Resonance Imagery (fMRI) is one of several techniques of brain imaging. It allows visualizing the brain regions activated by the presented stimulus (see e.g. Figure 2). The fMRI system tracks blood flow changes in the brain. When a brain region is activated, the blood flow in that region increases, attains its peak about 6 to 10 seconds later and returns to normal activity about 16 seconds later. A new stimulus can nevertheless be detected if launched about 4-8 sec after the first one [34]. Due to the ongoing activity in the brain, the same type of stimulus needs to be repeated several times, so that the signal can be averaged. At the same time, the repetition induces a risk of habituation. This makes it difficult to evaluate the emotional impact of design alternatives; the measurement would more exactly concern the comparison of different categories of design. For example, among the studies presented below, Erk et al. [35] presented pictures of different categories of cars (sports cars, limousines and small cars) and had 22 different car pictures per category. Bar and Neta [36] studied object contours, using 140 pictures per category and 80 pictures as control.

The participant needs to lie perfectly still, and only limited, totally controlled, movements are allowed, like pushing a button. The head is also completely surrounded by the machine; the visual stimuli are often presented through a 45-degree rotated mirror. Here is a description of the positioning of a participant in [37, pp. 415-416]: “Head fixation was performed by foam pads and a soft headband. Earplugs were employed to protect against scanner noise and to allow for communication with the volunteer […]. The headset was additionally fixed to the coil to improve head immobilization.” This may not seem to be the optimal way of presenting emotionally loaded designs, but no response on this issue has been reported in the literature.

A study can be very costly. A moving-image fMRI machine (acquisition cost: $2.5 million) is rented for $1,000 an hour at Emory University in Atlanta; “A single experiment, which includes at least 12 participants, can cost $50,000” [10]. BrightHouse Institute for Thought Sciences in Atlanta, one of the few companies that own an fMRI charges $250,000 for a 30-participant study [10]. The price of the machines is between 1 and 3 million dollars. At that price, most machines are at universities and hospitals, which also limits their availability. The lower priced (around $100,000), weak-magnetic-field, MRI prototypes currently developed [38] have much lower resolution and are intended for clinical use (detection of tumors). The use of such machines in neuromarketing will not happen in the near future.

Finally, the technique itself and subsequent interpretations are also complex. A review of the main difficulties (for neuroeconomics) is presented in [39].

Measurements of emotions and pleasure with fMRI

Basically, fMRI permits matching a specific product experience to the regions involved in pleasure and emotions in the brain. A description of the regions of interest involved in emotional response is beyond the scope of this paper and can be found in [28,40,41]. In some cases, even other neural substrates are of interest, like the visual cortex for some visual stimuli, as shown in Bar and Neta [36]; see next subsection. fMRI studies of emotions can be made by following the dimensional, the categorical or any other advanced emotion model.

Studies related to emotional experience of product appearance

In one of the two seminal works (the second one being McClure [14]) in the area of marketing, Erk et al. [35] could detect a differentiated activation of the reward system of 12 male participants viewing car pictures (study supported by DaimlerChrysler). The view of sports cars activated the brain regions concerned with reward more than limousines and small cars, confirming the hypothesis that sports cars are more attractive than other types of cars. They also concluded that "artificial cultural objects associated with wealth and social dominance elicit activation in reward-related brain areas."

Bar and Neta [36] investigated the link between object preference and object contour. They confirmed that people usually prefer rounded objects. The amygdala was more activated by sharper objects (Figure 2), independently of the preferences, showing that the assessment of an object contour is computed at a perceptual level, before being modulated at a semantic, conscious level. The amygdala is mostly involved in fear, and sharpness is probably associated with threat. Thus there can be a bias in any justification of preference because the participant may not be aware that he/she is systematically influenced by the sharpness of the object in question, and may not know to which degree he/she is influenced. fMRI is used here to give a grounded scientific explanation to an observed phenomenon.

Knutson et al. [42] have recently proved that product assessment and price consideration prior to purchase are the results of two different neuronal circuitries, one involved in positive arousal during positive product assessment, and the other related to loss due to excessive price. These two systems together could significantly predict subsequent purchase (in comparison with self-reporting).

Stoll et al. [43] have investigated the attractiveness of packages (30 food and non-food packages) and could, like Erk et al. [35], show that this attractiveness could be detected using the fMRI technique, even for a small sample (11 participants).

Finally, many works have concerned branding (see [13] for a review), an important part of the product experience, as people's brand preference is the discriminating factor among nearly identical products [37,44]. The result of McClure et al. [14]'s study is noteworthy; it showed that preferred brands (at least for beverages) activate the reward system by anticipation, showing that brand preference is not necessarily a social construction, a result of group pressure, but is really *felt* by the participant in question. Yoon et al. [45] also showed that the neural substrates involved in the judgment of a person were different of those of a brand (or a product). According to the authors, this can have implications for anthropomorphically-based design.

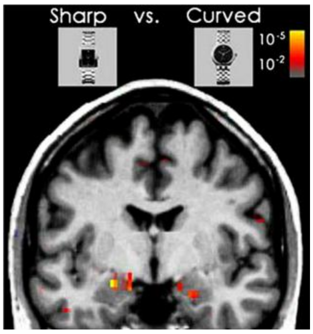

Figure 2. Stronger activation of the amygdala for sharp objects [36].

Discussion

The fMRI technique is a spectacular tool, and that explains the enthusiasm it created for physiological measurements. Many results concern *consumer neuroscience* more than *neuromarketing*, that is, many studies' results permit better understanding of certain affective behaviors previously unknown, but few studies are dedicated only to the measurement of the emotional impact of product appearance.

There is a good reason for this: in the applied field of emotional product perception assessment, there are few cases where it is necessary to visualize the brain area activated by the stimuli. For example, the study by Stoll et al. [43] on packages presents the interest, as [9] puts it, of giving significant results with stimuli that were not specifically designed to be attractive or unattractive. In other words, [43] tries to use fMRI as a predictive tool. But there are other cheaper and yet reliable physiological techniques that could achieve the same results, for example electrodermal activity. Bar and Neta [36]'s results on contour preference represent an advance for *consumer neuroscience* and affective neuroscience in general. At an applied level, however, those results had already been obtained by more established methods (among others by the very same authors in a preliminary study [46]. Likewise,

linking specific physical attributes to affect or purchase decision was achieved decades ago by less constrained methods (symmetry and complexity [47,48], mere exposure effect [49]…). Knutson's important discovery (at the explanatory level) of two separated systems for price and product considerations nevertheless has inferior prediction power than a survey asking a set of consumers whether they would buy a product given a certain price (which should produce reliable answers for most everyday products).
On the other hand, some works justify the use of fMRI (or at least of a physiological measurement technique): Erk et al. [35]'s and McClure [14]'s results could hardly be obtained by classical methods. Finally, fMRI can specify the response to a stimulus in terms of reward or avoidance, which few other methods do (facial recognition is a good candidate).
There are probably many more applied neuromarketing studies of products than those reviewed, but because companies finance them the results are not divulged in scientific journals or popular magazines.

4.2 Electroencephalography (EEG) and Magnetoencephalography (MEG)

The technique, advantages and limitations
Electroencephalography (EEG) measures the electrical activity of the brain. This electrical activity, simply put, is the integration of the electrical signals neurons propagate when they are active. The system consists of a set of electrodes positioned at specific locations on the skull of the participant (see Figure 3). As with fMRI, the stimuli need to be repeated several times in order to differentiate the responses specific to them from other signals. The averaged signal is called the event-related potential, or ERP.
EEG, like any other tool dedicated to physiological measurement, is very sensitive to noise, among other things. As an example, Electrooculographic (EOG) activity needs to be recorded to eliminate the variance it causes to the data (for example eye-blinks). Consequently, as with fMRI, the movements must be extremely limited.
Most emotion studies involving EEG have been done with video clips, far fewer with emotional pictures (and in that case not with the mainstream method of measuring emotions), see e.g. [50-52]. The clips seem to get better results. According to [53], the problem seems experimental, and the authors present an improved experimental protocol. Only one of the studies related to emotional product experience reported below made use of pictures [54].
The price of high quality, research-purposed EEG systems can range from $10,000 to $100,000, but cheaper EEG systems exist that can cost from a few hundred to a few thousand dollars.
Two studies used magnetoencephalography, or MEG: related to EEG, MEG measures the integrated magnetic signals emitted by activated neurons. The spatial resolution can be superior because magnetic signals are not as disturbed by the skull or the brain tissues as are electrical signals.

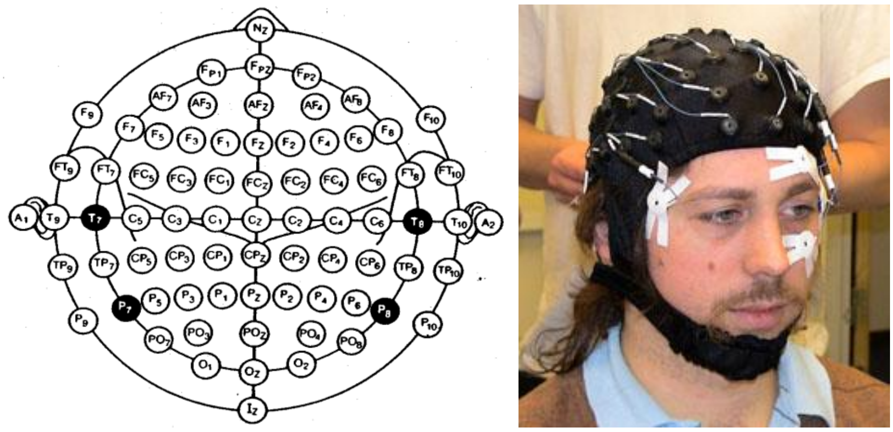

Figure 3. Left: Electrode positions for a high-density EEG. Right: an EEG system at Lund University.

Measurements of emotions and pleasure with EEG and MEG
The main model of emotion applied in EEG measurements is the dimensional ones. Studies have shown that the left side of the brain is more activated when positive affect is experienced, while the right side is more responsive to negative emotional stimuli [55], mainly in the frontal region [56,57].

Moreover, the arousal level of the emotion may be related to the absolute frontal activation in the frontal region [58,59]. This phenomenon is associated with the variation of the alpha waves (8-13 Hz): measured at the right and left frontal sides, they indicate which side is more activated. The studies on design experience presented below rely on this model.

There have been fewer EEG studies using the basic emotions model, and the results are contradictory. In a study of disgust—with video clip,: Sarlo et al. [60] found higher activation either in the right or in the left hemisphere, depending on the categories of 'disgusting' stimulus. Current EEG methods are also not mature enough to be used for investigating basic emotions.

This EEG asymmetry is advantageous, because it does not require a lot of electrodes. Schmidt and Trainor [59] had only four. The system used by Yamanaka and colleagues [61] has only two (Figure 4) and it is relatively non-intrusive. Asymmetry may also have good prediction value for valence. However, like for fMRI, the need to repeat the presentation of the stimulus may limit the range of product experience-related experiments.

There are many other ways to study affect with EEG, although the studies reported below made use of only frontal asymmetry. Two of them deserve to be mentioned, as they do not necessarily require more subtle experimental design. First, some studies have reported that the parietal lobe (superior part of the brain) seemed more sensitive to valence change for pictures [50,52,53]. Second a relatively usual object of study of affective pictures with EEG in the field of affective neuroscience is the so-called late positive potentials (LPP) observed during the affective picture processing with a peak at around 700 ms after stimulus presentation. This higher potential (relative to neutral pictures) last several seconds after the stimulus and can be 'easy' to uncover. Only arousal is detected though (see [29, p. 194-196]).

Studies related to emotional experience of product appearance

Because EEG gives good results with clips, it has been used extensively with the study of television, media and advertisement. ([8] cites a nearly forty-year old study, Krugman [62]). As mentioned earlier, however, most studies concern engagement, i.e. controlling whether the advertisement got the attention of the viewer, see e.g. [2]. The studies related directly to product experience are scarcer.

Yamanaka and colleagues, from Tsukuba University, Japan, have developed a specific tool, the HSK-centered rhythm monitor slim device [61], see Figure 4. Based on the frontal asymmetry specificity, two electrodes embedded in a head-mounted device are placed on the forehead of the participant. The device is almost non intrusive and its appearance does not evoke any clinical device. The data computation is slightly different from the asymmetry model presented above: the data from the left brain electrode corresponds to valence and the right electrode measures arousal [54]. Two studies concerning product appearance have been published in English. Kang and Yamanaka [54] compared the pleasantness of four different chairs as measured by the apparatus with the relative preference of the participants to each chair. No correlation was found. This indicates that the sensation of pleasantness is not a major factor of preference. Tomico et al. [63] let 5 participants test 6 pens and measured with the HSK-centered rhythm monitor slim device the level of 'comfort'(the level of comfort is considered as a combination of the data from the left and right electrodes and has been determined in Zhang et al. [64].) In [63] the participants executed four different tasks: look at the pen, manipulate it a first time, write with it, and manipulate it a second time. The 'comfortableness' was averaged for each task. It was then possible to follow the evolution of the sensation of comfort: a value of comfort during the first manipulation smaller than during the 'look' task, indicated that the product did not live up to what the pen's look promised. Then the participants filled a self-report questionnaire related to the four tasks. The results of the self-report and the physiological measurements were mapped for each task: there was a certain overlap for the 'look' task and the second manipulation.

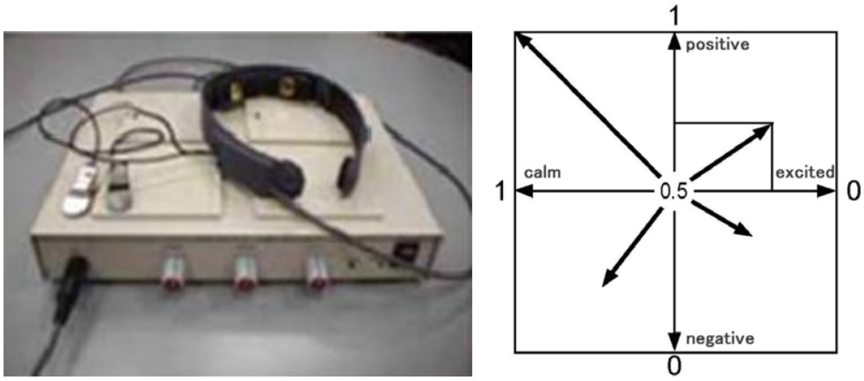

Figure 4. HSK-centered rhythm monitor slim device (from [65]).

Jenkins and colleagues have started a research programme aiming at investigating the use of Infrared Thermography (IRT) for emotional evaluation of product design. Facial temperature can be related to emotional arousal and valence and, after a first pilot study [66], Jenkins et al. [67] compared EEG measurements, IRT measurement and a self report method. The stimulus was however not related to product design: it was a ‘thought experiment’, more designed to trigger engagement (involvement, interest) than affect. The values were averaged along the thought experiment duration. For 16 participants, there was no significant correlation between EEG asymmetry and IRT asymmetry. The EEG system could detect a significant arousal but any valence or engagement. Due to the experimental setup, it is difficult to assess whether the non significant results are due to the physiological measurement or the task to perform. Moreover, the EEG recorded frequencies between 2 and 38 Hz, which includes not only alpha waves but also beta waves (13-30 Hz), theta waves (2-7 Hz).

The study of Braeutigam et al. [68] was not directly related to product appearance *per se*. The team investigated real-life product choice in a retail store, using a MEG system. They found evidence that, after appearance consideration, there is an activation of the semantic memory compatible “with the hypothesis that at this time, the images are being recognized and compared with data recalled from long-term memories of the relevant brands and products” [68, p. 251]. A subsequent study [69] confirmed this, with one supplementary finding: the intention of purchase may be detected through a stronger activation in the right parietal cortex. According to the post-test questionnaire, the participant choices were consistent with their familiarity with the items. Appearance also played a small role in the choice of the product; however this research was made with 270 mundane items. It would be interesting to test in the same setup to which extent non mundane product appearance would affect the action of buying by habit.

The study of Ma et al. [70] is in the domain of brand extension: the study of the extension of a company’s product portfolio given a certain brand. This corresponds basically to a classification task (can a new product type be positively associated with the company’s brand), which can be related to the study of the emotional experience of product appearance (to match product appearance and emotion). Ma et al. [70] have both developed an EEG-based method for the study of brand extension and an explanatory model. There is evidence that a positive potential appears in the associative memory region 300 ms after a classification stimulus onset (so-called P300). Their hypothesis was that this P300 would be more pronounced with products more congruent with the brand names, which was significantly true in their experiment.

Discussion

The sensitivity of the apparatus makes it still difficult to use it outside a controlled experimental setup. The EEG system is light and portable, experiments can be done outside the lab, but it is unlikely that EEG can be used for measuring “emotions” while doing any moderate physical activity like walking in a mall [8] or testing large products. The ambulatory EEG systems that exist are used to measure abnormal activities for patients that for example may have experienced seizures. Dedicated tools are beginning to emerge, like the Emotional Spectrum Analysis ESA-16, reviewed by [71], and the HSK-centered rhythm monitor slim device [61]. Other EEG-based equipments are now being developed, mainly for gaming [72], or brain computer interface [73], and it could soon be possible to see similar equipment for marketing purposes. Their reliability is difficult to assess as they are often proprietary systems: it is not possible to know how the data is collected and transformed.

As this equipment is much cheaper and less cumbersome to use than fMRI, there is a clear tendency towards applied studies of emotional experience of product appearance ([54,63,67] *viz.* [68-70]). EEGs are more common in marketing consultancy agencies. These studies clearly consider EEG a reliable prediction tool for emotional reaction (arousal and valence).
The affective neuroscience community does not share this view. As mentioned above, it has been difficult to establish the validity of the EEG asymmetry model. There are also other issues. One growing controversy concerning the EEG asymmetry and concerns our field is the question whether one measures a motivational differentiation rather than emotional [74]. Often a positive emotion is linked with a greater motivation to obtain what is presented, and vice-versa. However, as Harmon-Jones puts it: "Appetitive motivations are not always associated with positive affects. Anger, greed, lust, and mania are some examples of approach motivations that may have deleterious consequences." [74, p. 52]. Furthermore, a participant who likes a product cannot be motivated to buy it: in that case the ERP would be that of a neutral affect. This goes beyond a simple measurement problem: even this must be clear in self-report questionnaires.

5 CONCLUSION

Unlike more traditional methods of emotion measurements, brain imaging techniques require an expert to manipulate the equipment but also to design most experiments, due to the extreme sensitivity of these apparatuses to noise. The measures are also very idiosyncratic, which makes it difficult to compare data across individuals and set up an absolute baseline. Some dedicated EEG instruments exist but their validity is difficult to assess. There is also a discrepancy between the proponents of these techniques for emotional design (the neuromarketing community) and the neuroscientific community: the former uses the methods for prediction purpose, and are confident that the data they get is what they were looking for. The latter is still arguing about the validity of, for example, the EEG asymmetry and takes draconian measures to control the experiments.
It is not impossible for EEG to have in the near future some reliable measurement of, for example, the valence and arousal of an emotion. But first, that would be an under-exploitation of the power of measurement that brain imaging provides. Second, there exist other psychophysiological measurement techniques that are reliable, measuring the electrodermal activity (for arousal) and facial muscle activity (for valence); see [75].
If these techniques are complex to understand and difficult to use, there is a need to reflect over the true advantages they may yield in comparison to more traditional methods. As shown in the studies reviewed, many results could have been obtained with different methods. Here are some suggestions of tasks where psychophysiological measurement techniques are superior to current classical methods:

- Measuring the first impression. This was mentioned earlier. It is however necessary to consider under what circumstances this is necessary. Indeed, if first impressions are sometimes forgotten, they probably have little impact on product design assessment or product purchase (this of course requires further research). Moreover, other factors than the emotional ones, not the least sociological, have strong influences on the purchase, like group pressure, trends, subcultures, etc.
- measuring taboo or politically correct issues. With politically correct issues like environment, or taboo issues like sexuality, it can be dangerous to rely on classical methods. The participant to a questionnaire may answer what is expected from him/her rather than what he/she really feels.
- Measuring in real time the interaction between the product and user.
- Verifying the validity of less complex methods.
- Developing explanatory models [54,63,67] that will validate the subsequent use of such methods in emotional design.

This work needs to be completed with the investigation of studies involving other psychophysiological measurement techniques. This is the object of a future study.
Finally, these psychophysiological techniques are concerned with models of emotion that are limited to basic emotions, or the level of arousal and valence of an emotion. Emotions can be described much more richly, and product designers rarely want to evoke a single emotion. Those techniques will never be able to fully replace classical methods of investigation, but have a clear role to play in combination with those methods as a control system.

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