

When Brain Informs Us About Mind: a Neuro-Ergonomic Approach to Study Web Sites.

Guercio Elena
Telecom Italia S.p.A.
Torino, Italy
elena.guercio@telecomitalia.it

Simona Collina
Università degli Studi Suor Orsola Benincasa
Napoli, Italy
simona.collina@unisob.na.it

Roberto Montanari; Chiara Ferrarini
Università degli Studi di Modena e Reggio Emilia
Reggio Emilia, Italy
roberto.montanari@unimore.it; chiara.ferrarini@unimore.it

Gabriele Garbin
Università degli Studi di Trieste
Trieste, Italy
g@gabrielegarbin.it

Abstract— In two pieces of research the role of information processing to evaluate a web site dedicated to the green culture and information has been investigated. The first study was based on behavioral techniques whereas in the second study participants were requested to perform an fMRI experiment. The purpose of the two pieces of research was to analyze the usability, and cognitive load of the website but, most important, to validate the reliability of the neuro-ergonomic approach while carrying out these analyses. The results put into evidence a correlation between behavioural and neuroimaging results. More important, neuroimaging methodologies proved to be sensitive to study the understanding of users 'cognitive load.

Keywords- ergonomics; neuroscience; cognition; web-site; information processing

I. INTRODUCTION

Neuroergonomics is the application of neuroscience to ergonomics. Recent researches in experimental psychology felt the need to integrate the classic behavioural paradigms with the recent neuroimaging methodologies [5]. Neuroimaging results can test and constraint cognition by evidencing whether a cognitive model formulated on behavioural results is biologically valid. Second, neuroimaging techniques can provide interesting insight on whether a function is processed by the brain in a localised or in a holistic fashion, providing evidence on the debates on classic cognition versus new embodied theories [1;3]. At the same time, neuroimaging needs experimental psychology and behavioural tests to explain the steps necessary to perform a given cognitive activity. The activation of neural circuits cannot explain alone the complexity of the cognitive experience [4]. So far, the introduction of neuroimaging techniques as the functional magnetic resonance (fMRI) has the advantage to map the brain circuits involved in a given activity thus reducing the gap between cognitive processes (mind) and the neural substrate supporting them (brain) whereas the behavioural methods clarify and specify the

steps and the processes involved at each functional level. Since the birth of cognitive science these points have been source of interesting debates. However, not all the fields of cognition have been investigated in equal manner in this perspective and even if the application/integration of behavioural and neuroimaging methodologies to study mind/brain dichotomy is well known, for example, in perception, attention, memory, language, and reasoning, some fields, especially the ones positing at the User Interface, has been often neglected. For this reason, data available in the ergonomic are far from being unitary.

Some attempts are going in this direction: as noted by Parasuraman [2] neuroergonomics can be a powerful tool to investigate cognitive functions in the real world, in the context, thus overcoming classic lab research where each variable is studied almost in isolation. In this respect, many different approaches have been proposed to apply neuroscience and ergonomics: electroencephalography (EEG), which represents the electrical activity of neural cells populations, event related-brain potentials (ERPs) which detect a specific cognitive event, and more spatially sophisticated methods as the functional magnetic resonance (fMRI). fMRI is becoming pervasive in neurocognitive research. It offers a very good spatial resolution and with an appropriate experimental design, the initial limit posited by the temporal resolution can be encompassed. So far, as it is a non-invasive method that offers the detection of brain activity while a cognitive task is performed, many areas of cognition make use of this method to investigate which neural circuits are responsible for a given cognitive process. One may argue that the method, for the limits given by the experimental set, may have ecological validity only when small portions of the cognitive activity are studied. However, the recent development of new experimental design gave the possibility to study also integrated-complex cognitive processes [6].

In this paper, a new approach will be presented. Two experiments were performed: the first experiment aimed at evaluating participants performance in interacting a web site

dedicated to the green culture (GREEN in the following) through a well validated battery of behavioural tests. In the second experiment, participants performed an fMRI experiment on the same web-site. The results evidenced a high correlation among participants performance in the two experiments. Moreover, fMRI was a sensitive tool to measure the cognitive load and actual understanding of the web-site “conceptual model”, opening a new scenario in the ergonomic studies.

The GREEN website investigated represents the major referent in Italy on the green world along three lines, namely ecology, environment and sustainability. As ecology is becoming more and more important in people lives, and the web site should be fruitful, easy and informative for everybody who wants to be informed on a green lifestyle. The website is structured in different sections: green world, news, events, experts, for company, shopping, community. These different sections have been studied in the two experiments.

Following, the two experiments will be presented. In Experiment 1 behavioural data will be described and discussed. In Experiment 2 an fMRI experiment will be presented as a new methodology to study web interfaces.

II. EXPERIMENT 1

A. Participants

Twenty adult participants (aged between 20 and 50) took part in the experiment. The 25% of them were female, the 75% were male. All participants were native Italian speakers. They had normal or correct to normal vision. Each of them owns a computer and spends at least three hours per week on internet. They received no compensation or credits for their participation.

B. Materials and methods

The GREEN webpage has been selected as key study. Two versions of the page were created, one reflecting how the page appears on the web, Fig. 1, (experimental condition), and one representing only a wireframe, Fig. 2,

with no colours and only category names information to use as a control condition.

The logic followed was to compare the webpage with a wireframe in order to extract the weight of the form and content information. Six different tasks were built according to the web page and wire frame structure. The design was a two level within factors so that each participant performed the task in the web page and wire frame condition. In the following, the tasks’ list is reported:

- Task 1: Search and visualize by clicking on it the most important news present in the website Task;
- Task 2: Search and visualize the third information of the “focus on area”;
- Task 3: Please find and click on the information that for you represent the most important advertising of the website;
- Task 4: You want to plan an ecologic tour. Please search in GREEN where you can find an eco-travel planner and click on it;
- Task 5: Buy a trash bin for waste separation;
- Task 6: You want to learn how to farm in an ecologic way. Visualize the advice of the bio-farmer.

C. Procedure

Participants were tested individually in a quiet room. They were seated in front of a computer at a distance of 1 m from the screen. Instructions were given by the experimenter. Before the experiment proper, participants were asked to familiarize with the materials (website and wireframe); they were encouraged to explore the pages and think aloud on the content and form. Next they were presented with the websites and with the wireframe.

The order of presentation of the tasks changed across the participants in a Latin-square design. In addition, if one participant was presented the website and then the wireframe condition, the following participant was presented them in reverse order so that materials were counterbalanced across participants.



Figure 1. Example of the GREEN webpage

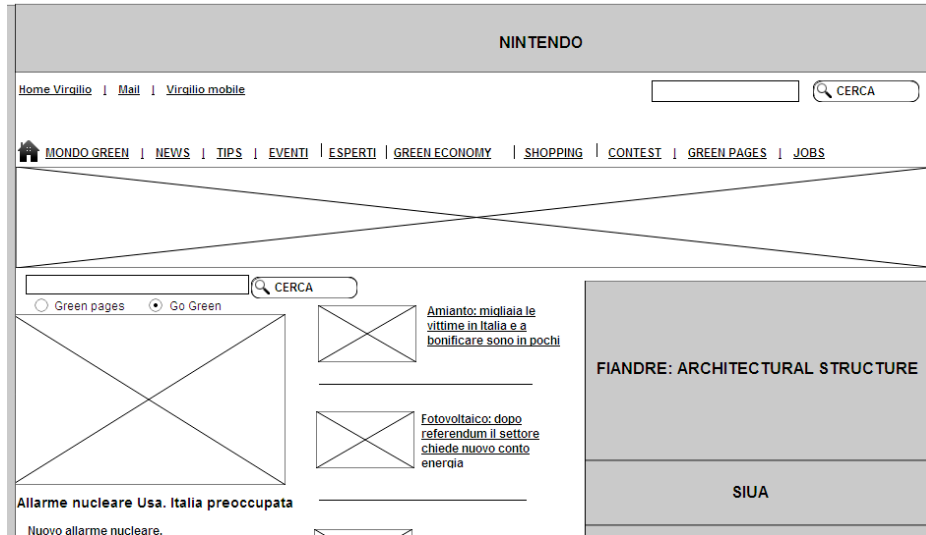


Figure 2. Example of the GREEN wireframe

Data were collected using a logger system (i.e. the remote usability Loop11) to plot and log parameters as time to task conclusion, errors committed, etc. At the end of the task a questionnaire on usability and cognitive load was administered to each participant. The experiment lasted for about one hour.

D. Results

Time to complete the tasks for the two conditions (webpage vs. wireframe) was recorded and submitted to t-test, Fig. 3. The result of task 1, 2 and 3 put into evidence a difference (even if for task 2 was not significant) between the two conditions, with an advantage in time completion for the wireframe (Task 1 $F= 2,137$; Task 2= ns; Task 3 $F= 3,650$, respectively). The result of task 4, 5 evidenced the opposite trend (Task 4 = 2,134; Task 5= 4,036). No difference was observed for task 6.

The percentage of errors was equally distributed across conditions. No other sources or interactions were found significant.

E. Discussion

The result of the behavioural experiment evidenced that participants easily found the information required as suggested by the low percentage of errors. The result of the tasks can be explained on a base of a form semantic distinction: in the first three tasks a strategy based on form could help in finding the information. So far, there was an advantage for the GREEN page compared to the wire-frame. This interpretation was supported by the results of the questionnaire administered. For the first three tasks the results evidenced that features as for example image dimension and position were crucial to correctly solve the task. On the contrary for task 5 and 6 content/semantic information were crucial so that a wireframe website, free of form information could help to solve the tasks. Task 6 was the more complex one: one possible hypothesis to explain

the results is that here the joint effect of form and content gave rise to a null effect. Of course this is only a speculation as the result was null. Finally, the questionnaire administered after the task suggested that the website induce qualitative considerations among participants. However, data were equally distributed in a range from positive to negative evaluations.

III. EXPERIMENT 2

The aim of the second experiment was to study participants' performance on the website from a neuroergonomic perspective. An fMRI experiment was designed in order to map the activation of the neural circuits involved in task performance reflecting the mental processes of the human-web interaction. The experiment was explorative in nature and can be considered a pilot experiment to test if fMRI is a useful tool in the research field.

A. Participants

Six participants were selected for the second experiment. All subjects were Italian monolingual or had no more than basic skills in one foreign language, as resulting after personal interview. All participants were healthy volunteers with a normal or corrected-to normal vision. None of the volunteers had a history of dyslexia or any neurological or psychiatric disorder. They were fully informed on the modality and execution of the scans before signing an informed consent agreement. Participant could leave the experiment at any time, although all completed the experimental sessions, and gave written permission to the treatment of personal data.

B. Materials and methods

The GREEN website was presented to participants in the 1, 5 Tesla scanner. They could see the webpage projected as long as they want.

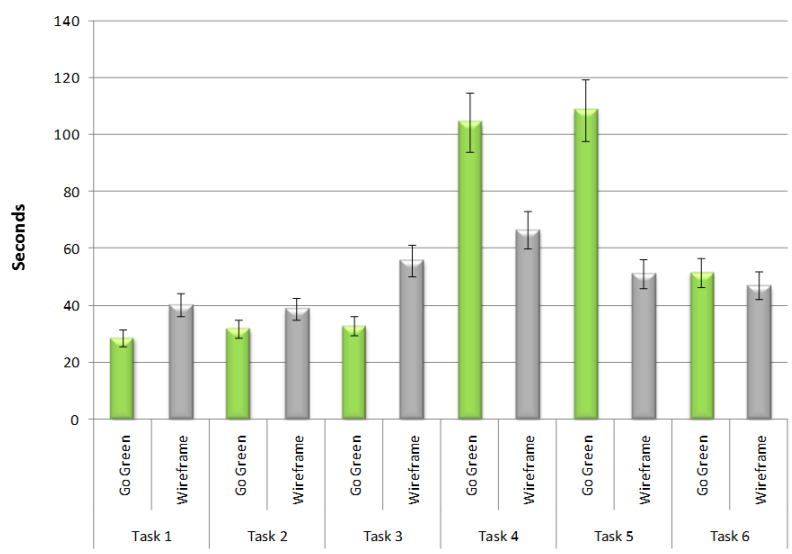


Figure 3. Time (sec) to complete the tasks (N=20)

Experimental sessions and rest alternate each other. Six experimental tasks were performed by participants. Experimental sessions, comparable to that of experiment 1, were adapted to the fMRI experimental settings. Silent reading tasks substituted task involving movements in order to avoid movement artefact. For the same reason a silent reading was preferred to an overt speech. Following, the list of the tasks:

- Task 1: Search the most important news in the website. When you find it read it silently;
- Task 2: Search the third information in the “focus area” and silently read the first word;
- Task 3: Please find the information that for you represent the most important advertising of the website and read the first word silently;
- Task 4: Search the animals represented in the community and think how many is there;
- Task 5: Think about an adjective to define the website;
- Task 6: Think about an adjective to define the colours.

C. Results

Pre-processed images were analysed on blocked protocol. Rests period were taken as baseline.

Encephalic volumes have been acquired using an MRI Achieva (Philips, The Netherlands) of 1.5T. Images obtained have been analysed using the SPM5 (Standard Parametric Mapping) [7] and the resulting activations have been identified with the results obtained by MSU (Michigan State University) and WFU PickAtlas.

Images have been realigned and the variation of intensity, due to local differences in the magnetic field, has been corrected. Volumes have been normalized on the standard coordinate space MNI (Montreal Neurological Institute). For each participant, images sequences of each session have been submitted to a blocked- design t-test. Cumulative analyses

have been run for the activation matrixes. Only cortical activations with a threshold of $p < 0.01$ were considered statistically reliable.

The cerebral activations obtained have been compared analysed, Table 1. Main results evidenced an activation of the frontal circuits (left and right) involved in linguistic tasks, but also involved in tasks requiring even simple problem solving, an example of activation areas is shown in Fig. 4. Linguistic components produced a strong activation that could have been overlapped other cognitive components, thus rendering difficult in task 4, for example the interpretation of the results.

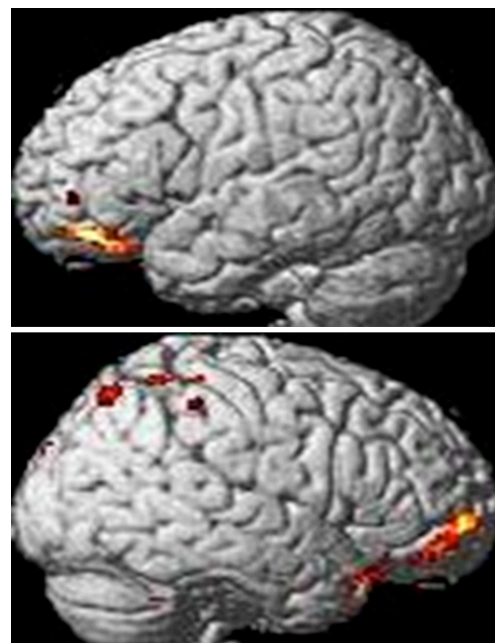


Figure 4. Example of activation areas for task 1 (experiment2)

TABLE I. ACTIVATION RELATED TO EACH TASK

Task	Areas	Brodmann Areas
1	Middle and Inferior Frontal Gyrus (L, R)	10, 11, 47
2	Frontal Lobe (L)	11, 47
3	Frontal Lobe (L,R)	10, 11, 45, 46
4	Inferior Frontal Gyrus (R)	46, 45
5	Inferior Frontal Gyrus and Insula (L)	47, 13
6	Parahippocampal Gyrus and Lingual Gyrus (R)	27, 18

IV. CONCLUSIONS

In two experiments, we tested whether behavioural and neuroergonomic methods can integrate each other to study web user interface. The case study was the GREEN web page. The results evidenced that neuroergonomic can be a useful tool to investigate the neural circuits involved in complex cognitive activities. In addition, it can be informative of the cognitive load a task requires for participants, opening a new scenario in the ergonomic research. It is a granted data that ergonomic is very well studied in its perceptual and attentive components.

However, less has been done on the central components of the activity as linguistic, semantic, comprehension components often required by tasks. Behavioural results evidenced that perceptual and semantic components can act with different weight and change the polarity of a result (task 1,2,3 vs. 4,5). An indication in this direction is also evidenced by the fMRI experiment with areas of activation linked to the cognitive components sensitive to tasks' requirements.

But, even if the neuroergonomic results were comparable to the behavioural results some problems still persist: the second experiment was just a pilot, with a low number of participants and explorative tasks used. But, in order to start a new line of investigation our main goal was to assess whether the tool could be a sensitive one for our purposes. By adding new data through the use of neuroimaging technique we may now formulate new hypothesis, that can take into account not only the cognitive variables implicated in an ergonomic- at work- scenario, but taking into account also the impact of these variables and task requirements on participants performance, thus disentangling effects due to the cognitive activity per se from methodological issue. In this respect, fMRI is sensitive to detect the cognitive load required by a task. However, the use of neuroimaging technique will be possible only because of behavioural tests, more conceptually sophisticated, replicated and able to overcome the limit in ecological validity sometimes suffering neuroimaging designs and settings. The research presented reflects an interdisciplinary approach that can be fruitful for future studies. This will be the challenge.

REFERENCES

- [1] A. Clark, *Being There: Putting Brain, Body, and the World Together Again* (Cambridge, MA: MIT Press), 1997.
- [2] R. Parasuraman, *Neuroergonomics: research and practice* Theor. Issues in Ergon. Sci., vol. 4, 2003, pp. 5-20.
- [3] F. Pulvermüller,, *Words in the brain's language*. Behavioral and Brain Sciences, 22, 1999, pp. 253-336.
- [4] P. Tabossi, *Intelligenza naturale e intelligenza artificiale. Introduzione alla scienza cognitiva*. Collana "Universale Paperbacks il Mulino", 1997.
- [5] R. Parasuraman "Putting the brain to work: Neuroergonomics past, present, and future". *Human Factors*, 50(3)eight, 2008, pp. 468-474.
- [6] U. Hasson, C. J. Honey, *Future trends in Neuroimaging: Neural processes as expressed within real-life contexts*, *NeuroImage* 62, 2012, pp. 1272-1278.
- [7] www.fil.ion.ucl.ac.uk/spm