BRAININFO 2018

The Third International Conference on Neuroscience and Cognitive Brain Information

ISBN: 978-1-61208-649-1

June 24 - 28, 2018

Venice, Italy

BRAININFO 2018 Editors

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BRAININFO 2018

Forward

The Third International Conference on Neuroscience and Cognitive Brain Information (BRAININFO 2018), held between June 24, 2018 and June 28, 2018 in Venice, Italy, was dedicated to evaluate current achievements and identify potential ways of making use of the acquired knowledge, covering, the neuroscience, brain connectivity, brain intelligence paradigms, cognitive information, and specific applications.

The complexity of the human brain and its cognitive actions stimulated many researches for decades. Most of the findings were adapted in virtual/artificial systems in the idea of brain-like modeling them and used in human-centered medical cures, especially for neurotechnologies. Information representation, retrieval, and internal data connections still constitutes a domain where solutions are either missing or in a very early stage.

We take here the opportunity to warmly thank all the members of the BRAININFO 2018 technical program committee, as well as all the reviewers. The creation of such a high quality conference program would not have been possible without their involvement. We also kindly thank all the authors who dedicated their time and effort to contribute to BRAININFO 2018. We truly believe that, thanks to all these efforts, the final conference program consisted of top quality contributions.

We also gratefully thank the members of the BRAININFO 2018 organizing committee for their help in handling the logistics and for their work that made this professional meeting a success.

We hope that BRAININFO 2018 was a successful international forum for the exchange of ideas and results between academia and industry and to promote further progress in the field of neuroscience and cognitive brain information. We also hope that Venice, Italy provided a pleasant environment during the conference and everyone saved some time to enjoy the unique charm of the city.

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Table of Contents

Evaluation of a P300 Brain-Computer Interface Using Different Sets of Flashing Stimuli

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***Abstract*—Thanks to brain-computer interface systems, patients with muscular impairments could have control of a device to communicate with people and manipulate their environment using only their brain signals, without the need of any muscular activity. The present preliminary study with four subjects is focused on the control of a 3x4 P300-based speller matrix which allows users to write and communicate. Seven different types of flashing stimuli were used to highlight the letters: i) white letters, ii) colored letters, iii) white blocks, iv) colored blocks, v) neutral pictures, vi) positive and excitatory pictures, and vii) negative and excitatory pictures. These preliminary results showed that conditions with pictures could offer the best performance, specially the set of negative and excitatory pictures. Regarding the other conditions, those ones with blocks presented better results than the standard letter paradigm.**

Keywords- Brain-computer interfaces (BCI); P300; speller; stimuli; evaluation.

I. INTRODUCTION

A Brain-Computer Interface (BCI) is a technology that lets establish a communication channel between a person and a device just through his/her brain signal [1]. Thanks to these systems, a user could interact with the environment without needing any kind of muscular activity. Thus, this technology can offer a significant improvement in the life quality of, for example, those patients affected by some lesions in the spinal cord or motor neuron diseases, such as Amyotrophic Lateral Sclerosis (ALS).

Most of these interfaces use electroencephalography (EEG) as the method to record the brain signal due to its combination of adequate temporal resolution, portability, and relatively low cost [2]. The EEG can register various types of brain signals such as Sensori-Motor Rhythms (SMR), Slow Cortical Potentials (SCP), Steady State Visual Evoked Potentials (SSVEP) or P300. Concretely, P300, which will be used by the proposed device in the present paper, is a positive deflection in the voltage of the EEG signal and is generally registered from the parietal lobe of the cortex, around 300 ms after the presentation of an uncommon target stimulus. According to [2], the main advantages of the P300-based systems are: i) they do not require extensive training for management, only a small calibration to adjust the system settings for each user system; ii) they tend to have high success rates and iii) they offer a high number of options to be chosen by the participant, due to the large number of stimuli that these systems allow using an oddball paradigm (e.g., [3]).

An interface which allows patients to communicate with people in their environment (e.g., [4]) could be considered the most widely studied application since the publication of [3]. The authors of this last proposal presented a virtual keyboard composed of a matrix of letters in which any of them could be selected by the user to communicate through typed (spelled) words. Their devised communication paradigm presented a 6×6 matrix of letters and numbers, whose rows and columns were briefly intensified (i.e., flashed) a given number of times in a random order. The user should keep his/her attention over the target character and count the number of times that it was flashed. As this character was presented in one specific row and column, the P300 can be used to find the target stimulus using the oddball paradigm. Once a sequence of flashes was over, the symbol that belongs to the row and column that had produced the largest P300 was regarded as the attended character and given as feedback to the user.

Following the paradigm presented by [3], numerous variations have been proposed to improve the use of a P300 speller matrix. Some works have been focused on certain parameters of the keyboard such as variations in lighting patterns [5], presentation times and brightness intensity [6], size of the stimuli and distance between them [7], color [8], number of stimuli [9] or even the nature of these, i.e., letters, faces, geometrical figures, etc. [10][11]. In addition, some studies pointed out outside the BCI field [12] that the emotional charge of stimuli can modify the amplitude of the Event-Related Potential (ERP) signal, such as the P300 or the late positive potential.

Comparing different conditions in the same experiment could be interesting to obtain a preliminary overview about the proper flashing stimuli set to control a P300 speller matrix. The flashing stimuli are those that appear when the letter is highlighted for a few milliseconds and trigger the P300 signal. Specifically, the present paper will test seven conditions in order to assess the influence of different flashing stimuli set.

Therefore, we hypothesized that four main factors may affect the speller performance: i) the size of the stimuli, two sizes were used, one size being the letters themselves and other a whole rectangle covering the letters; ii) the heterogeneity, i.e., if the interface uses the same flashing stimulus for every item or, otherwise, it uses different chromatic stimuli composition for each letter, as in [4] using different colored letters; iii) the nature of the stimuli, where letters, monochromatic blocks and images will be compared; and iv) the emotional charge of the stimuli, two sets of emotional pictures (excitatory positive set and an excitatory negative set) will be compared in terms of accuracy to neutral sets (neutral pictures, blocks and letters).

The rest of the paper is structured as follows. In Section II (Method), it is described who participated in the experiment, the different spelling paradigms, the procedure, and the data acquisition and signal processing that were carried out. In Section III (Results and discussion), the gathered data are shown and discussed in order to identify the main findings. Finally, in Section IV (Conclusion and future work), the paper is concluded offering possible proposals according to the obtained results.

II. METHOD

A. Participants

The study involved four participants (aged 30 ± 8.72, one female, all heterosexuals) who had normal or corrected-to-normal vision. Two subjects had previous experience controlling BCI systems and the other two did not. The study was approved by the Ethics Committee of the University of Malaga and met the ethical standards of the Helsinki Declaration. According to self-reports, none of the participants had any history of neurological or psychiatric illness or were taking any medication regularly.

B. The spelling paradigms

The present work employed seven paradigms that were used by participants. All these paradigms were initially based on the previously mentioned row-column lighted paradigm of [3]. However, the current proposal used a 3x4 matrix of 25 cm x 17.2 cm displayed on a 15.6-in (39.6 cm) screen at a refresh rate of 60 Hz. A Stimulus Onset Asynchrony (SOA) of 304 ms was used, and an Inter-Stimulus Interval (ISI) of 96 ms, so each stimulus was presented for 208 ms. A 3500 ms pause was established between letters. The only difference between the compared paradigms was the employed flash stimuli for each condition. Thus, the seven presented paradigms were: i) White Letters (WL), ii) Colored Letters (CL), iii) White Blocks (WB), iv) Colored Blocks (CB), v) Neutral Pictures (NP, low arousal and medium valence images), vi) Excitatory Pleasant Pictures (EPP, high arousal and valence images), vii) the Excitatory Unpleasant Pictures (EUP, high arousal and low valence images). All conditions are presented in Fig. 1. The font used for the letters in all conditions was arial bold in capital

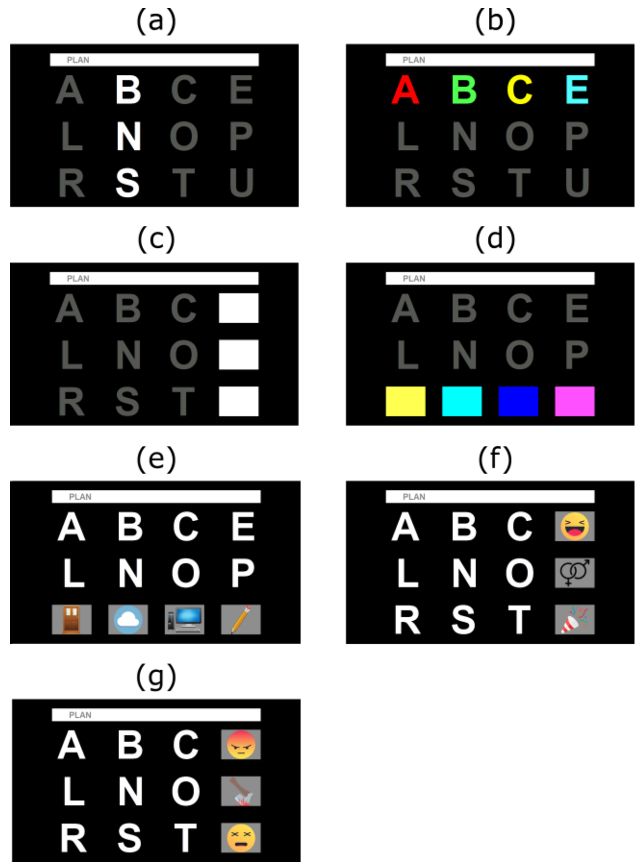

Figure 1. Spelling paradigms used in the experiment: a) White Letters (WL), b) Colored Letters (CL), c) White Blocks (WB) and d) Colored Blocks (CB), e) Neutral Picture (NP), f) Excitatory Pleasant Picture (EPP) and g) Excitatory Unpleasant Picture (EUP). Due to copyright reasons, the actual pictures used in the experiment were replaced in this figure by these chosen emoticons to represent each condition.

letters. Moreover, the size of the stimuli (i.e., letters, blocks and pictures) was adapted to the same space, 4.7 cm x 3.5 cm, presented at a distance of 60 cm, approximately.

Regarding the conditions with figures, they were obtained from the International Affective Picture System (IAPS; [13]). On the one hand, the images of the EPP and EUP conditions were selected using the following procedure: i) those images with high value of arousal (above the 90th percentile) were collected; ii) the 12 pictures with highest and lowest valence for the EPP and the EUP conditions, respectively, were finally selected. On the other hand, for the NP condition: i) the selected images were those that placed below the 10th percentile in arousal level, and ii) the first 12 images whose valence was nearer to the mean were selected. Only those images that maintained the proportion of the aforementioned size were selected, i.e., the images that filled all the space and did not have black paddings. Those images with high predominance of black color or those that were excessively difficult to be recognized were also removed. The IAPS' codes of the selected pictures are presented in Table 1. In all conditions, the letters were adapted to the same size of the figures, so they occupied the largest possible space within the aforementioned dimensions.

 ISBN: 978-1-61208-649-1

TABLE I. THE SELECTED IMAGES OF THE INTERNATIONAL AFFECTIVE PICTURE SYSTEM (IAPS) PRESENTED IN ROW-MAJOR ORDER PER CONDITION.

Speller condition	Selected images according to gender	
	Man	***Woman***
Neutral picture (NP)	7490, 7059, 2411, 5390, 7179, 5731, 7001, 7003, 7017, 7020, 8465, 7160	7020, 5471, 7050, 7055, 7010, 7161, 7179, 2190, 2397, 2840, 7041, 6150
Excitatory pleasant picture (EPP)	8080, 4225, 8501, 4002, 4659, 4008, 4085, 4090, 4210, 4220, 8370, 4250	5621, 4525, 8030, 8158, 4698, 8179, 8180, 8186, 8370, 8490, 8001, 4668
Excitatory unpleasant picture (EUP)	6563, 3131, 3000, 3130, 6510, 3060, 3068, 3069, 3071, 3080, 9250, 6231	3068, 3000, 3080, 3100, 3053, 3130, 9075, 3010, 9410, 9433, 3069, 3001

C. Procedure

The experiment was carried out in an isolated room where only the participant was present at the time he/she was performing the task in order to concentrate on it without external distractions. It consisted of only one exercise: a calibration task to adapt the system to the user. In addition, there was no writing task in which the user actually controlled the interface. Consequently, the study was performed in one session.

An intrasubject, also called repeated measures, design was used, and so all the users went through all the experimental conditions. The conditions order for each participant was selected pseudo-randomly to prevent any unwanted effect, such as learning or fatigue, and all conditions were equally distributed.

We used three words for calibration purpose and each one had four letters, having a total of 12 characters per condition, with a short break between words (variable at the request of the user). Each letter flashed 20 times and the user was asked to count these flashes to maintain the attention. The writing time for each character in this phase was 25.77 s. The specific Spanish words were: “PLAN” (plan), “TRES” (three) and “CUBO” (cube).

D. Data acquisition and signal processing

The EEG was recorded at a sample rate of 500Hz using the electrode positions: Fz, Cz, Pz, Oz, P3, P4, PO7 and PO8, according to the 10/20 international system. All channels were referenced to the left earlobe and grounded to position AFz. Signals were amplified by an acti-CHamp amplifier (Brain Products GmbH, Munich, Germany). Neither online nor offline artifact detection techniques were employed. All channels impedances were reduced below 10.0 kΩ before recording. All aspects of EEG data collection and processing were controlled by the BCI2000 system [14]. A Stepwise Linear Discriminant Analysis (SWLDA) of the data was performed to obtain the weights for the P300 classifier and calculate the accuracy.

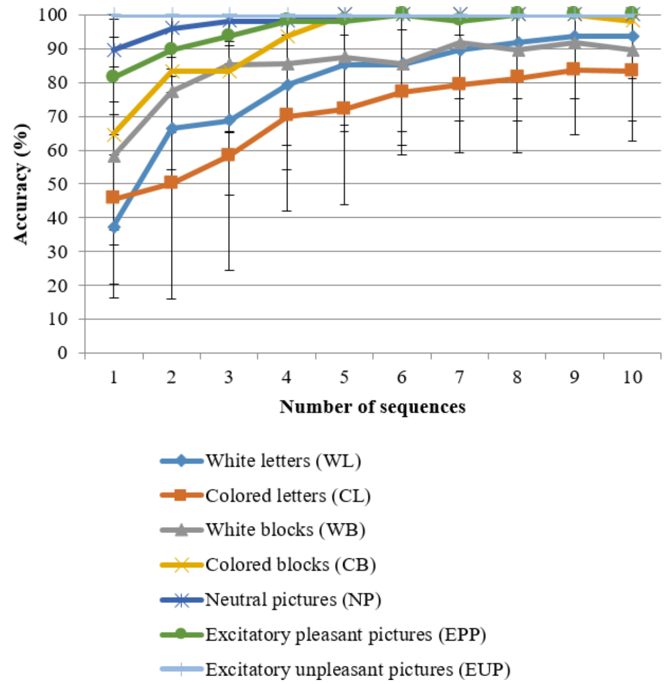

Figure 2. Classification accuracy of the seven tested spellers as a function of the number of sequences per row and column during calibration.

III. RESULTS AND DISCUSSION

Fig. 2 shows the mean classification accuracy achieved by users for each of the seven conditions, as a function of the sequences (due to the small simple size, statistical significance is not considered). Each sequence is composed of two flashes, namely, the corresponding flash from the column and other flash from the row.

Despite the low number of users, these preliminary results showed some trends that are worth to be mentioned. Firstly, the three different conditions with pictures produced the best results, especially the EUP paradigm, which has shown a 100% accuracy since the first sequence by the four users. Then, it seems that the CB paradigm had better results than the remaining non-picture conditions, since it achieved 100% accuracy at least in some point (sequence = 5, i.e., with 10 flashes). Regarding the standard condition of white flashing letters, i.e., the WL paradigm, it started with the lowest performance in the first sequence but it gradually improved until it achieved its maximum accuracy of 93.75% in the second-to-last sequence, i.e., with 18 flashes.

A remarkable detail that should be inspected in later experiments is the apparent superiority of the WL paradigm versus the CL paradigm, which is the opposite of what [4] and [15] showed using a slightly different paradigm. It is also important to highlight that WL and WB paradigms start to improve equally from the fifth sequence.

Regarding the superiority of the conditions with pictures, it should be studied more deeply with a larger number of participants. In addition, despite the hypothesis about the excitatory and emotive pictures that could modify the brain activity and improve the attention [12] and, thus, it could

 ISBN: 978-1-61208-649-1

improve the performance of the user, Fig. 2 shows that the NP paradigm obtained better results than the EPP paradigm, at least in the three first sequences. Therefore, it would be interesting to study which variable is actually improving the performance of the users while using pictures on the speller.

Another interesting result is that the hypothesis about the stimuli size significance described in this paper's introduction, seems correct since, in general, the conditions with figures and blocks obtained better results than the conditions with letters.

IV. CONCLUSION AND FUTURE WORK

The present preliminary study about the effect of different set of flashing stimuli using a P300-based speller has shown some trends that should be further explored in future proposals. The main finding is that the use of pictures, especially with the negative and excitatory pictures, could improve the performance controlling this device. However, for future experiments, it should be considered the application of an online phase where the user can write and, thus, obtain some feedback. Moreover, it would be absolutely necessary to use a larger sample of participants to obtain stronger results and conclusions before we move forward to the next step: to test the hypothesis with patients.

ACKOWLEDGMENT

This work was partially supported by the Spanish Ministry of Economy and Competitiveness through the projects LICOM (DPI2015-67064-R), by the European Regional Development Fund (ERDF) and by the University of Malaga. Moreover, the authors would like to thank all participants for their cooperation.

REFERENCES

[1] J. R. Wolpaw, N. Birbaumer, D. J. McFarland, G. Pfurtscheller, and T. M. Vaughan, "Brain-computer interfaces for communication and control," *Clin. Neurophysiol.*, vol. 113, no. 6, pp. 767–791, 2002.

[2] L. F. Nicolas-Alonso and J. Gomez-Gil, "Brain computer interfaces, a review," *Sensors*, vol. 12, no. 2, pp. 1211–1279, 2012.

[3] L. A. Farwell and E. Donchin, "Talking off the top of your head: toward a mental prosthesis utilizing event-related brain potentials," *Electroencephalogr. Clin. Neurophysiol.*, vol. 70, no. 6, pp. 510–523, 1988.

[4] D. B. Ryan, G. Townsend, N. A. Gates, K. Colwell, and E. W. Sellers, "Evaluating brain-computer interface performance using color in the P300 checkerboard speller," *Clin. Neurophysiol.*, vol. 128, no. 10, pp. 2050–2057, 2017.

[5] G. Townsend *et al.*, "A novel P300-based brain-computer interface stimulus presentation paradigm: Moving beyond rows and columns," *Clin. Neurophysiol.*, vol. 121, no. 7, pp. 1109–1120, 2010.

[6] Y. Li, S. Bahn, C. S. Nam, and J. Lee, "Effects of Luminosity Contrast and Stimulus Duration on User Performance and Preference in a P300-Based Brain-Computer Interface," *Int. J. Hum. Comput. Interact.*, vol. 30, no. 2, pp. 151–163, 2014.

[7] Y. Li, C. S. Nam, B. B. Shadden, and S. L. Johnson, "A p300-based brain-computer interface: Effects of interface type and screen size," *Int. J. Hum. Comput. Interact.*, vol. 27, no. 1, pp. 52–68, 2011.

[8] K. Takano, T. Komatsu, N. Hata, Y. Nakajima, and K. Kansaku, "Visual stimuli for the P300 brain-computer interface: A comparison of white/gray and green/blue flicker matrices," *Clin. Neurophysiol.*, vol. 120, no. 8, pp. 1562–1566, 2009.

[9] E. W. Sellers, D. J. Krusienski, D. J. McFarland, T. M. Vaughan, and J. R. Wolpaw, "A P300 event-related potential brain-computer interface (BCI): The effects of matrix size and inter stimulus interval on performance," *Biol. Psychol.*, vol. 73, no. 3, pp. 242–252, 2006.

[10] T. Kaufmann, S. M. Schulz, C. Grünzinger, and A. Kübler, "Flashing characters with famous faces improves ERP-based brain–computer interface performance," *Journal of Neural Engineering*, vol. 8, no. 5. p. 56016, 2011.

[11] M. S. Treder, N. M. Schmidt, and B. Blankertz, "Gaze-independent brain–computer interfaces based on covert attention and feature attention," *J. Neural Eng.*, vol. 8, no. 6, p. 66003, 2011.

[12] G. Hajcak, A. Macnamara, and D. M. Olvet, "Event-related potentials, emotion, and emotion regulation: An integrative review," *Dev. Neuropsychol.*, vol. 35, no. 2, pp. 129–155, 2010.

[13] P. J. Lang, M. M. Bradley, and B. N. Cuthbert, "International Affective Picture System (IAPS): Technical Manual and Affective Ratings," *NIMH Cent. Study Emot. Atten.*, pp. 39–58, 1997.

[14] G. Schalk, D. J. McFarland, T. Hinterberger, N. Birbaumer, and J. R. Wolpaw, "BCI2000: A general-purpose brain-computer interface (BCI) system," *IEEE Transactions on Biomedical Engineering*, vol. 51, no. 6. pp. 1034–1043, 2004.

[15] D. B. Ryan, K. Colwell, S. Throckmorton, L. Collins, and E. W. Sellers, "Enhancing Brain-Computer Interface Performance in an ALS Population : Checkerboard and Color Paradigms," pp. 9–10, 2013.

Training and Transfer Effects Achieved with N-Back Task in Older Subjects Evidenced with EEG

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***Abstract*—Working Memory (WM) and cognitive functions decrease with age. Although WM training has been extensively studied, transfer effects to other cognitive functions are still inconclusive. We examined whether 10 sessions of N-Back training could improve not only the trained task but also lead to significant transfer effects to similar cognitive functions (near-transfer), such as spatial memory, and to different cognitive functions, such as intelligence and attention (far-transfer). We analyzed behavioral, as well as electroencephalogram (EEG) data recorded during task performance. Our results showed significant differences in N-Back performance and near-transfer effects, but no evidence for far-transfer effects.**

Keywords-N-Back; transfer effects; EEG; P300; cognitive training.

I. INTRODUCTION

Working Memory (WM) has been intensively researched in the last decade. Baddeley [1] describes WM as a brain system that provides temporary storage and manipulation of information necessary to complete complex tasks. With age, cognitive functioning has been shown to decline especially in terms of WM as it is the earliest symptom a person experiences [2]. The possibility to trigger the aging brain's plasticity processes by cognitive training seems promising as several studies reported a slowdown in WM decline [3][4] and even an improved cognitive functioning [4][5].

Following a series of studies, it has been reported that, after intensive WM training, improvements in the trained task can be obtained [3], although a generalization to other non-trained functions (transfer effects) is still unclear [6][7]. Jaeggi et al. [7][8] used an N-Back task for cognitive training and showed improvements not only in the trained task but also transfer effects to other cognitive functions, such as fluid intelligence. The latter is an example of a far-transfer effect as the brain regions activated during N-Back task performance overlap only slightly with those involved in fluid intelligence [7]. In support of the overlap theory, previous studies assume a partial overlap with the fronto-parietal network to be sufficient to exhibit also an improvement in other cognitive functions. A second hypothesis states that WM training effects transfer only if cognitive training improves specific cognitive processes required in both training and transfer tasks. Dahlin et al. [9] found transfer, after WM updating training, to an N-Back task that resembled the original trained task in also relying on updating processes (near-transfer effect), but not to a Stroop task that involved inhibition but no updating.

Motivated by the previous findings on the effectiveness of the N-Back task [10], we decided to also use it in our cognitive training experiment. The N-back task was originally developed by Wayne Kirchner in 1958 [11] as a four load factors (''0-Back'' to ''3-Back'') visuo-spatial task for measuring WM. The N-Back task involves different processes, such encoding, monitoring, maintenance, updating of the sequence, and stimulus matching. It reflects a number of core Executive Functions (EFs), besides working memory, such as inhibitory control and cognitive flexibility, problem solving, decision making, selective attention, and other functions [12]. The task requires participants to maintain stimulus information and decide if the currently shown picture is the same as the one presented N times before (Figure 1). Owen et al. [6] reported the following brain areas to be activated during this task in healthy subjects: lateral premotor cortex, dorsal cingulate and medial premotor cortex, dorsolateral and ventrolateral prefrontal cortex, frontal poles, and the medial and lateral posterior parietal cortex.

The N-Back task can be measured behaviorally and with EEG. Brouwer et al. [13] showed a clear differentiation between N-Back levels and the amplitudes of certain Event-Related Potentials (ERPs). In particular, the P300 component, defined as a positive deflection in EEG amplitude that appears approximately 300 ms after stimulus presentation. The P300 amplitude is inversely proportional to task difficulty level. P300 has been related to updating working memory [14], executive functions [15], and stimulus evaluation and categorization [16].

In the present study, we examined whether N-Back training improves the trained task in healthy older adults compared to a passive control group that did not undergo any training, and whether we could detect near- and far-transfer effects to untrained cognitive functions. We hypothesize improvements in the trained task and near/far-transfer effects in the training group, but no significant outcomes for the passive control group.

In Section 2, we describe the materials and methods used in our study. In Section 3, we report our results and discuss them briefly, and formulate our conclusions, in Section 4.

II. Materials and Methods

In this section, we describe our subject recruitment, used cognitive tests, N-Back training, and EEG recording.

A. Subjects

We recruited 15 healthy older participants (9 females and 6 males), between 55 and 70 years old (M = 60.98, SD = 0.11) from Senior Centers in Leuven, Belgium (Table 1). The selection criteria were: Mini Mental State Examination (MMSE) score above 27, no history of neurological or psychiatric diseases, no experience with WM training, normal vision, and not taking any medication that could interfere with cognitive functioning. Power estimation for sample size was calculated and indicated N = 8 based on accuracy, and N = 8 based on ERP-P300, in the case of the pre-post N-Back task. Our participants were assigned to either a training group (N = 8) or a passive control group (N = 7). The passive control group only completed two sessions of cognitive testing and did not undergo any WM training. The training group completed 10 sessions of WM training in 4 weeks, and performed 2 sessions of cognitive tests before and after training. During the first session, participants were informed about the goals of our study and what would be done with the recorded data. When they agreed to participate, they read and signed the informed consent form. The study was prior approved by our university hospital's ethical committee.

TABLE I. DEMOGRAPHICS

a. **F=female, *M= male

DEMOGRAPHICS	TRAINING GROUP		PASSIVE CONTROL GROUP		GLOBAL VARIABLES (over groups)	
	M	***SD***	***M***	***SD***	***M***	***SD***
Age	62.25	4.83	59.71	4.68	60.98	4.77
Education	10	3.5	6	1.27	8.33	3.2
Sex (F**)	4	(4M*)	5	(2M*)	9	(6 M*)
MMSE	29.75	0.46	29.86	0.38	29.8	0.41

B. Pre-post cognitive tests

The battery of cognitive tests included the Test Of Variables of Attention (TOVA), CORSI and RAVEN tests, and was used to detect behavioral differences before and after training, in the training and control group. The TOVA test is a cognitive test that gauges attention [19], the CORSI block tapping test is used to assess visuo-spatial short-term WM [20], and the RAVEN test is used for measuring abstract reasoning and intelligence [21]. The CORSI test is used to assess near-transfer effects, the TOVA and RAVEN tests to assess far-transfer effects.

C. N-Back task

Considering the encouraging results of Jaeggi et al. [7][8], using a N-Back task, subjects were administered an adapted version of the N-Back task shown in Figure 1. Participants had to decide whether the presented picture is the same as the one presented N times before. The task was divided into four difficulty levels (0-back, 1-back, 2-back and 3-back). Each level consisted of 100 stimuli (i.e., meaningful drawings) presented in pseudorandom order. Participants were required to have answered 70% of the current trials correctly before passing to the next level. For each block of 100 stimuli, 33% of them were target and the stimuli were presented during 1 s followed by a 1.5 s inter-stimulus interval (ISI) and 0.5 s of feedback presentation (red frowny/green smiley). Between stimuli, participants were shown a crosshair centered on the screen. They received a monetary reward (max 20 euros per session) and were informed of the reward at the end of each session. In total, there were 10 sessions of N-Back training for 4 weeks.

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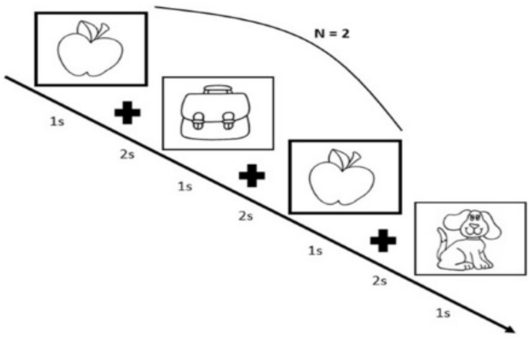

Figure 1. Example stimulus sequence of the N-Back task (2-Back) with its timeline.

D. EEG Recordings

EEG was recorded continuously with a SynAmpsRT device (Compumedics, Australia (www.compumedics. com.au)) at a sampling rate of 2kHz and using 32 Ag/AgCl electrodes. The electrodes were placed at O1, Oz, O2, PO3, P8, P4, Pz, P3, P7, TP9, CP5, CP1, CP2, CP6, TP10, T7, C3, Cz, C4, T8, FC6, FC2, FC1, FC5, F3, Fz, F4, AF3, AF4, Fp1, Fp2, with the reference placed at AFz and the ground at CPz. We placed four electrodes around the eyes for Electro-Oculogram Recording (EOG) following the instructions given by Croft and Barry [22] for removing eye movement and blinking artifacts [23]. The recorded EEG signal was re-referenced offline to the average of the two mastoid signals (average mastoid reference, TP9 & TP10), band-pass filtered in the 0.1 – 30 Hz range, and cut into epochs starting from 100 ms pre- till 1500 ms post-stimulus onset. Baseline correction was performed by subtracting the average of the 100 ms pre-stimulus onset activity from the 1500 ms post-stimulus onset activity. Finally, the epochs were downsampled to 1000 Hz and stored for ERP component detection. A two-way ANOVA (N-Back level x session) was applied to the P300 amplitudes, calculated as the average over a time window between 250-400 ms, for channels Fz, Cz and Pz. Epochs with incorrect behavioral responses were excluded from further analysis. In addition, epochs with EEG signals greater than 50μV were also excluded as they could be motion artifacts.

III. Results

In this section, we discuss the results of N-Back training and near/far-transfer effects to other cognitive tasks.

A. Behavioral Responses – training

To assess differences in behavioral performance of healthy older subjects that underwent N-Back training, we examined the response accuracy and Reaction Time (RT) of our participants. We hypothesize that RT decreases and accuracy level increases following N-Back training. The responses to the stimuli were divided into four categories: hit (target and button press), false alarm (non-target and button press), correct rejection (non-target and no button press), and miss (target and no button press). We performed a two-way ANOVA looking at the interaction between sessions and N-Back level, and we found a significant effect of accuracy for N-Back level ($F(2) = 12.2$, $p<0.001$), sessions ($F(9) = 9.93$, $p<0.001$), and for the interaction N-Back x sessions ($F(27) = 3.57$, $p<0.001$). For RT we found significant results for N-Back level ($F(2) = 6.98$, $p<0.05$) and sessions ($F(9) = 10.09$, $p<0.001$). Both findings confirm that cognitive training increases accuracy and reduces RT of healthy older subjects (Figure 2).

B. ERPs responses – training

As several studies showed that, during an N-Back task performance, the most activated brain regions are the lateral premotor cortex, dorsal cingulate and medial premotor cortex, dorsolateral and ventrolateral prefrontal cortex, frontal poles, and medial and lateral posterior parietal cortex [6], and that the P300 amplitude is defined over the midline electrodes (channels Fz (frontal), Pz (posterior), and Cz (central)), we decided to analyze the P300 amplitude using a 32 electrodes cap that covered these brain areas. Furthermore, as Dahlin et al. [9] reported that training with an N-Back task improves WM in older healthy subjects, based on a functional Magnetic Resonance Imaging (fMRI) study, we hypothesize that the P300 amplitude increases at the end of the training. Grand-averaged epochs (time window between 250 and 400 ms) for target to non-target trials, for each difficulty level of the N-Back task (0, 1, 2, and 3), are shown in Figure 3. A two-way ANOVA (N-Back level x time) was used to detect significant modulations of P300 amplitude, for all three channels (Fz, Cz, Pz). Based on our results, we observed that the P300 amplitude changed significantly pre-post training mostly for central and posterior (Cz and Pz) channels. We found significant results pre-post training in channel Cz ($F(1) = 11.7$, $p<0.001$) for 2-Back, and in channel Pz ($F(1) = 7.37$, $p<0.05$) for 2-Back, and ($F(1) = 3.83$, $p<0.05$) for 3-Back. No significant pre-post training differences were found for channel Fz.

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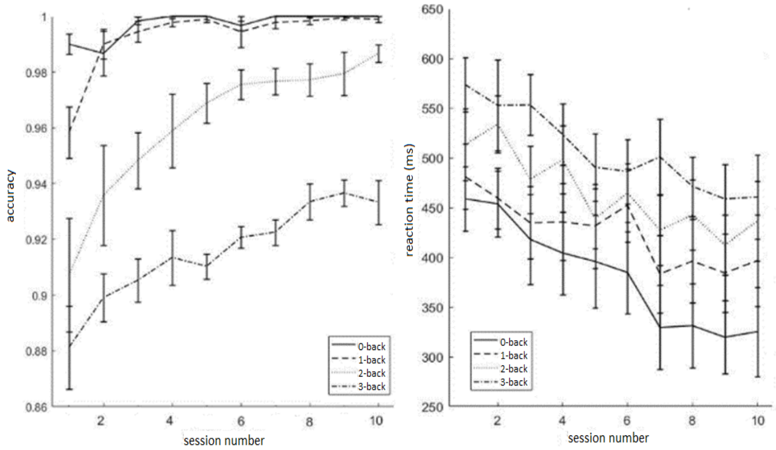

Figure 2. Mean accuracy (left) and reaction time (right) during N-Back training. Error bars indicate SEM (Standard error of the mean)

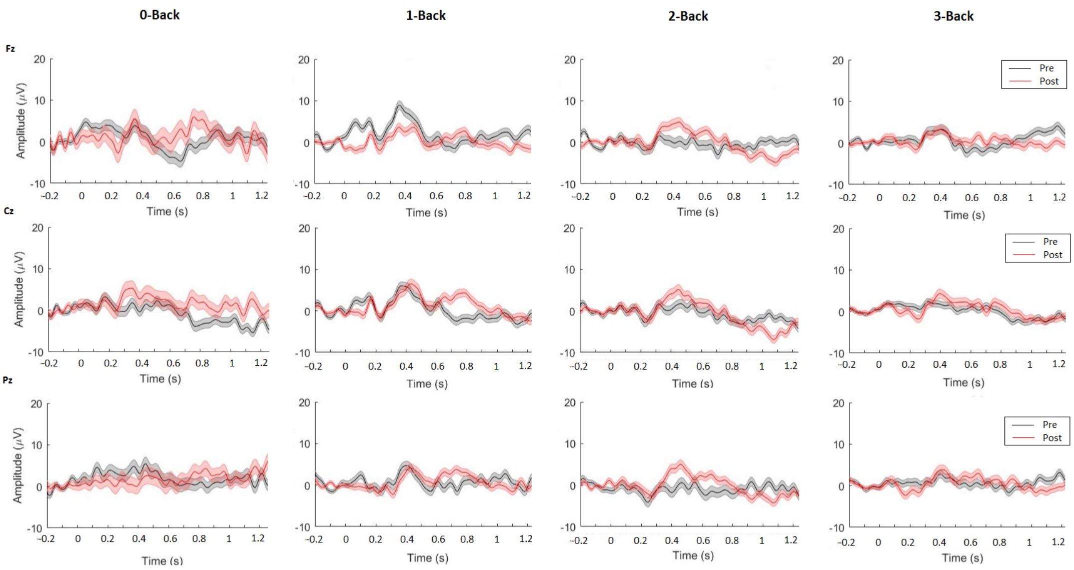

Figure 3. ERPs (P300, target – no-target) of healthy older subjects during N-Back training. Significant differences are indicated by horizontal lines and measured using two-way ANOVA (N-Back x sessions). Error bars indicate SEM.

C. Pre-post tests- transfer effects

To test whether we could find any transfer effects, we administered pre-post training tests and performed a paired t-test analysis, intra- and inter-group (Table 2). We found significant effects for N-Back ($p = 0.000157$) and CORSI ($p = 0.01$), thus evidence for a near-transfer effect. In the passive control group, we did not find any significant effects. Furthermore, the comparison between the two groups showed significant differences only for the trained task (N-Back) with $p = 2.78 \times 10^{(-05)}$ ($p<0.001$).

TABLE II. ACCURACY PRE-POST COGNITIVE TESTS IN HEALTHY OLDER SUBJECTS BETWEEN TRAINING GROUP AND PASSIVE CONTROL GROUP (PCG).

Cognitive tests	Training Group Pre-Test		Training Group Post-test		Passive control group Pre-Test		Passive Control Group Post-Test		T-TEST*
	Mean	*SEM*	*Mean*	*SEM*	*Mean*	*SEM*	*Mean*	*SEM*	*p-values*
CORSI	77.50*	3.42	76.25*	3.03	87.5	7.40	90	5	0.01*
TOVA	95.31	0.83	97.19	0.66	44.17	0.93	44.38	0.62	0.80
N-Back	18.81*	8.18	76.34*	4.46	44.4	13.19	51.6	14.87	0.000157*
RAVEN	65.42	7.58	79.17	3.19	82.92	3.45	85	2.5	0.09

a.*Significance using t-tests (p<0.001).

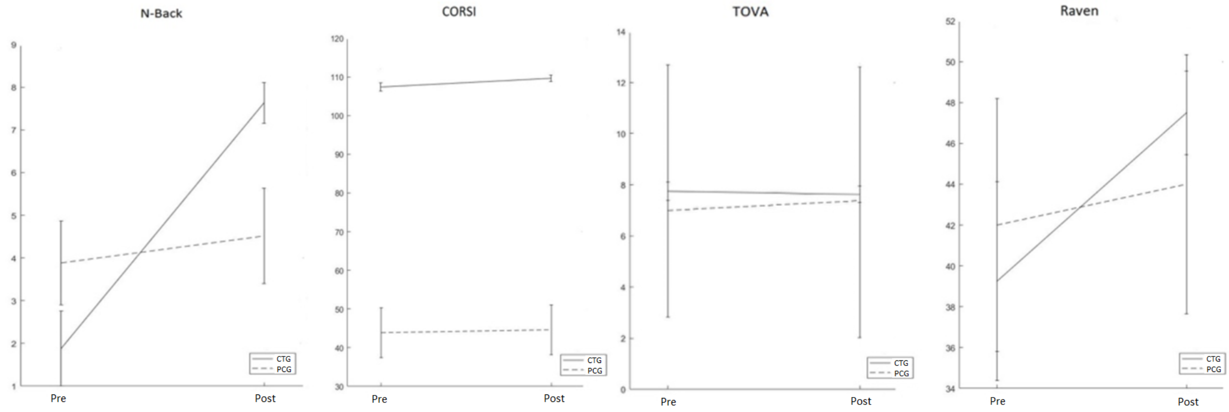

Figure 4. Accuracy of pre-post cognitive tests in healthy older subjects between training group and passive control group (PCG). Error bars indicate SEM.

We also run a two-way ANOVA analysis (N-Back x sessions) for pre-post training tests, see Figure 4, and found significant differences between groups in the trained task (N-Back task) per session ($F(1) = 12.73$, $p<0.05$) and more interestingly for the interaction between N-Back x sessions ($F(1) = 0.0078$, $p<0.05$).

IV. Discussion and Conclusion

The aim of our study was to determine whether N-Back training of healthy older adults improves not only the trained task, compared to a passive control group, but also yield near- and far-transfer effects to untrained cognitive functions (spatial memory task, attention and reasoning and intelligence). We had two groups of healthy older subjects: one group performed 10 sessions of N-Back training and another group was not trained (passive control group). Both groups were administered a battery of cognitive tests (CORSI, TOVA, RAVEN). The first group pre- and post-training for which case we expected to find significant differences [28][29]. We found significant evidence for near-transfer effects to spatial memory (CORSI), based on accuracy level, but no evidence for far-transfer effects. This could be due to our small sample size. The results are in line with those of Dahlin et al. [9] who observed that working memory training improves performance in related cognitive tasks, such as spatial memory, but not in other cognitive functions. Furthermore, the N-Back task (trained task) improved significantly in accuracy and RT in the trained group compared to the passive control group. Besides the behavioral findings, the P300 ERP results also showed a significant effect pre-post training, especially for 2-Back in the central and parietal channels. As expected [23], we could observe clear differences in P300 amplitudes for different N-Back levels, thus, supporting the results of Colom et al. [24] and Salminen et al. [25] who reported improvements after an N-Back training in healthy adults.

The novelty of our study was to add the P300 ERP component, by looking at pre-post differences after N-Back training. As mentioned before, we found significant differences for the 2-Back task, showing that this task level could be important to improve WM in older subjects. Future research could look more into detail at differences in pre-post training in the 2-Back task of healthy older subjects and repeat the experiment in patients with mild cognitive impairment (MCI) and Alzheimer's disease (AD) as it is known that these patients have significant difficulties in WM [26]. Reducing cognitive decline in MCI patients could delay the diagnosis of AD, as we know that MCI patients have a high risk to convert to clinically-probable AD in a few years' time [27]. In light of our results, N-Back training could be an effective tool for improving WM and related cognitive functions and for delaying cognitive decline. Furthermore, another point that we would like to suggest for future research is to test whether by using a specific strategy during an N-Back training could achieve significant transfer effects in untrained cognitive tasks, as there is a gap in the literature about what WM training strategies to use. What we do know is that the strategy of mental rehearsal has been proven to be effective in enhancing performance [28].

Acknowledgment

Valentina Pergher is supported by research grant No. G088314N, sponsored by the Belgian Fund for Scientific Research-Flanders, Marc M. Van Hulle by research grants No. PFV/10/008 from the Program Financing program, No. IDO/12/007 from the Interdisciplinary research project of KU Leuven, No. IOF/HB/12/021 sponsored by the Industrial research fund project of KU Leuven, No. G088314N and No. G0A0914N sponsored by the Belgian Fund for Scientific Research-Flanders, No. IUAP P7/11 from the Interuniversity Attraction Poles Programme – Belgian Science Policy, No. GOA 10/019 from the Flemish Regional Ministry of Education (Belgium) and No. AKUL 043 sponsored by the Hercules Foundation. Benjamin Wittevrongel is supported by the Flemish Agency for Innovation and Entrepreneurship (VLAIO).

REFERENCES

[1] A. Baddeley, "Working memory", Science, vol. 255, no. 5044, pp. 556-559, 1992.

[2] R. De Beni and P. Palladino, "Decline in working memory updating through ageing: Intrusion error analyses," Memory, vol. 12, no. 1, pp. 75-89, 2004.

[3] T. Klingberg, "Training and plasticity of working memory," Trends in cognitive sciences, vol. 14, no. 7, pp. 317-324, 2010.

[4] K. Ball et al., "Effects of cognitive training interventions with older adults: a randomized controlled trial," Jama, vol. 288, no. 18, pp. 2271-2281, 2002.

[5] T. Klingberg et al., "Computerized training of working memory in children with ADHD-a randomized, controlled trial," Journal of the American Academy of Child & Adolescent Psychiatry, vol. 44, no. 2, pp. 177-186, 2005.

[6] M. Owen, K. M. McMillan, A. R. Laird, and E. Bullmore, "N-back working memory paradigm: A meta-analysis of normative functional neuroimaging studies," Human brain mapping, vol. 25, no. 1, pp. 46-59, 2005.

[7] S. M. Jaeggi, M. Buschkuehl, J. Jonides, and W. J. Perrig, "Improving fluid intelligence with training on working memory," Proceedings of the National Academy of Sciences, vol. 105, no. 19, pp. 6829-6833, 2008.

[8] S. M. Jaeggi et al., "The relationship between n-back performance and matrix reasoning implications for training and transfer," Intelligence, vol.38, no. 6, pp. 625–635, 2010.

[9] E. Dahlin, A. S. Neely, A. Larsson, L. Backman, and L. Nyberg, "Transfer of learning after updating training mediated by the striatum," Science, vol. 320, no. 5882, pp. 1510–1512, 2008.

[10] P. Verhaeghen and C. Basak, "Ageing and switching of the focus of attention in working memory: Results from a modified N-Back task," The Quarterly Journal of Experimental Psychology Section A, vol. 58, no. 1, pp. 134-154, 2005.

[11] W. Kirchner and K. Wayne, "Age differences in short-term retention of rapidly changing information," Journal of experimental psychology, vol. 55, no. 4, pp. 352, 1958.

[12] M. J. Kane and R. W. Engle, "The role of prefrontal cortex in working-memory capacity, executive attention, and general fluid intelligence: An individual-differences perspective," Psychonomic bulletin and review, vol. 9, no. 4, pp.637-671, 2002.

[13] M. Brouwer, M. A. Hogervorst, J. B. Van Erp, T. Heffelaar, P. H. Zimmerman, and R. Oostenveld, "Estimating workload using EEG spectral power and ERPs in the n-back task," Journal of neural engineering, vol. 9, no. 4, pp. 045008, 2012.

[14] J. H. Smith-Spark and J. E. Fisk, "Working memory functioning in developmental dyslexia," Memory, vol. 15, no. 1, pp. 34-56, 2007.

[15] T. P. Zanto, B. Toy, and A. Gazzaley, "Delays in neural processing during working memory encoding in normal aging," Neuropsychologia, vol. 48, no. 1, pp. 13-25, 2010.

[16] H. M. Morgan, C. Klein, S. G. Boehm, K. L. Shapiro, and D. E. Linden, "Working memory load for faces modulates P300, N170, and N250r," Journal of cognitive neuroscience, vol. 20, no. 6, pp. 989-1002, 2008.

[17] E. Dahlin et al., "Plasticity of executive functioning in young and older adults: immediate training gains, transfer, and long-term maintenance," Psychology and aging, vol. 23, no. 4, pp. 720, 2008.

[18] S. C. Li et al., "Working memory plasticity in old age: practice gain, transfer, and maintenance," Psychology and aging, vol. 23, no. 4, pp. 731, 2008.

[19] G. B. Forbes, "Clinical utility of the test of variables of attention (TOVA) in the diagnosis of attention-deficit/hyperactivity disorder," Journal of clinical psychology, vol. 54, no. 4, pp. 461-476, 1998.

[20] R. PC. Kessels, M. J. Van Zandvoort, A. Postma, L. J. Kapelle, and E. H. De Haan, "The Corsi block-tapping task: standardization and normative data," Applied neuropsychology, vol. 7, no. 4, pp. 252-258, 2000.

[21] J. C. Raven et al., "Raven's progressive matrices," Western Psychological Services, 1938.

[22] R. J. Croft and R. J. Barry, "Removal of ocular artifact from the EEG: a review," Neurophysiologie Clinique/Clinical Neurophysiology, vol. 30, no. 1, pp. 5-19, 2000.

[23] R. J. Croft and R. J. Barry, "EOG correction: a new aligned-artifact average solution," Clinical Neurophysiology, vol. 107, no. 6, pp. 395-401, 1998.

[24] R. Colom et al., "Adaptive n-back training does not improve fluid intelligence at the construct level: Gains on individual tests suggest that training may enhance visuospatial processing," Intelligence, vol. 41, no. 5, pp. 712-727, 2013.

[25] T. Salminen, T. Strobach, and T. Schubert, "On the impacts of working memory training on executive functioning," Frontiers in human neuroscience, vol. 6, pp. 166, 2012.

[26] S. Belleville, H. Chertkow, and S. Gauthier, "Working memory and control of attention in persons with Alzheimer's disease and mild cognitive impairment," Neuropsychology, vol. 21, no. 4, pp. 458, 2007.

[27] Levey, J. Lah, F. Goldstein, K. Steenland, and D. Bliwise, "Mild cognitive impairment: an opportunity to identify patients at high risk for progression to Alzheimer's disease," Clinical therapeutics, vol. 28, no. 7, pp. 991-1001, 2006.

[28] J. E. Driskell, C. Copper, and A. Moran, "Does mental practice enhance performance?" Journal of applied psychology, vol. 79, no. 4, pp. 481, 1994.