EMOTIONAL DESIGN THROUGH MEASUREMENT OF PSYCHOPHYSIOLOGICAL AND BEHAVIORAL PARAMETERS:

TAKING STEPS TOWARDS NEURODESIGN

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ABSTRACT

There are a number of unknowns regarding conventional Emotional Design methodologies, especially in terms of the feedback from target users. Grey areas include questions such as: why are these methodologies so trusting of the user's response? Does the user really understand what is being asked of them? How do such methodologies consider the external factors that condition the emotional state of the individual, and therefore their answer? Is a subjective analysis of the emotion resulting from the cognitive interpretation of a stimulus sufficient? If it is indeed possible to measure the physiological reflex of an emotion, why is this parameter rarely considered as a viable option?

The main objective of this investigation is to respond to these questions, thus making the possibility of project development via emotional design more accessible. This can be achieved by leveraging the objectivity of the physiological register through the use of appropriate technology, and by fine-tuning the technical specifications and product design parameters which relate to the end-user's various needs, in terms of product functionality, usability and the user's emotional involvement.

KEYWORDS: *neurodesign, biofeedback, neuroscience, psychophysiology, brain, neuromarketing*

INTRODUCTION

Throughout history, cognition and emotion have been considered as being independent, even opposing, processes. The Greeks made the distinction between reason and passion, thus separating thoughts from feelings. Reason was considered the medium for thinking clearly by controlling our passions, which in turn were thought of as out-of-control emotions that blur our capacity for reasoning (Belmonte, 2007). During the 17th century Descartes lent weight to this idea and supported this distinction in his research. He considered that the mind was void of either **spatial extension** or physical content, two characteristics that would allow it to live when the body no longer existed. By discounting any of the physical properties of the mind, Descartes rendered the link between mind and body for the fulfillment of its supposed functions impossible. The mind-body conundrum has remained unsolved until the present day, recurring as a constant subject of debate in the fields of psychology and philosophy. Even in the 20th century, and in spite of the evolution of the sciences of mind and brain, there were so many opposing approaches and methodologies that it was impossible to tackle the problem with any hope of reaching a solution (Damasio, 2011). It seems that finally in the last decade, thanks largely to the contributions of important scientists and neurologists such as Joseph LeDoux and Antonio Damasio, the close link between emotion and cognition has started to gain acceptance. Underlying the conscious components of both, it is clear that diverse, subconscious brain mechanisms interact to determine the conscious characteristics of thought and emotion.

Thanks to the work of these scientists, and the advances in the technological aspects of the devices used in their research, new advances in neuroscience have been made that allow us to recognize that cognition and emotion are unified and that they contribute jointly and equally to the control of thought and behavior (LeDoux, 1995).

Cognition includes aspects such as perception, memory, attention, or action, while *emotion* ranges from a person's subjective feelings to their body's physiological and physical reactions to stimulus.

THE STRUCTURE OF EMOTIONS

As with its theoretical conception, there is no general consensus on the structures that make up emotions. Some researchers use categories, others dimensions, some employ bipolar concepts, some **unipolar concepts**, some propose a simple structure, some a circumplex model, and still others a hierarchical model (Russell & Feldman, 1999).

For Russell, emotions cover too many types of event to be described in a unique scientific category, and it seems impossible to merge them together to form a unique structure. As an example, let us take the distinction between core-affective and prototypical emotional episodes. The former refers to the consciously accessible elementary processes of pleasure and activation, which are caused by multiple factors, and are always present. Its structure implies two bipolar dimensions. The latter corresponds to a complex process developed over time, consisting of a series of causally-connected components (for example, background, personal evaluation, physiological, affective and cognitive changes, behavioral responses, autocategorization), but has a single perceived cause and is singular in nature. Its structure includes verbal categories, vertically organized in a confused hierarchy, and horizontally organized as part of a circumplex. This approach to the discrepancy between a structure based on categories and another based on dimensions was also discussed by Fijda y Mesquita (1998).

One of the main difficulties of the categorical structure is that the terms used to define the categories themselves in any given language are similar in other languages but not identical. To this, add the fact that each category is more a question of degrees than of absolute extremes, and the distinctions between these categories become blurred. Furthermore, these categories describe complex processes formed by a set of temporally-ordered and causally-related components.

The variability of the relationship between the components of an emotion and the ambiguity, from a semantic point of view, of the concepts of emotions therefore render named categories less adequate than the names given to their component emotions (or dimensions).

THEORIES OF EMOTIONS

As a consequence of the ambiguity in the definition, classification or structure of emotions, a great diversity of approaches has arisen, each derived from different theoretical models as a function of the emotional component that formed the basis of its interest.

The principal conceptual developments can be classified in a similar way to that of Plutchik (1980): evolutionist, cognitive, behavioral, psychological, and neurological, although in this article we will cover only the last two.

Psycophysiological

The psychophysiological part of the idea proposed by James (James, 1884, quoted by Chóliz, 2005) considers that an emotion arises as a consequence of the interpretation of a determined physiological response produced by a definite event. According to the hypothesis of James-Lange, each emotional reaction could be identified through a determined and differentiated physiological pattern. This directional fractionation (Lacey, 1967, cited by Zhóliz, 2005) is characterized by the fact that an emotional response is either sympathetic or parasympathetic, favoring the appearance of differentiated response patterns for each affective reaction. Numerous studies along these lines have allowed the identification of variables such as heart rate, conductivity, or body temperature when faced with specific events. These results could be explained through the existence of psycho-biological programs specific to each emotion, which would facilitate our ability to adapt our behavior to a given situation. The various studies that have been performed have involved the monitoring of different systems including electrodermal response, gastrointestinal activity, cardiovascular activity, muscular activity, respiratory activity and, with the evolution of technology in the last few years, asymmetry in Electroencephalography when experiencing a range of emotions.

Neurological

Even though the James-Lange hypothesis established that the physiological base of emotions is located in visceral mechanisms, Cannon considered that the physiological base was in the thalamus and hypothalamus. The thalamus gives an emotional quality to the impulses that pass through it; an environmental stimulus acts on the receptors, which send that stimulus to the cortex via the thalamus. The cortex again stimulates the thalamus, which then acts according to predetermined patterns corresponding to specific forms of emotional expression. For Cannon, the activation of thalamic neurons acts as an activator of muscles and viscera, and sends feedback to the cerebral cortex, demonstrating that emotional experience and physical change occur almost simultaneously (Palmero, 1996). Ultimately, the Cannon-Bard activation theory argues that an emotion is a sign of an emergency situation, and motivates the organism to react and control that emotion.

Papez and McLean established the physiological base of emotions as residing in the limbic system. For both the authors, the hypothalamus and limbic system provide the biological substrate for an emotional experience. Papez speculated on the existence of specific brain areas dedicated to emotions. He considered that the hypothalamus was the sender and receiver of information to and from the limbic brain and that the hippocampus acted as coordinator or regulator between the hypothalamus and the cingulate cortex and the parahippocampal gyrus (Belmonte, 2007). The expression of emotions implies a hypothalamic control of visceral organs, while

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feelings appear in the 'Papez circuit' (Palmero, 1996). In the end, the brain areas that form this circuit are related to the limbic system, as referred to by McLean (McLean, 1949, cited by Palmero, 1996). The main contribution from McLean was the consideration that the human encephalon is a system formed of three layers, colloquially known as the 'Reptilian complex', responsible for the automatic, instinctive behavior necessary for the organism's survival; the 'Paleomammalian complex', in charge of the conservation of both the species and individual; and the 'Neomammalian complex', necessary for the development of rational strategies and for verbal capacity.

Lindsley's 'activation theory' situates the physiological base of emotion in the reticulated formation of the brain stem, and accepts that the hypothalamus is the main area for the organization of emotional expression. Lindsley considers that the reticulated system must be activated in any significant expression of behavior. When a stimulus appears, sensory, visceral, and somatic impulses take the following course: arrival at and integration into the reticulated formation, followed by transmission to the hypothalamus and thalamus centers where they activate the cerebral cortex. This activation occurs concurrently to electro-cortical de-synchronization, giving rise to the possibility of finding a minimal level of activation in non-emotional situations, and the highest level of activation in situations of extreme emotional excitation (Palmero, 1996).

The relationship between emotion and activation is defined by the existence of a main process, wherein cortical, autonomous, and somatic systems are coordinated. This process would be responsible for the quality of the different affective reactions. As a consequence, prominent studies have been characterized by the selection of a particular physiological variable as an indicator of the activation level, in order to register its correlation to different emotional reactions.

Damasio (2011) proposes the following hypothesis about work on emotions: strictly speaking, an emotion such as happiness, sadness, shame or sympathy is a complex set of chemical and neuronal responses that form a distinctive pattern. A normal brain produces responses when it detects an Emotionally Competent Stimulus (ECS). This is the object or event whose presence, whether real or remembered, triggers the emotion. Such responses are automatic.

In every emotion, neuronal and chemical discharges occur that temporarily modify, in a specific way, our internal state, our visceral organs, and our musculo-skeletic systems. Everything that makes up a human being, from facial expressions to behavioral patterns, is established in this way. Damasio (2011) has established schematically that the trigger and execution of emotions happens as follows: firstly, the evaluation and definition of an ECS activates the areas of the cerebral cortex associated with the senses and those of a higher order; next, what Damasio refers to as the emotional 'trigger', or induction, occurs, which takes place in the cerebral amygdala. Subsequently, emotional execution occurs in the basal fore-brain, involving the hypothalamus and brain stem. Lastly, the emotional state is produced, causing a series of transitory changes in the internal condition.

FROM NEUROSCIENCE TO MARKETING: NEUROMARKETING

Neuroscience, 'the science of the brain', is defined by Kandel (2000) as a fusion of different disciplines, including molecular biology, electrophysiology, anatomy, embryology and developmental biology, cell biology, and behavioral biology. This fusion aims to contribute to the explanation of human behavior in terms of brain activity and how their environment, and even the behavior of other human beings, influence cells.

A pioneering example of the application of neuroscience to business can be seen in marketing, whose development has been based on knowledge gained from other disciplines such as psychology, sociology, economics, and anthropology. When advances in neuroscience and neuropsychology were incorporated, an extraordinary evolution took place, resulting in the creation of a new discipline known as neuromarketing (Braidot, 2005).

Neuromarketing incorporates a range of resources based on the understanding of brain processes linked to sensory perception, information processing, memory, attention span, rationality, emotions, and mechanisms that interact during learning and decision making, allowing us to overcome potential errors caused by a lack of awareness of the related internal processes and the metaconscious.

According to Epstein (1994), people sense reality in at least two different ways: cognitively, which is considered to be analytical and rational, and affectively, which is considered to be intuitive and experiential. Recent studies have determined that up to 95% of our decision-making happens at the fringe of our consciousness. Our senses receive around eleven million bits of information every second, whilst the conscious brain can only process some forty bits per second. The subconscious, or the affective way of processing information, is some 200 times faster. This is due mainly to the fact that cognitive processes involve an automatic and simultaneous search of our experience database. In some ways, it is as if the brain searches in its memory database for related events, including possible combinations and consequences.

This means that the cerebral areas of rationality cannot work in isolation from the areas of biological-emotional regulation. The two systems communicate with one another and hence jointly affect our behavior.

The great challenge seems to lie in predicting the latent needs of users and what their behavior will be during their interaction with the product or service, so as to contribute to a more positive user experience (Khalid, M.H., 2006).

One example of Neuromarketing can be found in the work of Lindstrom (2008), who carried out various studies employing magnetic resonance to record the majority of their results. One of the most surprising insights they gained into the relationship between our brain and emotions concerns the warnings found on tobacco and cigarette packaging. From a rational perspective, such warnings should, in principle, act as a deterrent and reduce tobacco consumption among smokers. In reality however, their effect is quite the opposite; they cause an activation of the ACCUMBENS centre of the brain, known as the 'point of anxiousness', which in turn increases the desire of the smoker to light up a cigarette. Nevertheless, from the responses given in a related questionnaire, the majority of these tobacco users felt that these warnings did indeed act as a deterrent. Such a response illustrates the fact that focusing solely on subjective aspects of our emotions can introduce a source of error in the interpretation of a study's results, a fact that highlights the importance of considering the use of technology as a complementary measuring tool in any such investigation.

In general, such studies relate to the field of marketing, and often serve as a way of confirming the emotional response generated by a given product or advertising campaign. This current investigation represents an attempt to incorporate emotional response data recording, and its interpretation as an integral variable in a project's development from its initial stages, so as to better guide its evolution in terms of variables such as its functionality, ergonomics, and usability.

QUANTIFYING EMOTIONS

Our brain has a series of automatic mechanisms, or subconscious reactions, which can be monitored both via our brain activity and from the point of view of their behavioral and psychophysiologic consequences. This additional information allows us to understand the behavior of human beings in a more clear and precise way.

As indicated by Braidot (2005), surveys, in-depth interviews, and focus groups can only provide superficial information about the underlying causes that relate to consumer behavior. This is due to the fact that the answers to both a questionnaire and a guided conversation during motivational research obtain information based exclusively on conscious reflexion, when actually most of our choices originate from unconscious reasoning. The key lays now not so much in the analysis of what clients say, or in monitoring the way they act, but rather in investigating the underlying causes behind their behavior.

Every time the brain is submitted to stimulus via the senses (sight, hearing, touch, etc.), its activity and the related consequences from a psycophysiological and behavioral point of view appear as a series of signals (electrical, magnetic, chemical etc). Different technologies have been developed to measure this activity, such as functional magnetic resonance imaging (FMRI), magnetoencephalography (MEG), positron emission tomography (PET), and electromyography (EMG). However, the application of these technologies remains complicated and they are not currently viable for use in real-life situations.

As a result, in this research paper we have taken a special interest in those technologies whose evolution and development in recent years have demonstrated a significant improvement in access to these devices, allowing a far wider group of professionals to employ them in their studies.

Galvanic skin response (GSR) or skin conductance response (SCR)

This technology is famous for forming the basis of the well-known polygraph or lie detector. It is based on the fact that our skin's electrical resistance changes in response to our emotional changes.

It measures the conductance of the skin, among other indicators, to infer the level of activation (excitement) of the subject. This activation is fundamental in regulating consciousness, attention span, as well as the processing of information, and is a crucial element in the motivation of specific behavior.

Portable electroencephalography system (EEG)

The electroencephalography system, or portable EEG, gives us information about the brain areas that are excited when it comes to interacting with different stimuli (colors, sounds, smells, forms, and so on), or when undertaking some kind of activity. As it is a portable system, this information is obtained in a real-life context and not under laboratory conditions, thus providing both qualitative and highly reliable data relating to the subject's experience.

Thanks to the EEG, we are able to measure variables such as emotional valence, cognition, attention span, vision, movement, and recognition.

Facial emotion recognition software

This is a software tool that allows the emotions experienced by the users to be determined through the automatic analysis of facial expressions. It facilitates the detection of the six basic and universal emotions: happiness, sadness, fear, anger, disgust, and surprise, as defined by Ekman (1992).

Furthermore, the software tracks the orientation of the user's head, which allows for a better identification of their facial gestures and, by using a complex algorithm, it identifies the muscles that are involved and analyzes their response in order to indicate which emotion the subject is experiencing at any given moment.

Behavioral analysis software

This software allows us to analyze the behavior of users through the observation of their interaction with the environment, and records behavioral data for subsequent review, analysis, and presentation. Furthermore, the system can be integrated with other devices such as those previously mentioned, in order to generate a more rigorous analysis.

Eye tracking system

This tool does not provide information about an emotional response, but rather acts as a compliment to the study.

It allows us to examine the visual pathways followed by the subject of the study, and thus create maps that signal the ‘hot spots’ of an image, meaning the areas in which vision is focused

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over the longest period of time. It can also indicate the trajectories that the eyes follow and thus the order in which elements are examined. The non-invasive character of the system allows the activity to be carried out without conditioning the interactive experience to the surroundings.

A PRACTICAL EXAMPLE OF APPLICATION

The main goal of this investigation is to demonstrate the possibility of developing products according to emotional parameters, making use of the constant evolution of technology and the desire of researchers to employ these new measuring systems. In addition, the 'democratization' of these technologies means that research can move away from its traditional areas of study, towards new disciplines such as marketing and design, allowing us to provide some objectivity to a topic as subjective as our emotions. To best develop this approach, we have opted to integrate these technological resources in a conventional design methodology, and as a practical example they have been applied to the development of a music stand.

The music stand has been relegated to a secondary role within the music world, despite being essential to academic training as well as professional practice. The world of music is an artistic discipline that, as such, incorporates emotion as an inherent property. However, the close relationship that develops between the musician and their instrument is never reached between the musician and the accessories needed for the performance of their activity, and especially not their music stand. This product, as has been shown in the case of this study, generally arouses negative emotions amongst its users, the result perhaps of the non-inclusion of certain ergonomics of emotional criteria in its design and development; conceivably as a consequence of its lack of evolution, or because of its complexity of use, both in terms of erecting and dismantling, and in the context of user-product interaction.

The development of this practical example was performed under a conventional design methodology (Figure 1), which covers everything from the strategical product definition and conceptual design to its engineering, production, and so on. Throughout the different developmental phases, we incorporated some of the aforementioned devices.

Senso-perceptive session

In the second stage of the design process, an activity called 'Senso-perceptive session employing touch' was held with the objective of identifying those materials and/or surface finishes that are more pleasing to touch, and which evoke a feeling of a higher quality of product. It was carried out using facial emotion recognition software that allowed us to identify emotions during the interaction between users and materials, and to visualize the results instantly.

The session took place in two phases, one being objective-behavioral and the other subjective-cognitive. Both are important, but on this occasion, the goal was to determine the emotional impact of the different possible materials as potential components of the completed music stand.

During the session, the subjects could not see the materials they were touching with their hands, therefore eliminating 'contaminating elements', which we understand as being small cognitive processes that prompt the subjects to interpret the colors and forms of the materials, creating connections and associations that did not form the object of the study.

In this way, the emotional facial expression of each of the subjects was analyzed during their tactile exploration of the materials, allowing us to analyze the instant emotional reaction that arises when the tactile perceptive system comes into contact with materials of different texture.

We would like to highlight the informative power that the perceptive tactile system provides, since the participating subjects of the research use their own hands as their main work tool. This information is fundamental, since musicians have a daily and constant interaction with their music stand. By determining which emotions different materials evoke, we can create emotional ties between the music stand and the musician. It has been proven throughout history that positive emotions create connections and establish associations with the individual that reinforce their current behavior, increasing the probability that this same behavior will be repeated in the future.

Once we had obtained objective and behavioral data, subjects were asked how they felt when touching the material. This question was associated with the so-called emotional valence, hedonistic value or the pleasure-displeasure scale. Subjects were allowed freedom to express their opinions and beliefs about what they considered they had touched, as well as expressing the different associations made between their perception and their past experiences with other objects that they find similar.

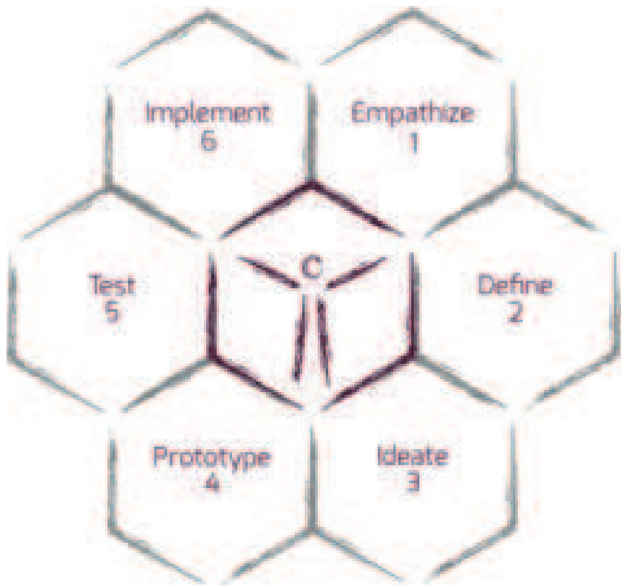

Figure 1. Methodology

83.33% of our sample (28 subjects) stated categorically that had they seen the materials, they would have reacted differently, because by seeing the colors and shapes, the emotion they displayed would not have been the same. Therefore, the sensory integration of the stimulus following different methods completes the processing of attributed information to such stimulus, reducing the informative power of those emotions measured in an indirect way.

Video catalog

At the end of the fourth stage, a new test was performed using facial emotion recognition software, combined with a brief questionnaire. The session was carried out on each of the participants individually, and it is important to point out that at no time during the session briefing were subjects informed that the prototype being developed had been included in the video catalog along with other types of music stand. This was done intentionally, since we were interested in finding out if they recognized it, and what the sensations were that it provoked among them. The two graphs included in Figure 2 show subjects' emotions at two different times whilst viewing the video catalog. It can be seen that at the beginning there is no clear dominance of any of the emotions measured by the software, whereas in the second graph, which corresponds to the time interval in which the prototype under development was shown, the prominent emotion is happiness.

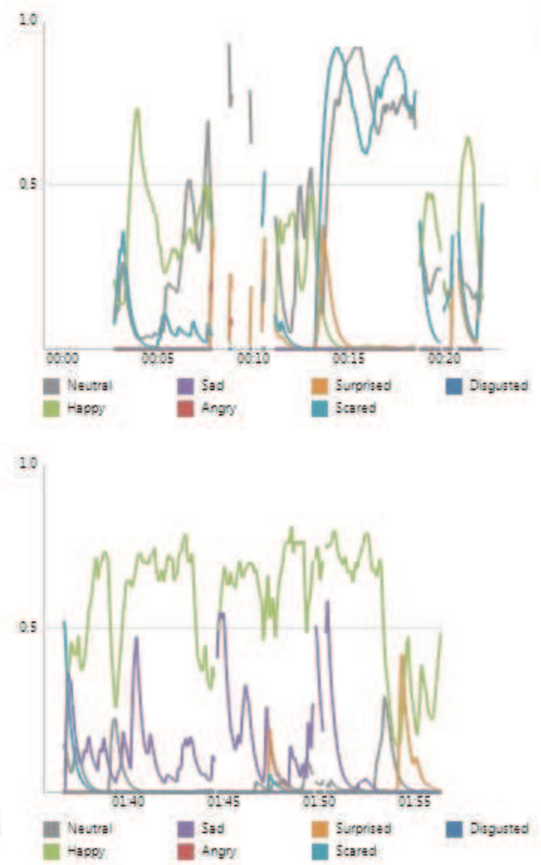

Figure 2. Measurement of time-dependent emotion

Musician-music stand interaction

After the prototype had been manufactured, a fifth stage was carried out in which users could experience the product first-hand, see the advantages of the prototype compared to the conventional music stand, and at the same time evaluate all the criteria that had been established when it was created. The session was divided into two parts: in the first part, the user read sheet music from the prototype, and in the second part they repeated the activity using a conventional foldable stand. The 'wind' parameter, simulated by a fan, was maintained constant for both parts, since wind is one of the main issues that musicians encounter when performing outdoors. Both the concentration level and the attention level required for the interaction were evaluated. In order to do so, an eye tracking system was used (Figure 3), which was capable of registering the movements of the human eye and determining the main points of focus, along with a galvanic skin response receptor that allows us to measure the subject's level of excitement. The visual mapping results obtained during the interaction with both stands, showed that with the prototype, users' eyes are directed at the center of the support, helping them to achieve a higher level of concentration, whereas focus is more dispersed when using the conventional stand.

Figure 3. Eye Tracking

The galvanic response data shows three phases, which can be seen in Figure 4. The first is marked by stable and prolonged electrodermal activity, up until the user's direct interaction with the prototype. In the second phase, during the interaction with the stand, we observed a marked rise in EDA (electrodermal activity), mainly obtained due to the user's lack of knowledge about the use of the prototype. Throughout this phase, a small series of regular peaks can be observed, due to this inexperience and lack of knowledge. Lastly, during the third phase a constant level of excitement is established, caused by playing the instrument during interaction with the music stand. This promotes a significant rise in the internal

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Figure 4. Galvanic response

control locus of the subject; we attribute this to the positive consequences of the interaction with their skills as musicians and not to other external causes.

As can be observed in the graph, the electrodermal activity measurements obtained from the device on the conventional stand are constant, with only slight variations. From this it can be deduced that despite the great familiarity that the subjects have with the music stand, since it does not have an adequate design, peaks of excitement are produced that translate into increases and decreases of the EDA. In this way, concentration and attention levels can be lowered significantly owing to poor interaction with what is essentially an unintuitive design.

CONCLUSIONS

In order to help facilitate the dissemination and implementation of emotional design and to promote research and development, in this paper we have shown a practical example based on a methodology of conventional design, but which relies on the use of certain tools, measurement techniques, and behavioral and psychophysiological measurements stemming from the study of emotions. During the course of the research certain limitations have emerged, but the results gained have been satisfactory and allow the validation, to a greater or lesser extent, of the study's initial main goals. The validation process allows us to demonstrate that the prototype developed was perceived in a very positive manner by the users, indicating that the developments made were adapted, to a large extent, to the functional and emotional expectations detected in the initial phases of the project.

The main contributions of this research can be summarized as follows: firstly, the demonstration, in both theoretical and practical areas, that it is possible to develop products with emotional criteria together with a set of techniques and tools of conventional design methodologies, without resorting to more specific, complicated, and difficult-to-implement methodologies. Secondly, affirmation that a product provokes emotion, and that this should be an inherent quality of any product, not only a marketing strategy. This research supports the idea that this claim can only be sustained through continuous monitoring of the emotional needs of users in different phases of the design process. Thirdly, we can achieve a more reliable measurement of the emotional state of the user during their interaction with a product by measuring physiological, cognitive, and behavioral dimensions.

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