**Evaluation of implicit contextual memory with EEG methods**

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**Abstract:** The present study provides information about the influence of acute recent stress on implicit contextual memory. Stress is a strong modulator of memory function. Implicit memory is not a single memory system but a collection of processes involving several different brain systems that lie deep within the cerebral cortex. Implicit memory tasks tend to be automatic and not involve reflection. Moreover, they do not involve awareness of learning and other cognitive processes or conscious, as comparison and evaluation. The study is based on the model of Chun and Jiang implicit contextual memory called contextual cueing (M M Chung & Y. Jiang, 1998). In the first part of the study we showed the effect of stress on implicit memory with response time index. On the second part of the study we realized the EEG mapping using sLORETA software to see which are the brain regions with the highest electrical activity, for the Stress Group and also for the Control Group. Control Group had to make a memory test during EEG recording and Stress group had to make a Stroop test (stress task) before the memory test and perform EEG recording. The study shows that for both types of configurations (Old displays - OD, New displays - ND), reaction time decreased due to learning process through exercises, regardless of contextual informations. The performance for guessing target locations in Old displays compared with those for New displays was numerically better in the second day experiment, approximately 67 ms on average, which means that stress influenced learning and contextual guidance.

Keywords: Biosignals, EEG, Evaluation, Implicit memory, Old displays, New displays.

1 **Introduction**

Implicit memory is a special type of long-term memory that is stored in perceptual, motor and emotional circuits. Implicit memory tasks tend to be automatic and not involve reflection. Moreover, they do not involve awareness of learning and other cognitive processes or conscious, as comparison and evaluation [6],[7],[12]. The subject responds to a stimulus repeatedly and his performance is gradually increasing. However, although implicit memory is acquired without conscious effort, its representations are robust and resistant in time, from days, weeks to years, both in normal subjects and patients with amnesia. A variety of conscious cognitive processes are facilitated when the context is similar with a previous one in which the experience occurred [8]. The neuroanatomy of this facilitation by predictive spatial context is the subject of many current scientific debates. Recent studies of functional magnetic resonance imaging (fMRI) using the present paradigm, have detected the presence of hippocampus activity, although this form of memory is implicit. Results so far in this regard, show that the hippocampus is involved in processes outside the domain of conscious learning and memory [10],[11],[12]. Furthermore, brain structures associated with contextual memory are susceptible to stress. However, studies so far are contradictory and not yet known in what measure the stress interferes with the effect of facilitation by spatial context.

The study is based on Chun and Jiang model of implicit contextual memory (M. M. Chung & Y. Jiang, 1998). In the real world, there are strong relationships between the environment and objects that are within it. Experiments involving the perception of scenes and visual search showed that the human visual system is used extensively for these relationships to facilitate the
task of detection, and subsequent recognition of the object, this implying that the visual system instantaneous processes the spatial context, while indexing the object features. This form of perceptual facilitation was translated into an original model by Chun and Jiang (1998), as contextual guidance (contextual cuing). Unlike other models of implicit memory, which used familiar objects and easily to distinguish all among them, contextual guidance involves distribution of attention to perform both search and retention of implicit context. The purpose of this study is to present recent acute stress effect on implicit contextual memory. In the first part of the study we demonstrate the stress effect on implicit memory using response time index and in the second part of the study using the EEG mapping.

2 Experiment

The experimental study was realized with 20 subjects and had two parts. In the first part we recorded response time during the memory test and EEG monitoring. In the second part of the experiment the EEG mapping was performed in order to visualize the brain regions with the highest electrical activity during contextual memory paradigm.

2.1 Methods

2.1.1 Participants

Experiments were conducted in the EEG laboratory of the Department of Physiology and Neuroscience, University of Medicine and Pharmacy "CAROL DAVILA" in Bucharest. Sixteen individuals participated as volunteers in the experiment. All the participants reported normal or corrected-to-normal visual acuity. The participants were 20 healthy young male right handed. Each subject signed an "Informed Participation Agreement" and an affidavit. The 20 subjects were randomly distributed equally in the Control Group, and Stress Group respectively. All subjects were given 15 minutes to adjust to laboratory conditions, during which the EEG cap was fit on the participants head, and electrodes were filled with gel, pulse oximeter and skin electrodes were attached. The experiment was conducted over two consecutive days for each subject: on the first day, the participants performed the learning session of contextual memory test (Context Storage) and on the second day - test evaluation phase (Context Retrieval). On the first day a Stroop task was given only to the Stress group, five minutes before Storage context.

2.1.2 Procedure.

The experiment was conducted in a soundproof laboratory. Subjects were seated in a chair at a constant distance from the display (60 cm) and the seat was positioned so that subjects' eyes to look each time on the central region of the display. Using the MP100 Biopac ® software and Acknowledge 3.90, We purchased the following electrophysiological recordings - EEG derivatives: FP1-F3, FP2-F4, F7-C3, F8-C4, T3-P3, T4-P4, O1-T5 O2-T6, the peripheral pulse usig pulse oximeter, skin electrical conductance using two silver chloride electrodes fixed around silver finger phalanges I, 3 and 4 from the left hand. The performance and reliability evaluation was realized with SuperLab ® program, which automatically recorded response time index in milliseconds from stimulus appearance. Contextual spatial memory task used in the study was a computerized version of the paradigm of Chun and Jiang (1998). Participants performed a visual search task for a target - point T rotated in two directions (left / right) - displayed among 11 L letters rotated to 90°-180°-270°. L were the distractor stimuli which complicate the search task. These displays were grouped into 12 blocks, each block consisting of 14 images each.

![Fig. 1](image-url)
computerized version of Stroop test color-word interference. In total, 60 stimuli were displayed in succession. Each stimulus disappeared from the display after every response or in two seconds if there was no response. Subjects were instructed to identify the color that has the word in the center of a group of 9 words (Fig. 2) and mark the answer as quickly as possible on the specially adapted keyboard colors.

BLUE GREEN YELLOW
PINK RED ORANGE
GREY BLACK PURPLE
TAN WHITE BROWN

Fig. 2

During the EEG recordings were recorded also the response time from stimulus appearance, with SuperLab ® program. This program assesses the performance and reliability tests. Each block of contextual guidance task consisted of a random combination between seven configurations every time new displays (ND) and 7 configurations old overall blocks (OD). Subjects have completed 12 blocks search - 8 blocks on the first day, and 4 blocks on the second day. To reduce statistical noise, image blocks were grouped two by two into epochs.

3 Results
As we expected search performance in the Control Group presented two learning components. For both types of configurations (ND and OD), response time index decreased over time due to procedural learning through exercise, regardless of contextual information. Secondly, visual search for targets in OD was better compared to ND, this illustrating contextual learning. This effect of facilitation by context was developed only through experience.

According to a convention applied in other studies also we appreciated the magnitude of the effect of contextual guidance as the difference between performance of OD and ND (∆RTI) in the last part of the experiment (epochs 4, 5 and 6). For the Control Group this analysis confirmed a performance with an average of 143 ms better for OD compared to ND.

Fig. 3 Evolution of response time index (RTI) for the Control Group depending on the epochs, for old configurations (OD) and respectively for new configurations (ND).

Fig. 4 Evolution of response time index (RTI) for the Stress Group depending on the epochs, for old configurations (OD) and respectively for new configurations (ND).

From the chart bellow we can see that the subjects encoded visual contexts around the target as they completed the search task, and the contextual information determined the faster searches of the target due to the progress of the implicit learning.

Unlike the Control Group, the effect of contextual guidance decreased on the second day of the experiment at the Stress Group with an average of about 67 ms, compared to the Control Group.
Evaluation of the contextual memory

Fig. 5. Evaluating contextual guidance. Differences in average of the response time for the last three epochs for the Control Group.

Evaluation of the contextual memory

Fig. 6. Evaluating contextual guidance. Differences in average of the response time for the last three epochs, for the Stress Group.

In the second part of the study we realized the processing of the activity of neural image from EEG recordings with sLORETA program. From the figures, we can observe that at the Control Group (who has not run the stress test before EEG recordings), the area with the maximum electrical activity is on the occipital and parietal areas. At the Stress Group (who has run the stress test before EEG recordings) the area with maximum electrical activity is the frontal area. For this study, it is important that the values from the temporal area are much smaller at the Stress Group compared to the values from the Control Group. That means that the action of the potential generation on the temporal lobe is poorer at the group that was stressed than at the one that was not stressed.

Fig. 7. Areas of maximum electric activity of the Control Group.

Fig. 8. Areas of maximum electric activity of the Stress Group.
4 Conclusions

In this study we have shown the effect of the recent acute stress on the contextual implicit memory. In the first part of the study we showed the effect of stress on implicit memory with response time index. On the second part of the study we realized the EEG mapping using sLORETA software to see which are the brain regions with the highest electrical activity, for the Stress Group and also for the Control Group. Participants performed a visual search task for a target point T rotated in two directions (left / right) displayed among 11 L letters rotated to 90-180-270 °. L was the distractor stimuli which complicate the search task. These displays were grouped into 12 blocks, each block consisting of 14 images each. In each block, half of the configurations were repeated in all other blocks- old images (Old Displays) - and half were not repeated, being generated randomly for each block - the new images (New Displays). As we expected search performance in the Control Group presented two learning components. For both types of configurations ( ND and OD ), response time index decreased over time due to procedural learning through exercise, regardless of contextual information. Secondly, visual search for detecting the targets in OD was better compared to ND (for the Control Group with 216 ms and for the Stress Group with 143 ms), this illustrating contextual learning. This effect of facilitation by context was developed only through experience. The memory responsible for this effect is the implicit memory, because subjects were not able and had no time to distinguish between the OD and ND configurations. Unlike the Control Group, the effect of contextual guidance decreased on the second day of the experiment at the Stress Group with an average of about 67 ms, compared to the Control Group. Which shows that stress influenced implicit learning context and faster progress in the target visual search? In the images obtained using sLORETA software, we have seen that the regions with maximum electrical activity are different at the Control Group than Stress Group. For the Control Group the area with the maximum electrical activity is on the occipital and parietal areas. At the Stress Group the area with maximum electrical activity is the frontal area. For this study, it is important that the values from the temporal area are much smaller at the Stress Group compared to the values from the Control Group. That means that the action of the potential generation on the temporal lobe is poorer at the group that was stressed than at the one that was not stressed.

References: