Brain Fitness – Clinical Trial to Measure the Effect of Cognitive Training in Brain's Capabilities

Ana Cruz	isabel_cruz@live.com
André Canelas	andre_canelas@hotmail.com
Filipa Machado	filipa_machado_89@hotmail.com
Joana Pedreira	jfpedreira13@hotmail.com
João Barroso	joaobarroso24@hotmail.com
Liliana Beirão	sousa_liliana@hotmail.com
Lúcia Freitas	luciasofia.m.f@hotmail.com
Luís Belo	luisbelo@ff.up.pt
Mafalda Seabra	mafseabra@hotmail.com
Maria Portero	jonasportero@hotmail.com
Mário Baptista	mario.xb@gmail.com
Rafael Oliveira	rafael_co23@hotmail.com
Tânia Maia	taniamomaia@gmail.com

Adviser: Armando Teixeira Pinto

Class 13

ABSTRACT

Context: Previous studies have demonstrated that the brain's capacity in older individuals can be improved through programs of cognitive training. However, the effect of "brain training" in young subjects is still poorly studied or understood.

Aim: To evaluate the effect of a "brain exercise" program on the brain's capacity of young individuals.

Methods: Two groups of 30 Medical students, aged 17-19 years of old, from the first year of Medicine in University of Porto, were invited to participate in this clinical trial. One of those groups was subjected to the training program (experimental group), while the other was not target with any training (control group). The participants were evaluated at two different periods, the first previously to the treatment (T1) and the second one three weeks afterwards (T2). The same test was presented before and after the training process; the test used was the "WAIS-III", constituted by three exercises, which permit to obtain the scores at each exercise ("Memory of digits", "Memory of letters and numbers" and "Symbol search") and the total score (sum of scores). At the end of training, two participants were excluded from the experimental group as they did not perform evaluation at T2.

Results: After the training program, the experimental group improved significantly all test scores, while the control group only presented a statistically significant improvement in the "Symbol search" test and in the Total score. At T2, the score obtained for “Memory of letters and numbers” was statistically significant higher for the experimental group. However, no statistically significant differences were observed between groups for any of the delta scores (T2-T1) obtained for the different exercises. When considering only the participants who have done more than ten sessions (half of the number of sessions desirable) we verified that both the test score at T2 and the delta score (Δ T2-T1) for “Memory of letters and numbers” was statistically significant higher for the experimental group.

Conclusions: Our data obtained with young individuals suggest that only those who performed minimally the training program achieved, effectively, an improvement in some of the brain’s capabilities. The improvement that we found was only significant for one of the tested scores (“Memory of letters and numbers”) and for those who performed at least 10 training sessions during three weeks. Further studies are needed to confirm our findings.

KEY-WORDS

Brain Mapping, Cognitive Science, Cognitive Therapy, Intelligence Tests, Memory, Mental Competency, Neuroplasticity.

INTRODUCTION

The development of science, more specifically, medicine, allowed the increase of life expectancy resulting in an aging population. Regarding this fact, the incidence of mental ravages of aging and diseases like Alzheimer or Parkinson have arisen. Thereafter, scientists and researchers felt the urge to fight these cognitive issues, in order to improve life quality.

This social context along with the developing techniques featuring the brain (like CT, MRI and scanning techniques)(1,2) allowed to conclude that adult brain continues to revise itself creating a new concept – neuroplasticity (3) – which denies the common belief that brain development was finished by adulthood. (2)

The appearance of these new concepts led scientist to make new studies concerning the ability to control this plasticity and therefore, answering the main question: “Can brain exercise keep the brain in shape?”. Nevertheless, most of these researches are focused on elderly population. However, knowing that we live in a world where intellectual requirements are each-day higher, and verifying that the whole amount of studies we based our research on are specially related to this kind of exercises on aged people, we felt intrigued about these results and if they would be the same in younger people.

Previous studies have shown that an online cognitive training for twenty minutes once daily for five weeks, improves significantly the visual attention and specially memory (4) and training interventions improve mental abilities and daily functioning in older, independent-living adults. (6, 8)

In order to do this, we considered answering the question “Can brain exercise develop the brain’s performance, in younger people?” we chose to make a clinical trial based on a training program designed to enhance several aspects of cognitive functions such as memory, concentration, and speed processing. Instead of just aiming to keep the brain in shape, as the studies about elderly groups usually do (6, 8), our study will aim to develop the brain’s capacity in younger people. This is possible, mainly because, unlike older individuals, younger people usually don’t have a decreasing brain capacity which needs to remain fit, but an increasing brain capacity that may be improved by this kind of brain-training programs. Thus we expect younger brains to have a most significant improvement than the others.

This study may also have consequences on everyday life events such as interacting socially, daily problem-solving, performance at work or attention and concentration. This is mostly aimed at older adults as well, but it may have the same effects on younger individuals.

RESEARCH QUESTION AND AIMS

The question that we proposed ourselves to answer is “Can brain exercise develop the brain´s performance, in younger people?”

By trying to resolve this question, our aim is to test the influence of computer-based exercise in memory, concentration and speed processing.

PARTICIPANTS AND METHODS

Study Participants

The participants of this study will be colleagues amongst the 1st year students of Medicine in University of Porto that are willing to fulfill our training program in its full length. Not all students from 1st year of Medicine in University of Porto will be considered eligible for our study; students who either are younger than 17 years old or older than 19 years old will be excluded from the eligible students group. Those students that do not have internet at home will also be excluded, because internet is needed for our daily training program – Lumosity - for brain exercise, making those without internet at home ineligible for our study. Finally the students from the13th class will be excluded because they will be handling the construction of the groups, the number attribution to each participant, and the test and result analysis and they know more about the study than the other classes which might influence the result of this clinical trial.

For those participants who pass the exclusion criteria mentioned above, there will be a query about their main basal variables such as age and sex to further analysis. In order to make the analysis easier the control and experimental groups were selected, each from two classes only that have lessons ‘Introdução à Medicina II’ together. The test used will be WAIS-III for evaluation of the participants in both pre-training and final times. This test consists in exercises of memory of digits in direct and inverse way, memory of letters and sequences of numbers and search for symbols. These three main types of exercises focus greatly on memory but also in the speed of processing (search for symbols) and concentration also.

Both groups were initially constituted by thirty elements. However, two individuals were excluded from the experimental group, as they did not perform the second evaluation at T2. Resulting from this, experimental group was constituted by twenty eight elements while control group included thirty elements.

Study Design

This study is a clinical trial since we are attempting to measure the influence of a particular kind of daily brain training in younger individuals and the most accurate way to do so is to use this type of study design. This brain training will focus only on the memory, concentration and speed of processing domains. In this trial, the participants that were considered eligible will be in two groups: the experimental group and the control group. Both groups will be subjected to a pre-test prior to any training. Afterwards, the experimental group will be subjected to an online daily brain training program (five games), during three weeks. The control group will be subjected to a placebo, which consists in evaluating the intellectual progression of the control group’s participants as active students of Medicine 1st year only, as they will not be subjected to the training in any way.

Furthermore in our study the blinding will not be a double blinding, since the investigators will know in which group each participant is, and also each participant will know the group he has been assigned to and in which group the other participants are. This impossibility in the blinding process derives from the fact that the WAIS-III test used consists in particular interviews to each of the individuals, which makes it very hard to maintain this blinding. Also the participants will know the group they have been assigned to since they are all students in the 1st year of Medicine and it is impossible to keep the secrecy this blinding would require. However, we will divide our class in two groups; one of them will interview the participants, see if they meet the inclusion criteria and pass the exclusion criteria and give them numbers for identification of the tests in the study, this group will also hand over the tests – pre-test and final test - to those people that are in the experimental and control groups. The other group of our class will be in charge of the comparison of both pre-test and final test results without knowing anything about the participants besides the number that has been given to them. The data collection and processing in SPSS data base will also be handled by this group.

Data Collection Methods

The data collection will be done through association of the results of a pre-test and a pos-test, concerning the training period to which the experimental group will be submitted. As we mentioned we'll apply the WAIS-III test because it has a simple application and interpretation and it is also standardized to the portuguese population. This will make the comparison of our results easier and also simple to spot if there are statistically significative changes in our study when compared to the portuguese population.

Variables Description

In this clinical trial the variables concerned are: memory, concentration and speed of processing.

According to Mesh Terms, memory is complex mental function having four distinct phases: memorizing or learning, retention, recall, and recognition. Clinically, it is usually subdivided into immediate, recent, and remote memory. The following, concentration or attention is focusing on certain aspects of current experience to the exclusion of others. It is the act of heeding or taking notice or concentrating. Lastly, speed of processing is the speed of performing basic cognitive operations.

We can consider the outcomes measurable, but only until a certain degree of precision because our variables are subjective and as we don't fully know how the scores obtained from the WAIS-III tests relate objectively to the improvements in the brain's capabilities we can't evaluate them. We measure these variables through three scores related to the three tests, in a scale from 1 to 19, which are converted in a total score (the sum of the three scores). These scores will work as our dependent variables and as independent variables we will have "group" (control/experimental) and "time" (between T1 and T2).

There are two variables from Lumosity training, that were used to correlate with test sores: BPI (Brain Performance Index) and Lumosity Points. BPI provides a measure of overall brain performance, because it converts scores in very different activities at Lumosity games to the same scale based on average scores across all users. Lumosity points are an indication of completing games and courses, being a measure of how much brain training the participant has done with Lumosity.

Statistical Analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS, version 17.0). Kolmogorov–Smirnov analysis was used to test if the results are normally distributed. Results that presented a normal distribution are presented as mean ± standard deviation. To compare the control and experimental groups we used Student's unpaired t-test; to compare test scores at baseline with those obtained at the end of the study period, we used Student's paired t-test. Categorical variables were compared between groups by using Chi-squared test or Fisher's exact test. Correlations between parameters were evaluated by calculating the Pearson´s correlation coefficient. Statistical significance was accepted at $P<0.05$.

RESULTS

The characteristics of participants are presented in Table 1. The control and experimental groups were matched for age, gender and time (hours/day) dedicated to study medicine.

The adhesion to the training program of the participants in the experimental group is presented in Table 2. The median value obtained for the number of sessions was 9.0. Only five participants performed 20 sessions or more during the three weeks of training.

Table 3 presents the test scores at baseline (T1) and at the end of the study (T2) for both control and experimental groups. The experimental group improved significantly all test scores, in contrast with control group that only presented statistically significant improvement in the Symbol search test and in the Total score (sum of the scores obtained in the three exercises which constitute the pre and post tests).

Regarding the comparison between groups, no statistically significant differences were observed for test scores between both groups at T1 (Table 2). At T2, however, the score obtained for "Memory of letters and numbers" was statistically significant higher for the experimental group. No statistically significant differences were observed between groups for delta scores (Table 4). Concerning the comparison between males and females for test scores, we found in the experimental (but not control) group that males present a significantly higher delta score in "Memory of digits and letters" (data not shown).

We found positive correlations between the number of sessions and test scores, particularly with total score, though without statistical significance (Table 5).

We decided to perform a sub-analysis including only those that performed ten or more sessions (ten sessions is half of the number of sessions desirable) and observed that not only the test score for Memory of letters and numbers at T2 was statistically significant higher for the experimental group (Table 6) but also the change in this test score (Δ T2-T1) was also higher. The total score was also higher in the experimental group at T2 and almost achieved statistical significance ($P=0.073$).

Table 1. Characteristics of participants

Characteristics of participants	Control group	Experimental Group	*P*
Number of cases	30	28	
Sex (male/female)	10/20	14/14	0.198*
Age (years)			0.238**
17 (*n*)	1 (3.3%)	0 (0%)	
18 (*n*)	14 (46.7%)	18 (64.3%)	
19 (*n*)	15 (50.0%)	10 (35.7%)	
Time dedicated to study Medicine per day (h)			0.153**
0-2 (*n*)	3 (10%)	7 (25.0%)	
2-4 (*n*)	22 (73.3%)	17 (60.7%)	
4-6 (*n*)	5 (16.7%)	2 (7.1%)	
?6 (*n*)	0 (0%)	2 (7.1%)	

*, Chi-square test; **, Fisher's exact test

Table 2. Adhesion to the training program (lumosity) in the experimental group (n=28)

Number of days	4.75 ± 3.18
Number of sessions	10.79 ± 9.31
Median (IQR)	9.00 (2.25-17.75)
Minimum-Maximum	0 - 34
Overall BPI	676.93 ± 323.94
Lumosity points	173.43 ± 158.89

Values are presented as mean ± standard deviation, unless otherwise indicated
BPI, Brain Performance Index
IQR, Interquartile Range

Table 3. Test Scores at baseline (T1) and at the end of study (T2) for control and experimental groups

	Control Group		*p*	Experimental Group		*p*	*p*	*p*
Characteristics of participants	T1	T2	(T1 *Vs* T2)*	T1	T2	(T1 *Vs* T2)*	(T1 *Vs* T1)**	(T2 *Vs* T2)**
Number of cases	30	30		28	28			
Test Scores								
Memory of digits	12.20 ± 2.59	12.73 ± 2.50	0.184	12.68 ± 3.14	13.57 ± 2.71	0.010	0.528	0.226
Memory of letters and numbers	11.67 ± 2.38	12.27 ± 2.43	0.116	12.29 ± 2.26	13.64 ± 2.71	0.001	0.315	0.046
Symbol search	12.40 ± 2.86	15.97 ± 2.55	<0.001	13.29 ± 2.93	15.75 ± 3.01	<0.001	0.249	0.768
Total score	36.27 ± 5.53	40.97 ± 5.67	<0.001	38.25 ± 5.83	42.96 ± 6.11	<0.001	0.189	0.202

Values are presented as mean ± standard deviation
*, Paired t test
**, Unpaired

:ores at T2 and T1

	ɔntrol	Experimental	*p* (Ctr *Vs* Exp)*
Number of cases	30	28	
Δ T2-T1 (Test Scores)			
Memory of digits	0.53 ± 2.14	0.89 ± 1.71	0.485
Memory of letters and numbers	0.60 ± 2.03	1.36 ± 1.95	0.153
Symbol search	3.57 ± 2.56	2.46 ± 2.86	0.127
Total score	4.70 ± 4.49	4.71 ± 4.28	0.990

Values are presented as mean ± standard deviation
*, Unpaired t test
Ctr = Control; Exp= experimental

Table 5. Correlations observed between test scores and the number of sessions, overall BPI and lumosity points,in the experimental group (n=28)

	Memory of digits (T2)	Memory of letters and numbers (T2)	Symbol search (T2)	Total score (T2)
Number of sessions	*r* = 0.251, *P* =0.197	*r* = 0.220, *P* =0.261	*r* = 0.249, *P* =0.202	*r* = 0.332, *P* =0.084
Overall BPI	*r* = 0.123, *P* =0.532	*r* = 0.144, *P* =0.463	*r* = 0.487, *P* =0.009	*r* = 0.359, *P* =0.060
Lumosity points	*r* = 0.221, *P* =0.257	*r* = 0.074, *P* =0.710	*r* = 0.234, *P* =0.230	*r* = 0.247, *P* =0.206

Table 6. Test Scores at the end of study (T2) and changes in Test Scores (T2-T1) for control and experimental (number sessions ≥10) groups

	Control	Experimental	***p*** (Ctr *Vs* Exp)*
Number of cases	30	13	
Test Scores at T2			
Memory of digits	12.73 ± 2.50	13.69 ± 2.90	0.278
Memory of letters and numbers	12.27 ± 2.43	14.00 ± 2.86	0.048
Symbol search	15.97 ± 2.55	16.77 ± 2.35	0.338
Total score	40.97 ± 5.67	44.46 ± 5.85	0.073
Δ T2-T1 (Test Scores)			
Memory of digits	0.53 ± 2.14	1.46 ± 1.81	0.181
Memory of letters and numbers	0.60 ± 2.03	2.00 ± 2.00	0.043
Symbol search	3.57 ± 2.56	3.00 ± 2.38	0.500
Total score	4.70 ± 4.49	6.46 ± 2.88	0.201

Values are presented as mean ± standard deviation
Ctr= control; Exp= experimental
*, Unpaired t test

DISCUSSION

Several studies have reported that “Brain exercise” programs improve cognitive effects in elderly persons (6, 8). However, as far as we know, only one study (11) addressed the effect of this type of programs in young people. In this way, we decided to perform a longitudinal study involving Medical students, aged 17-19 years of old, in order to evaluate how Lumosity program improves cognitive function in young people.

Our study was composed of an experimental group (with three weeks of exposure to the Lumosity program) and a control group (with no exposure to the program). Both groups were matched for the maximum of characteristics (age, gender and time dedicated to study medicine) and presented similar test scores at the beginning of the study (Tables 1 and 3). This is important to avoid possible bias, i.e., the possible differences in test scores between groups should be mainly attributable to the test exercise and not greatly affected by other factors.

The adhesion to the training program in the experimental group was weak (Table 2). Indeed, the median value obtained for the number of sessions was 9.0 (less than half of the desirable number of sessions: 20); only five participants performed 20 sessions or more during the three weeks of training and three did not perform any session. Even thus, we decided to perform a global analysis of the results involving all participants in the experimental group, in order to consider an “intention to treat analysis”. We found that all test scores were significantly improved in the experimental group, in contrast with control group that only presented statistically significant improvement in the Symbol search test and in the Total score (Table 3). However, when evaluating differences between groups at T2, only the score obtained for “Memory of letters and numbers” was statistically significant higher for the experimental group. Moreover, no statistically significant differences were observed between groups for delta scores, i.e., in the differences obtained between T1 and T2 for test scores (Table 4). The analysis of delta scores is of great importance, as it adjusts for individual differences at the beginning of the study. Thus, in this first analysis, we were unable to find clear evidence of a higher improvement in cognitive capabilities in the experimental group compared to the control group.

Considering that the adhesion to the training program was weak and that the number of sessions correlated positively with test scores at T2 (even though without statistical significance), we figured important to perform a sub-analysis involving only those that performed at least 10 sessions (half of the number of sessions desirable) in the experimental group. When comparing this subgroup with controls, we found that not only the test score for Memory of letters and numbers at T2 was statistically significant higher for the experimental group (Table 6) but also the change in this test score (Δ T2-T1). These results suggest that only those who performed minimally the training program achieved, effectively, an improvement in some of the brain’s capabilities. These findings are in agreement with those obtained by Jaeggi *et al.*(11) who found "significant improvements" in young participants who took part in their trial (to whom were given daily exercises lasting around 25 minutes, during 19 days).This work also found a significant gain in the control groups, presumably because of retest effects. Other reason why the control group improved significantly the Symbol search score and the Total score may be related to several factors, namely a different motivation to the study in the two evaluations. This different motivation may be related to the fact that the present study was not purely blind. However, we must not exclude the hypothesis that this and other factors may also be involved in the experimental group. It is essential to keep in mind that the positive linear associations found between the number of sessions and test scores at T2 were not strong, suggesting that the major part of the test scores is determined by factors other than the number of training sessions.

It is important to highlight that our results were obtained involving only medical students, aged 17 to 19 years of age. On the other hand, we should also have in mind that this study included a small number of participants, not allowing the desirable test power, and was performed only during three weeks (mainly due to the academic calendar). It would be important to perform more studies involving different and larger sample populations and a longer period of training.

In summary, our data showed that young medical students who minimally perform the Lumosity training program seem to achieve some improvement in their brain's capabilities. The improvement that we found was only significant for one of the tested scores ("Memory of letters and numbers") and for those who performed at least 10 training sessions during three weeks. Further studies are needed to confirm our findings. Future studies should include a higher number of participants during a longer period of training and involving strategies that encourage a greater adhesion to the training program.

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