Validation of a low-cost EEG device in detecting neural correlates of social conformity

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***Abstract*— The study of conformity from a neurobiological point of view has interested many authors: among them, Shestakova and colleagues (2013) have showed how conformity can be assessed through the analysis of event related potentials (ERPs). More specifically, the P300 component of the ERP was shown to be sensitive to the behavioral adjustment that an individual makes when not agreeing with the majority of a group. Starting from these contributions, in the present study, the famous experiment of Solomon Asch [1] was replicated *online*. The experiment was conducted on a sample of university students, using an innovative and low-cost tool capable of recording the brain signal (a wireless headset equipped with fourteen electrodes, called Emotiv EPOC). The present research aims to demonstrate how cheap and little sensitive tools enable the detection of ERP components that characterize social conformity in an ecological context.**

I. INTRODUCTION

Conformity is a major concern of social psychology. Among the most famous experiments that have been able to shed light on this phenomenon, we remember those of Asch [1] and Sherif [2], which have demonstrated the enormous impact of the majority on people. The results of these experiments have generally turned on the curiosity towards this topic; therefore, many authors have ventured in an attempt to bring out the dynamics and the factors from which conformity and its consequences generate. Nevertheless, only in recent years, tools capable of recording the brain signal have been employed with the specific aim of studying the conformity phenomenon. These devices, however, tended to alter the ecological nature of the tasks because of their invasiveness and the problems due to the signal detection in group interactions (i.e. more subjects together). This theme of social psychology has been studied in the field of neuroscience by using tools capable of measuring event related potentials (or ERPs). The P300, one of the most well-known ERP components, is an established index of attention, decision making, short-term memory and may also reflect the subjective awareness of conformity [3]. Kim [4] has showed the occurrence of a late peak related to the experimental subject's response, explaining how the social deviance is able to activate the error monitoring system of the brain. Moreover, Shestakova [5] has noted that the amplitude of a late component (about $380\,\mathrm{ms}$) is a predictor of conformist behavior. Furthermore, the negative-going ERP wave, called N200, is a mismatch detector and it may represent the experienced internal conflict and the consequential activation of response inhibitor mechanisms. There is also evidence that the N200 wave varies with changes in the response expectancy. ERP—correlates of response selection in a response conflict paradigm [6]. The work of Chen et al. [7] has showed how experimental subjects tended to conform more to the others when their opinion was in contrast with the group's positions, exhibiting a greater N200 component compared to individuals who appeared to be more independent. Furthermore, the particular ERP component called late positive potential (LPP) is known to be elicited by affective stimuli [8] and may indicate emotional regulation. Motivational significance and cognitive effort are known to trigger different LPP [8]. Despite LPP has not been investigated before in conformity studies, it could be interesting deepening the neurobiological activation that characterizes this phenomenon also online and, therefore, this study may contribute to expand the knowledge in this research field. In the work of Cuthbert et al. [9], the LPP generally began in the region of P300, classic index of attention, recognition, and stimulus probability [10], suggesting an association between these ERP measures. The studies listed above share the main limitation that they are hard to replicate, since they used particularly expensive and complex tools for the detection of EEG signals. Therefore, it could be advisable to use cheaper tools so as to broaden the knowledge of this phenomenon. Thus, in our experiment, we used an economic device characterized by a virtual interface that simulated the answers of the majority (by means of bots), with the experimental subject always placed in the sixth response position, in order to influence him with the answers provided by other five participants out of seven. In detail, the adopted device, Emotiv EPOC, is a wireless EEG-based headset that enables the detection of electrical brain signals on the scalp's surface, in order to record and analyze the ERP components elicited in conformist and non-conformist subjects. Emotiv EPOC is innovative for its practicality of use (it is wireless and it uses Bluetooth technology), and affordability for any laboratory, thanks to its low cost. The features that make the Emotiv EPOC headset so practical to adopt have allowed its use during BCI experiments [11], which also considered the P300 waveform [12]. What this paper tries to investigate is the possibility to use a cheaper,

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more suitable and handy tool to carry out these experiments in an ecological environment, in order to identify the ERP correlates involved in the conformity phenomenon. We hypothesize to find a significantly greater P300-like potential in the case of conformist subjects, between 250 and $500\,\mathrm{ms}$ after the stimulus administration. Furthermore, we suppose to detect a greater negative depression between 150-$200\,\mathrm{ms}$ after the stimulus administration and a late cognitive LPP wave as regards the conformist subjects of our study.

II. Materials and Methods

The experiment emulates an online test, where a group of people were asked to select the most appropriate answer among a set of three, given a primer (cue word). The software algorithm presents a window showing the total number of expected participants; then the number of participants selecting each of the possible answers is displayed and, finally, the primer and the answers are presented to the user, enabling him/her to provide the answer. Thus, we are able to assess the effect of the conditioning (percentage of users providing each answer) on the behavior of the user. Actually, the only real participant is the user undergoing the test, as the remaining participants were simulated by the software algorithm, that generates answers, using a random timing, in order to match the desired distribution of probability.

Participants

Sixty healthy Italian native speaker students, 13 males and 47 females, with normal or corrected-to-normal vision, participated in the experiment. The sample was predominantly composed by females due to the preponderance of psychology students. The Ethics Committee of the University of Florence approved the study and all subjects gave their written informed consent.

Stimuli

The stimuli were selected through a two-step procedure: in the first step, a focus group composed by psychologists was involved in creating both cultural and apperceptive items. The cultural items consisted in a cue word associated with three adjectives with different levels of semantic relation with the cue word, while the apperceptive items consisted in a computer-generated word (i.e. sounding plausible but not existing) that is associated with existing adjectives, or a real word associated with three computer-generated adjectives. Each category of stimuli included 45 items. In the second step, the items were submitted to a preliminary sample of 80 gender balanced people, with normal or corrected-to-normal vision: these subjects were mainly academics, in order to detect and eliminate trivial stimuli, where the dispersion of the answers was too low. A sample of the possible stimuli is shown in Fig. 1.

Procedures: Before starting to play, the subjects had to wear the Emotiv EPOC headset. The stimulation was administered using an online interface specifically developed for the experiment, using Google Script, as to emulate an online questionnaire. The interface emulated a group of seven subjects playing at the same time, starting with the connection of the real and emulated users; thus, the first phase of the experiment required the user to wait until all (emulated) users completed their login and the connections were established. Then, the subject received the instructions: he could provide his response only when its icon turned green and, therefore, the stimulus was administered. Once the setup was completed, the interface indicated the start of the game, and began to show the first question to the first user. The interface then generated emulated answers with randomized response times, providing feedback, during the process, on the number and distribution of the generated responses. The experimental subject was always placed in sixth position, as in the original study performed by Asch, thus he/she was presented the distribution of the first 5 answers, before the presentation of the stimuli and the possible answers. The recording of the EEG started automatically before the first stimulus appeared on the screen, and continued until the end of the experiment.

EEG Recording

During the experimental session, the EEG was continuously recorded from 16 sites, aligned with the 10–20 system: AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, FC4, M1, and M2 by Emotiv Systems Inc. (San Francisco, USA) $EPOC$® 16-electrode cap Fig. 2. One mastoid (M1) sensor acted as a ground reference point to which the voltage of all other sensors was compared. The other mastoid (M2) was a feed-forward reference that reduced external electrical interference. The data were digitized using the embedded 16-bit ADC with $128\,\mathrm{Hz}$ sampling frequency per channel and sent to the computer via Bluetooth. The data were band-pass filtered in the 5-$30\,\mathrm{Hz}$ range. The impedance of the electrode contact to the scalp was visually monitored using the Emotiv Control Panel software during all the procedure.

Data analysis

Each subject response was classified in conformist and non-conformist. When the subject selected a response on the basis of the majority of the other five emulated users it was considered as a conformist response whereas if the subject selected a response not related to the outcome of the other users it was considered as non-conformist response.

In the offline analysis, the EEG data were processed using EEGLAB [13] and MATLAB [14]. The EEG data were epoched (-100 to $850\,\mathrm{ms}$ relative to the stimulus onset) and baseline-corrected from -100 to $0\,\mathrm{ms}$. All epochs contaminated with ocular artefacts ($\pm 60\,\mu\mathrm{V}$) were automatically rejected. Moreover, epochs were visually scanned to find further artifacts (EMG artifact and alpha wave intrusions). For each participant, the ERPs were then averaged separately for each channel, and low-pass filtered at $25\,\mathrm{Hz}$ ($24\,\mathrm{dB}$ cut-off). The total number of trials was 90 for each subject. ERPs were constructed by separately averaging trials for conformist response and non-conformist response. The ERP components of interest were selected on the basis of previous studies on social conformity [5], [7], [15]. A sample signal

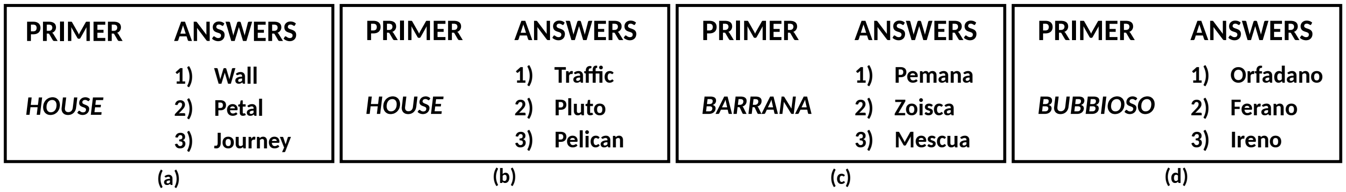

Fig. 1. **Stimuli Example** Four different examples of the stimuli adopted in the experiment are shown; a) represents a trivial case, where the association between the cue word and the answer is trivial; b) is a sample of cultural stimulus, where there is loose coupling of the cue word and the answers (thus, users more likely provide different answers); c) and d), finally, represent apperceptive stimuli, where the cue word or the answers do not represent real words.

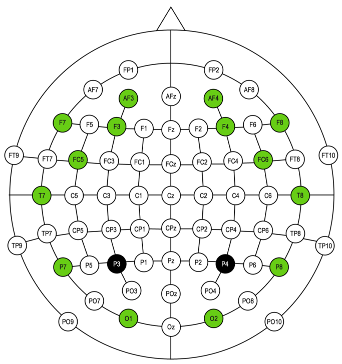

Fig. 2. Electrode locations for the Emotiv Epoc headset.

obtained for each case (conformist and non-conformist) is shown in Fig. 3 for both the frontal and the fronto-central electrodes. Hence the ERP analyses were conducted on the mean amplitude values of N200 and P300 in fronto-central sites. Specifically, we analyzed the N200 (between 100 and 350 ms) as an index of conflict resolution [16] and the P300 (between 250 and 350 ms) as an index of social conformity [7]. For each time window (50ms), the ERP data were analyzed by repeated measure ANOVAs with 2 levels of social conformity (conformist response, non-conformist response). All the ANOVAs applied the Greenhouse–Geisser correction (adjusted degrees of freedom rounded to the nearest whole number are reported) [17] and all the post hoc tests were performed by using Bonferroni correction.

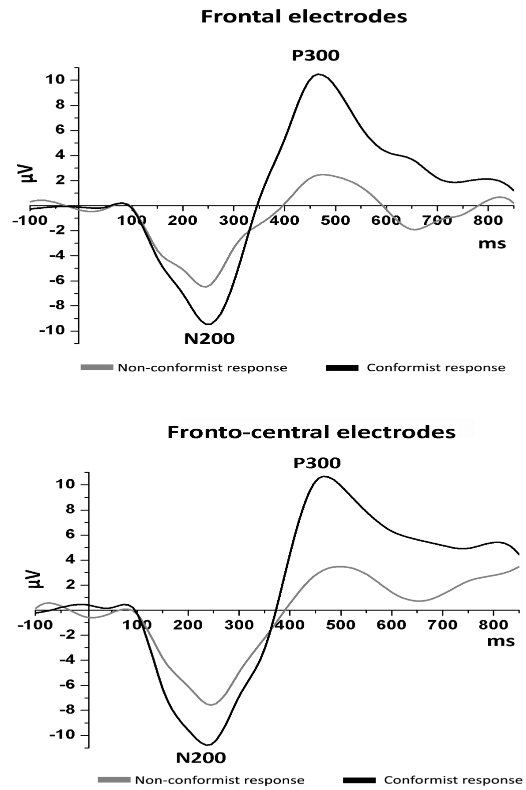

Fig. 3. Sample waveform obtained by averaging the frontal (top) and the fronto-lateral (bottom) electrodes for a non-conformist and a conformist subject, respectively.

III. Results

In agreement with our hypothesis, the results evidenced an effect of condition (conformist and non-conformist) in both the N200 and P300 time-windows, in frontal (F3, F4, F7, F8) and fronto-central (FC5, FC6) electrodes. An enhanced negative potential was found at each time point of the N200 waveform in frontal electrodes for the conformist as compared to the non-conformist response, with the exception of the first (100 ms) and last (350 ms) time points. A similar result was found for N200 in central electrodes, showing an enhanced negative potential for the conformist as compared to the non-conformist response at 200, 250, 300 and 350 ms. Conversely, an enhanced positive potential was found in the P300 waveform for conformist as compared to non-conformist response in 9 time points (namely, from 400 to 800 ms), inside the P300 time window. As for N200, a similar effect on P300 was found also in central sites. In fronto-central electrodes, a significant difference in ERP, with higher values for the conformist as compared to the non-conformist condition, was detected for all the time points of the 300-850 ms window, with the exception of the 800 and 850 ms time points. All results of the repeated measure ANOVAs, obtained for each time point in frontal and fronto-central sites, are reported in Table I.

IV. Discussion

The present study shows the feasibility of detecting typical conformity ERP components using an ecological tool.

The ERP analysis suggests that the P300 waveform is significantly greater in conformist subjects. This is compatible with previous studies, which have detected a stronger P300 component in participants who were more likely to conform to others. Furthermore, in the case of conformist

TABLE I

MEAN ERP AMPLITUDES IN FRONTAL AND CENTRAL ELECTRODES FOR BOTH CONDITIONS (CONFORMISM, NON-CONFORMISM).

Time points (ms)	Frontal electrodes: Conformist	Frontal electrodes: Non-conformist	Central electrodes: Conformist	Central electrodes: Non-conformist
-100	-0.23	0.12	-0.28	0.29
-50	0.21	0.34	-0.09	0.24
0	0.43	-0.56	0.12	-0.38
50	0.18	-0.22	-0.11	-0.24
100	-0.26	-0.32	-0.19	-0.11
150	-6.31	**-3.84****	-4.20	-3.58
200	-9.57	**-6.08****	-7.02	**5.08***
250	-10.61	**-7.56****	-9.50	**-6.46****
300	-6.85	**-4.94***	-6.06	**-3.34****
350	-3.10	-2.23	0.51	**-1.49***
400	4.69	**0.52****	5.28	**0.13****
450	10.26	**2.78****	10.06	**2.18****
500	9.91	**3.48****	9.47	**2.32****
550	7.86	**2.87****	6.26	**1.49****
600	6.30	**1.44****	4.30	**-0.31****
650	5.63	**0.71****	3.68	**1.91****
700	5.16	**1.22****	2.19	**-1.20****
750	4.92	**2.31****	1.90	**-0.70****
800	5.40	**2.72****	2.13	0.43
850	4.45	3.48	1.19	0.19

Mean ERP amplitudes (μV)

Values in bold indicate a significant effect (* $p < 0.05$; ** $p < 0.01$).

subjects, results always show the presence of N200 and LPP waveforms, confirming the existing literature. Our findings suggest that the Emotiv EEG system may prove a valid alternative to laboratory ERP systems for record data on P300 and N200 components linked to a social conformity task. The light-EEG tool presented in this study may also help to overcome barriers to the adoption of this technologies such as high costs and the need of a high degree of expertise that are necessary to use medical-grade EEG devices.

V. CONCLUSIONS

Modulations of the ERP signal, as the P300 (associated with the awareness of the conformity of the answer) and N200 (signalling the internal conflict and the activation of inhibitory mechanisms), can be considered predictive of the phenomena that characterize the social conformity. Therefore, our work confirms the existing literature regarding the analysis of ERP signals and conformity [4], [5], [7], despite the use of a more economical, and less complex EEG recording instrument. Our findings highlight how the sub-component Late Positive Potential (i.e. the emotional regulation) results of interest within the online social conformity [18]–[20]. The set of recognized components of the ERP allowed us to clearly distinguish the plots of conformist subjects from those non-conformists (specifically, N200, P300 and LPP are significantly greater in the case of those who conform to the majority, whereas RP and ERN are significantly greater in the case of those who do not conform). Therefore, the Emotiv EPOC device is able to record and identify the changes in the ERP signals typically associated with the social conformity phenomenon, enabling more ecological measurements even in group conditions, despite its reduced sensitivity and lower temporal resolution. However, in our study gender condition was unbalanced due to a higher presence of female participants, so in future research is recommended to collect data on a wider experimental sample as to observe also a possible gender effect. In conclusion, reliable EEG parameters for research purposes can be obtained from a cheap, commercial, wireless headset. This will hopefully lead to more widespread use of EEG technologies.

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