UNDERSTANDING CEREBRAL ACTIVATIONS IN NEUROMARKETING

A Neuroelectrical Perspective

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Abstract: This paper aims to be a survey of recent experiments performed in the Neuromarketing field. Our purpose is to illustrate results obtained by employing the popular tools of investigation well known in the international neuroelectrical community such as the MEG, High Resolution EEG techniques and steady-state visually evoked potentials. By means of temporal and frequency patterns of cortical activations we intend to show how the neuroscientific community is nowadays sensible to the needs of companies and, at the same time, how the same tools are able to retrieve hidden information about the demands of consumers. These instruments could be of help both in pre- and post-design stage of a product, or a service, that a marketer is going to promote.

1 INTRODUCTION

For a long time in the neuroscience the experimental psychology has been the main method to investigate the human being. In that field, they measure the execution time of the experimental subject as well as his/her reaction time to particular stimuli. In particular, the subject can answer, move the finger, do free mental associations and the experimenter will measure some variables correlated with the internal processes of the subject. Of course, the access to the internal state of the subject is restricted, since it is observed by means of his/her behavioural answers. The experimental context plays an important role in these kind of experiments, since the subjects are required to answer in a short time in order to cause errors. The measure of the amount and frequency of such errors is important as an indirect measure of the internal processes of the subject. These behavioural techniques can be applied with a low cost to a large amount of people. The brain imaging techniques have the capability to show images of the cerebral activity during the execution of a particular experimental task. The most popular method is the functional Magnetic Resonance Image (fMRI), which returns a sequence of images of the cerebral activity by means of the measure of the cerebral blood flow. Although such as images are "static", i.e. they are related to around ten seconds activity, they have a high special resolution that no other neuroimaging method can offer. Nowadays, fMRI scanners are employed in the neuromarketing field and in literature there exists some scientific studies showing the activation of particular cerebral areas during the tasting of a couple of popular drinks such as Coca-Cola and Pepsi (Mc Clure et al., 2004). It must be noted that the design of the fMRI studies rely on highlighting cortical areas which differ between the experimental task and the control one. The issue is connected with the data interpretation which can be given by the activation of particular cerebral areas during the experimental task proposed. In order to solve this problem there is the need to generate a proper experimental design in order to remove these kind of confounding factors. As stated above, the brain imaging allows us to observe cerebral areas activating during a particular task but it does not explain why, neither in which way the information is

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processed within the experimental subject. In this way we are not accessing the cerebral answer of the subject by his/her behave but directly by means of the activity of his/her neurons. The role of the brain imaging in the neuromarketing field is to refine, on the basis of a selected sample of people, some theories and hypotheses the neuropsychological research draw from the same experimentation on a larger number of subjects.

In the following paragraphs we intend to give a survey about the neuromarketing research performed in the neuroelectrical community. Our purpose is to show the results obtained by different group of research, their congruence and similarity leading towards a shared model which is able to extract information about the memorization and the pleasantness perceive by subjects while watching TV advertisements. In particular, this paper will focus on the results achieved by employing the magnetoencephalography (MEG) and electroencephalography (EEG) technique along with a discussion about patterns of cortical functional connectivity and indexes derived from the graph theory.

Finally, we describe the experimental findings obtained by a steady-state visually evoked potential analysis.

2 TEMPORAL PATTERNS OF CORTICAL ACTIVITY

In this context, the research team of Sven Braeutigam (Braeutigam et al., 2005, 2004, 2001) has employed the MEG in order to study the temporal relationship of cerebral areas involved in consumers' choices when they have to make decisions among different items within a laboratory.

In this study they wanted to analyse the cerebral behaviour by distinguishing male subjects from females during a simulated shopping.

Cerebral activations induced by choices to make reflect the level of familiarity or the preference that a particular experimental subject has with the presented products. These factors can be considered by taking into account the relationship between the current choice of a product on the shelf and the relative frequency of choice and usage of that product in the past.

In particular, the main observation came to light from these studies presents the consumer's choice like a complex sequence of cerebral activations that greatly differ according to the consumer's sex and to the probability of choice. From a behavioural point of view, choices with a high probability were faster than those less predictable. This can be interpreted by supposing that in the case of more difficult choices the cortical activities are more complex than those simple to make. As illustrated in figure 1, they distinguished two distinct cerebral paths. The first

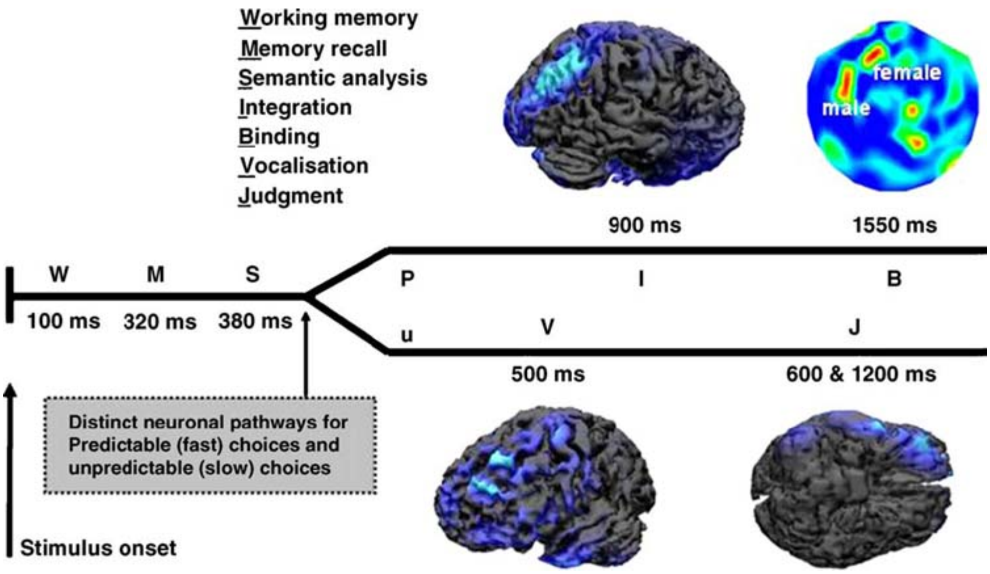

Figure 1: Cortical activations associated to the decisions of an experimental subject. Predictable choices are the ones related to familiar items which has been often bought or used in the past. Cortical maps present the brain areas activated during the different decision stages in the frequency range of [30, 40] Hz. Modified with permission from Braeutigam et al., 2003.

one is referred to predictable choices, i.e. associated to products that the experimental subject already used in the past or said to prefer; the second one is related to unpredictable choices, i.e. associated to unfamiliar products to the subject. In the experiment, a first stage in the decisional process has been individuated around 100 ms after the stimulus onset with an activity located in the occipital cortex. At this stage of decision (W) the subject compare the product to choose with the list of products seen before, by involving the working memory.

The sequence of cortical activations observed in the experimental subjects continues with two neuronal stages partially correlated (M, S) which can be observed between 280 and 400 ms after the beginning of the decisional process. In this period the selective attention of the subject is oriented towards images of products to identify, classify and compare with those stored in the memory related to the preferred products and brands. This memory can involve the past experience to have bought the particular item or to have watched the commercial of the specific brand. The cerebral activation differs in this time interval between men and women. In particular, female subjects showed a stronger activation with respect to the males in the left parieto-occipital lobule of the brain while males presented a stronger cortical activity in the right temporal lobe. These differences connected with the sex of the subjects characterize both the stage of choice of the product and its discrimination. This observation suggest that, at this temporal stage, women tend to employ a strategy based on the knowledge of the product to buy, while men tend to act according to a spatial memory strategy (Kimura, 1996).

After 500 ms from the beginning of the decisional process, two patterns of cortical activations can be identified according to the predictability of the choices adopted by the subjects. In particular, as to the predictable choices, we can observe a strong activation in the right parietal areas around 900 ms after the beginning of the experiment (I). In later time latencies, predictable choices of products recall strong MEG oscillations in the frequency band between [30, 40] Hz in the left prefrontal cortex (B). Parietal cortex receive inputs from many cortical areas since it is involved in the spatial integration of sensorial information. Differences in the cortical activity between men and women can strengthen the hypothesis of two different groups of strategies. On the contrary, unpredictable choices generate a strong activation in the right inferior frontal cortex (V), at a latency of around 500 ms, and in the left orbitofrontal cortex (J) between 600 and 1200 ms after the stimulus presentation. In the case V, the cortical patterns are consistent with the activity in the Broca's area, which is involved in the spoken language, which is also active during the observation of videoclips. Hence, the cortical activity at this latency may indicate a tendency to vocalize brands, as a part of strategy which helps in the decision when it is difficult. The activity in the orbitofrontal cortex (J) can be explained by stating that during an unpredictable choice we have to evaluate the outcome in terms of convenience. Overall, these results explain a complex neuronal network which is active during a simple decisional process connected to the purchase of a product. The generation of a choice is considered as an information processing which can be highly influenced, sensible to the complexity of the decision to make and to the rush in which the decision is made and many other factors.

A strong involvement of parietal areas during the observation of the TV commercials with an affective and cognitive content was also noted in a previous study, performed by using sophisticated MEG recordings (Ioannides et al., 2000). In this study, cognitive frames elicited a stronger activity in the parietal areas and superior prefrontal cortex while the observation of the affective ones is correlated with the activation of the orbitofrontal and retrosplenial cortex, amygdala and brainstem. The magneto field tomography (MFT) results showed an increasing activity during the observation of cognitive stimuli rather than affective commercials in parietal and superior prefrontal areas known to be associated with executive control of working memory and maintenance of highly processed representation of complex stimuli (Summerfield et al., 2005). Although the affect related activations are more variable across subjects, these findings are consistent with previous PET and fMRI studies (Cahill et al., 1996; Maddock 1999; Grabenhorst et al., 2008) showing that stimuli with affective content modulates activity in the orbitofrontal and retrosplenial cortex, amygdala and brainstem.

3 FREQUENCY PATTERNS OF CORTICAL ACTIVITY AND FUNCTIONAL CONNECTIVITY

The research in the neuromarketing field performed in the recent years showed result suggesting that the cortical activity elicited during the observation of the

TV commercials that were forgotten (FRG) is different from the cortical activity observed in subjects that remembered the same TV commercials (RMB). In fact, the principal areas of statistical differences in power spectra between such conditions are located almost bilaterally in the prefrontal Broadmann Areas (BAs) 8, 9 as well as in the parietal BAs 7, as showns in figure 2. The spectral amplitude in the RMB condition was always higher than the power spectra in the FRG conditions over the BAs 8, 9 and 7 (Astolfi et al., 2008). A statistical increase of EEG spectral power in the prefrontal and parietal areas for the RMB dataset compared with the FRG one is in agreement with the suggested role of these regions during the transfer of sensory percepts from short-term memory to long-term memory storage. Although in this study the differences in the cortical power spectra between the RMB and FRG conditions are relatively insensitive to the particular frequency bands considered, there are experimental evidences showing that there is a stronger engagement of the left frontal areas in all the subjects analyzed during the observation of the TV commercials that were remembered (Vecchiato et al., 2010).

In particular, the analysis of the statistical cortical maps in the condition RMB vs FRG suggested that the left frontal hemisphere was highly active during the RMB condition, especially in the theta and gamma band. These results are in agreement with different observations on the RMB condition performed in literature by studying different experimental paradigm (Summerfield et al., 2005; Werkle-Bergner et al., 2006). Taken together, the results indicated the cortical activity in the theta band on the left frontal areas was increased during the memorization of commercials, and it is also increased during the observation of commercials that were judged pleasant by subjects. These results are in agreement with the role that has been advocated for the left pre and frontal regions during the transfer of sensory percepts from the short-term memory toward the long-term memory storage by the HERA model (Tulving et al., 1994; Habib et al., 2003). In fact, in such model the left hemisphere plays a key role during the encoding phase of information from the short term memory to the long term memory, whereas the right hemisphere plays a role in the retrieval of such information.

It must be noted, however, that the role of the right cortices in storing images has been also recognized for many years in neuroscience (Braeutigam et al., 2005, 2004; Babiloni et al., 2000; Astolfi et al., 2009, 2008). It is worthy of note that the subjects were unaware of the kind of questions that the researcher asked them after the viewing of the documentary. Hence, the cortical areas elicited by this study are likely to be involved just in the process of the memorization of the pictorial material, owing to an increase of attention during the observation of the TV commercial. In addition, there was no particular set of commercials remembered that was common to all the subjects.

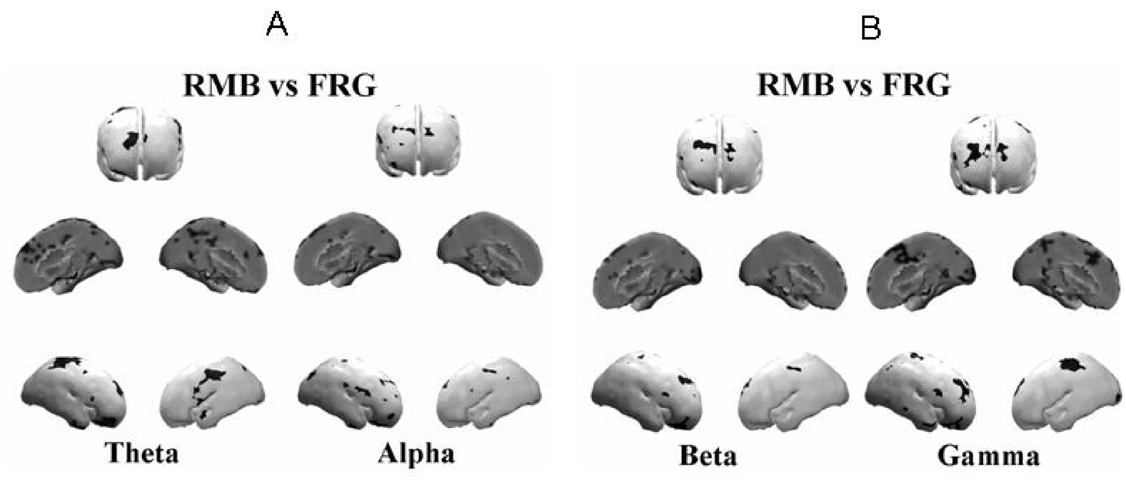

Figure 2: Figure presents the results of statistical comparisons of RMB and FRG groups in the theta and alpha frequency ranges (panel A), and in the beta and gamma bands (panel B). In particular, the picture is composed by three rows: the first one shows the brain from a frontal perspective, the second one is related to a medial- sagittal perspective while the third one presents statistically significant images associated to the left and right lateral vision. Modified with permission from Astolfi et al., 2008.

The results also suggest an active involvement of the Anterior Cingulate Cortex (ACC) and the Cingulate Motor Area (CMA) as sources of links to all the other cortical areas during the observation of the TV commercials remembered after ten days. In this case the increased activity related to an increase of the outflow of PDC links from ACC and CMA towards other cortical regions could be taken as a sign of increased 'emotive' attention to the stories proposed by different TV commercials that significantly aid successive memorization.

The EEG spectral and cortical network analyses performed in these study also suggest a key role of the parietal areas as targets of the incoming information flow from all the other cortical areas. Functional networks in the frequency domain were also estimated by evaluating the global- and local-efficiency indexes derived from the graph theory, employed as a measure of the level of communication in the networks (De Vico Fallani et al., 2008). The changes of these indexes could be related both to memory coding activity as well as to increase/decrease of attentive state of the subjects. As to the RMB condition, the functional network in the beta and gamma band state a significant non-homogeneous allocation of the involved information flows and a consequent reduction of the efficiency in the overall communication between the network nodes. In the beta and gamma frequency bands, the respective reduction of global-efficiency, as well as the reduction of local-efficiency for the alpha band of the cortical network communication could represent a predictive measure for the accurate recall of the commercials that will be remembered.

A contrast of the activity elicited by observing pleasant (LIKE dataset) and unpleasant (DISLIKE dataset) audiovisual content has been performed in a previous study (Vecchiato et al., 2010). The result of this experiment shows that the activity of the brain is greater in the LIKE condition than in the DISLIKE

except that in beta band, being the activity in the LIKE condition for the gamma band rather symmetrical. The results here obtained for the LIKE condition are also congruent with other observations performed with EEG in a group of 20 subjects during the observation of pictures from the International Affective Picture System (IAPS, Aftnas et al., 2004). Such observations indicated an increase of the EEG activity in the theta band for the anterior areas of the left hemisphere.

4 STEADY-STATE VISUALLY EVOKED POTENTIALS

These results are also supported by findings obtained from the group of Richard Silberstein which measured the steady-state visually evoked potential (SSVEP) by means of the steady-state probe topography (SSPT), which is a particular version of

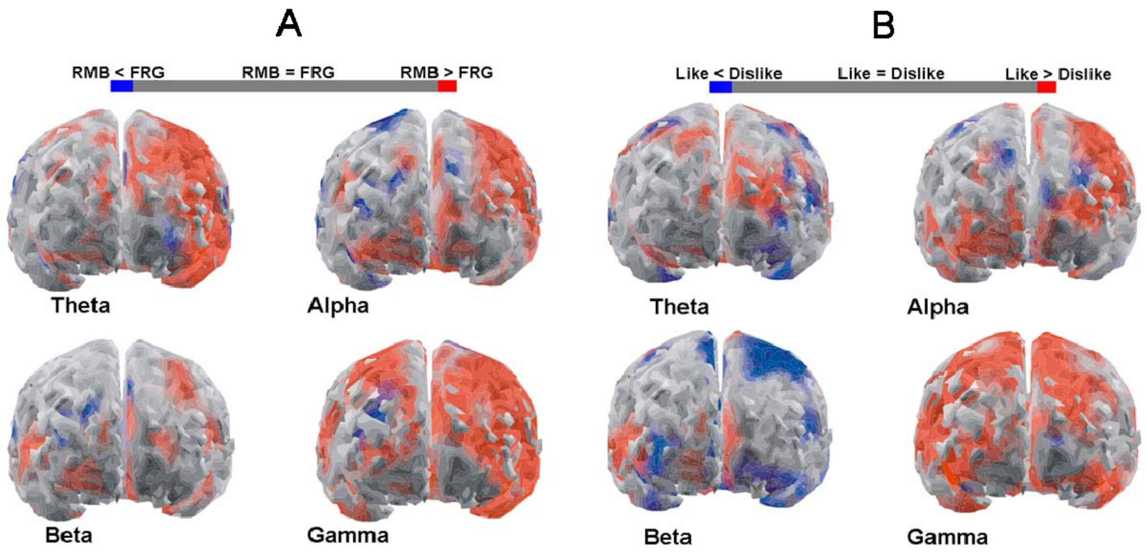

Figure 3: Figure presents four cortical z-score maps, in the four frequency bands employed. Colour bar represents cortical areas in which increased statistically significant activity occurs in the RMB group when compared to the FRG group in red, while blue is used otherwise ($p < 0,05$ Bonferroni corrected). Grey colour is used to map cortical areas where there are no significant differences between the cortical activity in the RMB and FRG groups (panel A). Panel B refers to the statistical comparison LIKE vs DISLIKE with the same conventions of panel A. Modified with permission from Vecchiato et al., 2010.

the EEG technology (Silberstein et al., 1990, 2000; Silberstein, 1995). In this study (Silberstein et al., 2000), they collected the cerebral activity from thirty five women that were subjected to the exposition of eighteen minutes documentary in which 12 US TV commercials were inserted within. Seven days after the recording, the participants were asked to recall the viewed advertisements from a series of frames taken from the same commercials. They found out that images corresponding to a minima of the posterior frontal latency were more likely to be recognized than images associated to a SSVEP latency maxima. Moreover, they showed a significant correlation between the recognition performance and SSVEP latency measured at electrode sites located in the left posterior frontal site suggesting that this kind of result can be employed in order to asses the strength of long-term memory encoding for the audiovisual stimuli they proposed.

5 CONCLUSIONS

In recent years, Neuromarketing has gained always more interest and attention in both the scientific community and mass media. Findings obtained so far show that results from these studies can be of help for many areas of marketing. For instance, marketers could exploit neuroimaging tools in order to achieve hidden information about products and services to advertise that is impossible to acquire. This information could be employed both during the design process of an item and during its commercial campaign. In fact, one could think to adopt these neuroelectrical tools to test different versions of the same object, evaluate the cerebral results and use them according to the requirements of the company and at the same time facing with the consumers' need. In addition, marketers could use an ad pre-test in order to create a TV commercial which is as closer as possible to the demand of the same. In this case we can distinguish two different point of view of the powerful and innovative tool: from one hand, product manufacturers could use cerebral information in order to force people to buy and consume products that they don't want and neither need; from the other hand, we hope that neuromarketing will be of help in design objects and the environment following the pleasures of each of us and for identifying new and exciting products that people want and find useful.

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