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Efficacy of a Cognitive Training and Domotic Control Program (BCI) to Prevent Cognitive Impairment

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Abstract

Over time, ageing can cause a state of disability and dependency. This study aims to evaluate the efficacy of cognitive training and domotic control with a computer program (Brain Computer Interface, BCI). In order to do so, estimated neuropsychological performance of the subjects has been evaluated with the Luria-DNA neuropsychological battery before and after training. A quasi-experimental design of repeated measures is defined where five areas are evaluated: visuospatial, spoken language, memory, intellectual processes and an attention test. Said study was carried out at The State Reference Centre for Disability and Dependency (CRE Spanish initials), San Andrés del Rabanedo, León (Spain). 63 people took part, 31 subjects in the experimental group and 32 in the control group. The results showed an improvement in almost all of the measured variables, revealing a significant increase in the cognitive capacity of the experimental group when compared with the control group. It can be concluded that with appropriate cognitive training, elderly people can delay cognitive impairment and enjoy an active ageing process which can have an effect on their life in terms of improving their independence.

Keywords: BCI; Neuro-feedback; Adult neuropsychological diagnosis; Luria-DNA; Active ageing; Cognitive impairment prevention

Introduction

Studies have been carried out in recent decades, their aims have been to evaluate the efficacy of cognitive training for adults in regard to subjective memory loss. The usual procedure for evaluation consists of standard neuropsychological tests, which measure general cognitive capacity, verbal memory and executive functions, among other faculties, before and after the training process [1-3]. The period chosen for evaluating the effects of the training varies. This period is normally six months after the training, although there are studies in which monitoring has taken place five years after the training [4-6], with interim reinforcement sessions.

Along these lines, it is necessary to create cognitive programs, which include tasks involving training of the cognitive process related to daily activities given their characteristics of functional priority for people [7,8]. Thus, the NeuronUp platform [9] has been created, which contains exercises for rehabilitating, stimulating or learning cognitive functions (orientation, attention, agnosias, praxias, etc) and in this way practice common daily activities (basic activities, instrumental activities, education, etc.), like real-life simulators and social abilities. The final purpose is to improve the quality of life of people [10-15].

There are studies within this frame of reference which conclude that cognitive practice is more effective than memory training as it provides greater cognitive challenges leading to cerebral plasticity because remembering things it is a short way and also memory outcomes doesn´t provide a functional character or memory strategies, based on a systematic study of all the clinical research carried out from 1980 to 2011 in the field of cognitive and memory training for adults at risk of dementia [16]. The authors of these papers reach the conclusion that of 175 reviewed research papers, only 10 meet the cognitive training criteria provided by the authors, these studies enrolling 305 subjects met criteria for cognitive training in MCI. Only five of the studies were randomized controlled trials. Meta-analysis was not considered appropriate due to the heterogeneity of interventions. Moderate effects on memory outcomes were identified in seven trials. Cognitive exercises (relative effect sizes ranged from 0.10 to 1.21) may lead to greater benefits than memory strategies (0.88 to -1.18) on memory.

In recent decades, there has been an attempt to raise awareness of incidence and prevalence of cognitive impairment associated with ageing [17,18]. There is, therefore, a need to draw up procedures for predictive cognitive tests and develop therapies which prevent its onset and/or halt its deterioration. This study presents a program, which, through cognitive training and domotic control, evaluates the progress of the participants' cognitive capacity in order to avoid cognitive impairment. The Luria-DNA neuropsychological battery (DNA: neuropsychological diagnosis for adults) has been used to prove the efficacy of the training [19]. It explores functions and abilities: Visuospatial (2 tests), spoken Language (2 tests), memory (2 tests), Intellectual process (2 tests) and attention test. The aim is to evaluate the efficacy of a Brain Computer Interface (BCI) cognitive training and domotic control program, analysing if there is an improvement in the neuropsychological profile of the subjects receiving the training. The neuropsychological profile evaluation was carried out in five areas: visuospatial, spoken language, memory, intellectual processes and attention.

Subjects

63 people took part in the study, selected by The State Reference Centre for Disability and Dependency (CRE Spanish initials), San Andrés del Rabanedo, León (Spain). 31 (13 men and 18 women, average age=68,18 age range=63–81) received cognitive training (experimental group), while another 32 (9 men, 23 women, average age=68.03, age range=61–80) received no training no active (control group). The criteria to select each group was the average in Mini-mental state examination test [20], the experimental group has reached between 18-23 mild cognitive impairment (level dementia) and the control group has been reached between 24-30 no cognitive impairment (without dementia).

No significant differences between independent groups were detected in the age or gender average (p>0.05, Mann-Whitney U-test) in both groups. All participants were over the age of 60, healthy, without severe neuropsychological pathologies and first-time BCI users (no previous BCI experience). The local ethics committee approved the study. All of the subjects gave their consent to participating in the study. The study was carried out at The State Reference Centre for Disability and Dependency (CRE Spanish initials), San Andrés del Rabanedo, León (Spain).

Method

This is a repeated measure, quasi-experimental study. The participants of the experimental group underwent an initial neuropsychological evaluation test, cognitive training with BCI and a final evaluation. The evaluation was carried out using the Luria-DNA neuropsychological battery comprised of nine neuropsychological test distributed among five different areas. In the area of spoken language, the expression test via expressive and receptive language (through recognition of words, cards, objects and sentence comprehension) was used. The expressive language test evaluated the formulation of discourse, narrative discourse and sentences. In order to evaluate the area of memory, immediate memory (10 words) was used, retaining and evoking in verbal/non-verbal tasks. Logical memorizing was evaluated via the relations the subjects made. For the evaluation of intellectual processes, a test comprising themed pictures and texts was used in order to analyse comprehension of messages provided via pictures and texts. Discursive and conceptual activity was evaluated via formation of abstract ideas and problem solving capacity. Finally, for the evaluation of attention-concentration, verbal and non-verbal tasks were used. The neuropsychological profile of each participant was thus established. Each participant used a Brain Computer Interface (BCI) cap, which translates the subject's intentions, collected via electrodes in contact with the scalp, into control commands for a device. P300 potentials, detected from the EEG signal, were used due to their greater simplicity for users and their not requiring a prior stage of intensive training. A portable, 16-channel biomedical signals amplifier with g.tec USB connection (Austria) was used to record the EEG signal. The reduced dimensions and weight of this device facilitated its portability. The recording equipment was completed with a cap-like device on which the electrodes are placed and worn on the head with the electrodes located in specific areas of the cortex. g.LADYbird (g.tec) active electrodes with a g.GAMMAbox (g.tec) low noise preamplifier, g.GAMMAconnector means of connection and g.GAMMAcap2SET (g.tec) caps were used in this study. The BCI system detected the correct cerebral pattern in the participant's cerebral activity, taking into account that if the subject did not achieve the objective, the visual feedback allowed them the possibility to maintain or change their strategy (**Figure 1**).

Figure 1 User carrying out test on the BCI system

Each experimental group participant took part in 10 training sessions: 5 neurofeedback training sessions (NFT) which were alternated with 5 work memory training sessions (WMT). Each NFT session lasted approximately 60 minutes, while each WMT session lasted around 20 minutes. The total duration of the training was 5 weeks, one NFT session and one WMT per week. The NFT session was comprised of 60 trials at different difficulty levels and the WMT session was comprised of 20 trials. The NFT training tasks had 5 progressive difficulty levels (**Figure 2**).

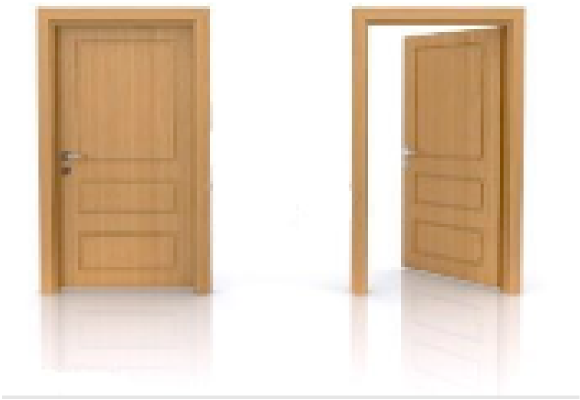

Figure 2 NFT. Trial open door

The WMT sessions consisted of combining the motor imagery tasks (described above) with memory exercises related to different shapes, colors and expressions (**Figure 3**).

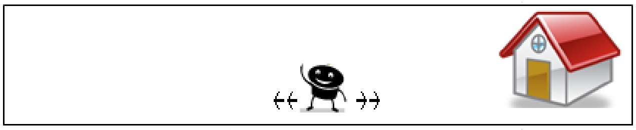

Figure 3 WMT. Combining the motor imagery tasks. Daily activities

Results

The data was analysed with the SPSS 19 program. The variables were evaluated for conformance with normality level via the Kolmogorov-Smirnov tests (K-S) test on a sample and all were parametric for all subjects. The Levene test was, in the same way, used to analyse the equality of variances and equal variances were observed across the board. The descriptive analysis was carried out. The pre/post-intervention INTRA-GROUP comparison was then analysed in each of the questionnaire factors via t the Student equation for related samples. Finally, repeated measures ANOVA (variance analysis General Linear Model) was applied in order to carry out the INTER-GROUP analysis, as well as the size of the effect and power observed. The homogeneity of the experimental and control group was checked with the same equation before applying the treatment, both in the age average via the Student t for independent samples (t=-0.70 and p=0.94) and in the average of each of the factors of the questionnaire (the t values oscillated between -0.196 and -1.197 and the p values between 0.845 and 0.053).

In the Intra-Group analysis of the Control Group (C.G) significant differences were observed in the variables for Visual Perception, Spatial Orientation, Pictures, Logical Memory and Concepts, all of which showed a significant improvement. In the Intra-Group analysis of the Experimental Group (E.G.), a significant improvement was observed in all factors except in the Attention Factor (**Table 1**).

In the Inter-Group analysis of the Visual Perception Factor (**Table 2**) significant differences were observed according to the moment (pre-post) [F (1.61)=31.49; p<0.001; effect size η2=0.341; power 1 - β=1] and a significant effect was proved between the Moment (pre-post) x Group (Control and Experimental) [F (1.61)=16.08; p<0.001; η2=0.209; 1 - β=0.977]. In the interpretation of the Inter-Subject Effects Test for the study of the existing effects between groups significant differences in said Factor [F (1.61)=6.65; p=0.012] were observed, the experimental group being the one which obtained the greatest average (post-test=56.61) with regards to the control group (post-test=40.62). Both in the Spatial Orientation and in the Receptive Speech, the Inter-Group analysis indicated that significant differences existed according to moment [F (1.61)=14.41; p<0.001; η2=0.191; 1 - β=0.962 and F (1.61)=13.49; p<0.001; η2=0.181; 1 - β=0.951 respectively] and no significant differences were observed in the interaction between Moment x Group [F (1.61)=3.75; p=0.057; η2=0.058; 1 - β=0.479 and F(1.61)=3.07; p=0.085; η2=0.048; 1 - β=0.407 respectively]. In the Inter-Subject Effects Test for the study of the existing effects between groups no significant differences were obtained [F (1.61)=0.12, p=0.727 y F (1.61)=0.86, p=0.355 respectively].

The existence of significant differences according to the moment [F (1.61)=13.38; p=0.010; η2=0.180; 1 - β=0.950] and in the interaction between Moment x Group [F (1.61)=4.20; p=0.045; η2=0.065; 1 - β=0.523] were observed in the Inter-Group analysis of the Expressive Speech Factor. The Inter-Subject Effects Test for the analysis of possible differences between groups indicated that no significant differences existed [F (1.61)=1.87, p=0.176]. In the Immediate Memory and Concepts Factors, however, the Inter-Group analysis revealed the existence of significant differences according to moment [F (1.61)=15.95; p<0.001; η2=0.207; 1 - β=0.976 and F (1.61)=21.07; p<0.001; η2=0.257; 1 - β=0.955 respectively] and in the interaction between Moment x Group [F (1.61)=19.25; p<0.001; η2=0.240; 1 - β=0.991 and F(1.61)=5.02; p=0.029; η2=0.076; 1 - β=0.597 respectively]. The Inter-Subject Effects Test for the analysis of the possible differences between groups indicated the existence of significant differences [F (1.61)=19.25, p<0.001 and F (1.61)=4.61, p=0.036 respectively], the experimental group being the one which obtained the greatest score in both factors in the post-test. In the Inter-Group analysis of the Pictures and Logical Memory Factors, the existence of significant differences according to moment were observed [F (1.61)=138.06; p<0.001; η2=0.694; 1 - β=1 and F (1.61)=51.97; p<0001; η2=0.460; 1 - β=1 respectively], but not so in the interaction between Moment x Group [F (1.61)=3.54; p<0.064; η2=0.055; 1 - β=0.458 and F (1.61)=0.13; p=0.717; η2=0.002; 1 - β=0.065 respectively]. In the interpretation of the Inter-Subject Effects Test for the study of existing effects between groups, no significant differences were observed [F (161)=1.21, p=.276 and F (161)=1.46, p=0.231 respectively]. Finally, on carrying out the Inter-Group analysis of the Attention Factor, no significant differences were established according to moment (pre-post)

[F (1.61)=2.12; p=0.150; effect size η2=0.034; power 1 - β=0.300] in the same way as in the interaction between the Moment x Group [F (1.61)=1.15; p=0.288; η2=0.019; 1 - β=0.184]. Neither were any significant differences observed in the Inter-Subject Effects Test for the study of existing effects between groups [F (1.61)=0.127; p=0.723].

Table 1 Differences in pre-post averages in each factor (t Student for related samples)

	Control Group						Experimental Group					
	N	M	DT	t	gl	p	N	M	DT	t	gl	p
Pre-Visual Perception.	32	38.28	14.56	-2.33	31	.026	31	41.61	15.56	-5.26	30	.000
Post-Visual Perception	32	40.62	14.63				31	56.61	15.51			
Pre-Spatial Orientation	32	40.46	13.81	-2.24	31	.032	31	41.12	12.89	-3.20	30	.003
Post-Spatial Orientation	32	42.18	13.85				31	46.77	14.91			
Pre-Receptive Speech	32	51.87	16.10	-1.98	31	.056	31	53.87	14.00	-3.15	30	.004
Post-Receptive Speech	32	53.75	14.86				31	59.51	12.33			
Pre-Expressive Speech	32	60.62	9.81	-1.79	31	.083	31	63.70	9.57	-3.24	30	.003
Post-Expressive Speech	32	61.56	9.37				31	67.25	9.38			
Pre-Immediate Memory	32	41.56	12.34	.421	31	.677	31	44.83	10.76	-4.85	30	.000
Post-Immediate Memory	32	41.25	12.44				31	51.93	10.22			
Pre-Pictures	32	30.68	22.80	-6.24	31	.000	31	32.90	15.74	-11.44	30	.000
Post-Pictures	32	51.56	15.57				31	61.29	11.17			
Pre-Logical Memory	32	51.25	15.65	5.29	31	.000	31	56.61	11.78	4.89	30	.000
Post-Logical Memory	32	32.71	23.05				31	40.32	16.12			
Pre-Concepts	32	44.68	12.82	-2.77	31	.009	31	50.80	11.69	-3.67	30	.001
Post-Concepts	32	46.40	10.64				31	54.83	12.34			
Pre-Attention	32	45.16	16.80	-.441	31	.662	31	44.35	21.93	-1.44	30	0.159
Post-Attention	32	45.64	17.49				31	47.74	19.52			

Discussion

There is a great diversity of instruction methods for cognitive impairment prevention tasks (individual or group format, paper and pencil or computerised), which prevents the generalisation of the benefits [7,8,21]. Though we are aware that computerised tests are not always effective, in line with [4,21,22], because the usual procedure for evaluation consists of standard neuropsychological tests, which measure general cognitive capacity, verbal memory and executive functions, among other faculties, before and after the training process, also the period chosen for evaluating the effects of the training varies. We confirm that there are studies, which prove the advantages of using programs for neurocognitive training in the prevention of cognitive impairment, like NeuroUp platform [9] to improve performance functional of a person and compensate the resulting cognitive deficits brain damage in order to reduce functional limitations, increasing the ability of people to perform life activities daily [8,9,12-15]. In this study the final purpose is to improve the quality of life of people like NeuroUp platform but we proved the usefulness of cognitive training via the BCI computer program, in a significantly shorter time than the reviewed studies, highlighting that improvements in different neuropsychological aspects in elderly subjects with cognitive impairment have been achieved in a reduced timeframe. In the pre-post of each factor, the experimental group obtained highly significant improvements in visual perception, spatial orientation, receptive speech, expressive speech, logical memory, immediate memory, picture recognition and concepts in comparison with the control group, which only obtained significant improvements in pictures, logical memory and concepts. If we compare the pre-post between both groups, the experimental group obtained improvements in visual perception, spatial orientation, expressive speech, immediate memory and concepts in contrast to the control group. The control group obtained improvements due to the cognitive training. We can think that the training with BCI computer program, in a significantly shorter time, persons without dementia could obtain improvements. If we compare the inter-subject effect of the analysis of differences, the factors that stand out between the groups are the improvements in visual perception, immediate memory and concepts in the experimental group's favour. This indicates that cognitive training which includes activities that stimulate memory and executive functions is more effective than mnesic training [7,8] or as [16] exposes, cognitive training that includes attention and processing speed activities is more effective than that which works solely with mnesic training activities.

Table 2 Multivariate contrasts and inter-subject effects of the analysis of differences

		Statistical Multivariate Contrasts Pillai Trace				Inter-Subject Effects				
Variable	Differences	F	p	η2	1 - β	Differences	F	p	η2	1 - β
Visual Perception	Moment (pre-post)	31.49	<.0001	.341	1	Group	6.65	.012	.098	.719
	Interaction (moment* group)	16.08	<.0001	.209	.977					
Spatial Orientation	Moment (pre-post)	14.41	<.0001	.191	.962	Group	0.12	.727	.002	.064
	Interaction (moment* group)	3.75	.057	.058	.479					
Receptive Speech	Moment (pre-post)	13.49	.001	.181	.951	Group	0.86	.355	.014	.151
	Interaction (moment* group)	3.07	.085	.048	.407					
Expressive Speech	Moment (pre-post)	13.38	.010	.180	.950	Group	1.87	.176	.030	.271
	Interaction (moment* group)	4.20	.045	.065	.523					
Immediate Memory	Moment (pre-post)	15.95	<.0001	.207	.976	Group	19.25	<.0001	.240	.991
	Interaction (moment* group)	19.25	<.0001	.240	.991					
Pictures	Moment (pre-post)	138.06	<.0001	.694	1	Group	1.21	.276	.019	.191
	Interaction (moment* group)	3.54	.064	.055	.458					
Logical Memory	Moment (pre-post)	51.97	<.0001	.460	1	Group	1.46	.231	.023	.222
	Interaction (moment* group)	0.13	.717	.002	.065					
Concepts	Moment (pre-post)	21.07	<.0001	.257	.995	Group	4.61	.036	.070	.562
	Interaction (moment* group)	5.02	.029	.076	.597					
Attention	Moment (pre-post)	2.12	.150	.034	.300	Group	0.127	.723	.002	.064
	Interaction (moment* group)	1.15	.288	.019	.184					

Conclusion

We can affirm that the proposed cognitive training and domotic control program is useful as a tool to prevent cognitive impairment caused by ageing. Using a program which includes activities of visual perception, spatial orientation, expressive and receptive speech, immediate and logical memory, picture recognition and concepts, applied to everyday life, within a reduced timeframe prevents cognitive impairment caused by ageing. The BCI computer program, therefore, opens up new horizons with the aims of educating and instructing people (even remotely via online participation) in order to prevent cognitive impairment, and ultimately, improve quality of life.

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Conflict of Interest

Authors declared there are no conflicts of interest.

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