TRAINING TO IMPROVE SELECTIVE ATTENTION IN CHILDREN USING NEUROFEEDBACK THROUGH PLAY

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Abstract: This paper has two objectives: a) to identify if selective attention and concentration in school children without learning problems can be improved through training with neurofeedback; and b) to assess the generalizability of such training as a useful, easy, fun and economical procedure that may be used to improve school performance. For training we used Mind-Flex, a toy first marketed in 2009. To measure a possible boost in attention we applied the d2 test of attention developed by Brickenkamp (1962), adapted in Spain by Seisdedos (2002). The results obtained from a sample of 65 children (aged 8 and 9) show a significant improvement in selective and sustained attention, cognitive-processing accuracy, attention control and balance between speed and accuracy.

Keywords: Selective attention; concentration; neurofeedback; children.

Entrenamiento mediante neurofeedback a través del juego para la mejora de la atención selectiva en niños

Resumen: El presente trabajo tiene un doble objetivo: a) observar si, mediante entrenamiento en neurofeedback, puede mejorarse la atención selectiva y la concentración en niños escolarizados sin problemas de aprendizaje, y b) valorar la posibilidad de generalizar este tipo de entrenamiento como un procedimiento útil, fácil, lúdico y económico, que pueda ser usado para la mejora del rendimiento escolar. Para el entrenamiento utilizamos un Mind-Flex, juguete comercializado en 2009. Para medir el posible incremento atencional se utilizó el Test de atención d2 de Brickenkamp (1962), adaptado en España por Seisdedos (2002). Los resultados obtenidos en una muestra de 65 niños (entre 8 y 9 años de edad) mostraron una mejora significativa en la atención selectiva y sostenida, la precisión del procesamiento cognitivo, el control atencional y el equilibrio entre la velocidad y la precisión.

Palabras clave: Atención selectiva; concentración; neurofeedback; niños.

INTRODUCTION

Attention has been defined as «a complex system composed of specific sub-processes associated with different neural mechanisms through which control of head orientation is achieved, information processing, decision making and behavior» (Ríos Lago, Penágez & Rodríguez, 2008). This attentional system acts by filtering and allocating the necessary resources to enable the internal adaptation of the organism to external stimuli. One of these sub-processes is selective attention, defined as the ability to select relevant information, the pattern of activity or action appropriate to the demand while focusing on what is relevant without being distracted by noise. Another of the attentional sub-processes involved in performance is sustained attention, which is defined as the ability of people to execute a task for long periods of time and which includes as subcomponents vigilance and concentration (Ardila, Rosselli, Pineda & Lopera, 1997). The concentration can be described as the «intensity» and «resistance» to diverting attention to other secondary stimuli.

At the physiological level, attention is manifested in the cerebral cortex through brain ac-

tivity. When a stimulus requires attention, there is a desynchronization of neuronal activity during which the *alpha* rhythm is replaced by the *beta* rhythm (Castillo, 2009). Regarding the association between specific brain patterns and cognitive tasks, there is evidence that *alpha* waves of low and high frequency (from 7 to 9.5 Hz and 9.5 to 12 Hz) are associated to attentional processes and working memory, respectively (Klimesch, Doppelmayr, Schimke & Ripper, 1997; Klimesch, Schimke, Ladurner & Pfurtcheller, 1990; Kimesch, Schimke & Schwaiger, 1994). It is precisely the association of specific cortical activity patterns with particular tasks that enables the use of neurofeedback training as a strategy for improving control and attentional capacity. There are other workouts in selective attention with schizophrenics using a pencil and paper format (Gil et al., 2012).

Neurofeedback is a form of biofeedback consisting of providing specific information about the electrical activity of the cortex. The goal of neurofeedback is that a person learns how to voluntarily modify a particular aspect of electrocortical activity, producing specific changes in certain electroencephalographic (EEG) wave patterns (based on amplitude, frequency and consistency). When the person associates the modification of a certain EEG state with improved cognitive performance, learning takes place through mechanisms of operant conditioning (Vernon, 2005; Sherlin et al., 2011).

The potential therapeutic benefits of neurofeedback training are being investigated in two main areas. The first application of this approach is for clinical treatment patients, including patients with acquired brain injury, patients with attention-deficit hyperactivity disorder (Navarro & García-Villamisar, 2011), and patients with autism spectrum disorders (López-Frutos, Sotillo, Tripicchio & Campos, 2011). The second area is the application of these techniques to the healthy population (this method has primarily been applied to athletes) with the objective of increasing their attentional control ability (Vernon, 2005).

For clinical populations with acquired brain injury, the meta-analysis conducted by Park and

Ingles (2001) on the basis of 30 published works concluded that the effects of training are significant, with large effect sizes (ES), in studies in which measurements were conducted before and after treatment, but these results were attributed to learning during the realization of the test because no significant results were found in studies with a sample design including pre- and post-treatment measures on a control group.

Regarding the applicability of this procedure in the case of ADHD, there have been several meta-analytic studies (Snyder & Hall, 2006; Lofthouse, Arnold, Hersch, Hurt & DeBeus, 2012), and there have been methodological improvements introduced in these studies (e.g., the inclusion of a control group, «double blind» designs, etc.). However, while the usefulness of the treatment is recognized, there is not enough evidence to consider neurofeedback training better than or as an adequate substitute for classic pharmacological treatment.

The review conducted by Vernon (2005) attempted to answer whether neurofeedback can produce cognitive changes in healthy subjects. His analysis indicated that the results are not definitive because the research efforts have significant methodological problems (e.g., a small number of subjects, lack of randomization or lack of a control group), which led him to state that it is too early to claim that neurofeedback training produces improvements in cognitive abilities.

Haapalainen, Kim, Forlizzi and Dey (2010) conducted a study on the possibility of obtaining an objective measurement of real-time cognitive activity with psychophysiological sensors in tasks of visual perception and cognitive speed. Their results indicate the existence of a psychophysiological signal that can be used to distinguish different levels of cognitive activity in subjects. Furthermore, Gholizadeh, Babapuor-Kheiraldin, Rostami, Beirami and Poursharifi (2011) studied the effects of neurofeedback in visual memory, and the results indicated that the subjects were able to achieve some control over the various components of EEG and increase their levels of memory performance.

Recently, Lutsyuk, Éismont and Pavlenko (2006) studied the efficacy of neurofeedback on modulating attention in healthy children 10 to 13 years old. This study evaluated the effectiveness of neurofeedback training of voluntary attention based on beta rhythms and changes in the EEG power spectrum. Variations in attention were assessed using Bourdon's test (2004). The authors introduced into the design the game «race of beetles», in which the speed of the game changes depending on the SP index values of EEG rhythms. The game is won when the child is able to change the relationship of the SP index (beta/theta intensity ratio) of the EEG rhythms in the desired direction.

The studies reviewed up to this point suggest that people are able to alter, in some manner, their electroencephalographic activity by neurofeedback training. At the University of Hull in the United Kingdom, Dr. Peter Clogh is currently conducting a project with students in the area of Knowsley, aiming to improve performance prospects in the areas of mathematics and the English language. He studies the effect of training with Mindflex® on what he calls «mental toughness», using a cohort of 400 students.

The present research was developed based on the aforementioned exposition. Therefore, our first goal is to study the possibility of conducting attentional training using neurofeedback, and if this is successful, the second objective of this research is the standardization of the intervention as a way to improve student achievement based on attentional boost. This research will involve playful intervention, during which participants «play» with Mindflex®, a toy based on NeuroSky technology[2]. It is hypothesized that by playing with this toy, normal school children will improve their attention and concentration levels.

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[2] NeuroSky is an American company that has developed the module ThinkGear to measure electrical brain activity. Two characteristics of their products are a) the usage of dry electrodes (Dry-Active) and b) the usage of a single electrode (in contrast to classic EEG recordings, which use several electrodes). Devices based on NeuroSky technology have low cost and are easy to use. Refer to www.neurosky.com.

METHOD

Participants

A total of 65 students (8 to 9 years old) were selected who attended one of two public schools (29 belonging to Center A and 36 to Center B) located in the community of Madrid (Spain). Of the students, 28 were boys, and 37 were girls, with 58% aged 9 years and 42% aged 8 years (see Table 1). In a second step, the sample was reduced to 47 individuals for reasons explained in the section discussing the applied procedure.

Table 1. Composition of the initial sample

	Center A	Center B	Total
Boys	13	15	28
Girls	16	21	37
Total	29	36	65

Instruments

The instrument of study is the Spanish-adapted version by Seisdedos (2002) of the d2 test of attention developed by Brickenkamp (2002). This test is a limited time test that measures selective attention and mental concentration. This test falls within the category of so-called cancellation tests. The test can be administered individually or collectively, with a completion time of approximately 10 minutes. The test evaluates processing speed, the following of directions and the goodness of execution in a visual discrimination task that allows the estimation of the attention and focus of a person with an age ranging from 8 to 60 years. The test consists of 14 lines with 47 characters (658 elements). The stimuli were the letters «d» and «p», which may be accompanied by one or two small lines individually or in pairs located at the top or bottom of each letter. The task consisted of checking, from left to right, the content of each line and marking all of the d's that had two small scratches on the following positions: two above, two below and one above and one below (which correspond to the correct stimulus). For each line, the subject had 20 seconds to complete the task.

The scores and their corresponding processes are described below:

TA =   Total number of answers. Number of items attempted in the 14 lines (i.e., processing speed and the amount of work).

TH =   total hits. Number of correct relevant items (i.e., accuracy of processing).

O =   Omissions. Number of relevant items attempted but not marked.

FP =   False positives. Number of irrelevant items marked relevant (i.e., precision and inhibitory control).

TOT =   TA – (O + FP). Total score (i.e., total effectiveness in the test).

CON =   TH – FP. Concentration.

TA+ =   Line with the highest number of items attempted (corresponds to the highest value obtained by the subjects).

TA– =   Line with lower number of items attempted (corresponds to the lowest value obtained by the subjects).

VAR =   (TA+) – (TA–). Total effectiveness in the test.

The test had a good discriminative capability with normal distributions of the variables, except for O and FP, which showed a significant positive skew indicating little discriminative ability in the low values but significant ability for the high values. Thus, high scores represent a high probability of relevant attentional problems being present. This pattern is why the scores were used as a criterion to ensure sample uniformity.

For training by neurofeedback, a toy called MindFlex® (marketed by Mattel) was used. This device belongs to a set of entertainment toys using NeuroSky® technology. The apparatus consists of two elements: a) a console that has holes at the top through which an air stream generated by an internal fan can exit; the fan has a variable speed switch, such that it can be adjusted to allow the air stream to maintain a small ball of light material suspended in mid-air; and b) a tape that supports the device that captures and processes the electrical signals from the cortex (using three electrodes, one that stands approximately three inches above the left eyebrow and two in the form of clamps, which are fastened on the lobes of both ears). The toy offers different play alternatives: individual and collective. In this study, the game called «follow the lights» was used and set to the intermediate level in the individual category. According to the manufacturer's specifications, the device records the EEG brain activity and processes this information so that variations in the concentration level of the player are translated into more or less fan speed and thus the height reached by the ball.

Design

This study is a quasi-experimental pre-test-post-test design with a control group. The independent variable was training with MindFlex®. The assignment of subjects to the experimental and control groups was randomized in each school. The dependent variables were the results of the d2 test before and after treatment.

Procedure

The experiment consisted of an initial session, held in a classroom at each of the two participating schools, during which the d2 test was administered to obtain a pretest measure. Several of the students attending this first session were eliminated from the study according to the following criteria: a) children who were in the 90th percentile of the variables O and FP according to their scores in the d2 test (this result was taken as a guarantee that no participants had any possible attentional disorder, according to the criteria established in the test manual); b) those whose parents did not give consent; and c) those who were not able to successfully complete the training session with MindFlex®. After the application of these criteria, the sample size consisted of two groups of 21 and 26 participants. Each group was divided into two subgroups, with the subjects randomly allocated to each of the subgroups (see Table 2).

Table 2. Composition of the sample after the pretest

	A	B	Total
Experimental	11	13	24
Control	12	11	23
Total	23	24	47

Once the two groups were established, both carried out jointly the pre-test and post-test in a subsequent session. After finalizing the pre-test session and eliminating the subjects who did not meet the characteristics mentioned, the experimental and control groups were formed by randomization. The participants who were in the control group were gathered and were told that they would be contacted on a different day to conduct the test.

Each experimental group was assigned to an experimenter who, according to the school, determined the location, dates and times for training. Each participant received 10 training sessions; the first focused on presenting the game, whereas the remaining sessions were focused on treatment. The sessions were developed as follows:

Session 1. Included testing of and conditioning to the instrument, using the game mode «free play», in which subjects have to lift a ball by exercising concentration. If attention is lacking, this lowers the height of the ball. All of the participants in the experimental group performed this session without problems, except one child who failed and was thus replaced.

Sessions 2 to 9. Made use of the game mode called «follow the lights», in which players have to «hunt» the lights that light up randomly during the game, keeping the ball high. Of the three levels of difficulty allowed in the game, the intermediate level was selected. Each session lasted 25 minutes with 5 min mid-session breaks (i.e., the game was played over two 10-minute sessions).

All of the sessions were conducted in the same room between 5-7 pm for 5 consecutive days. The last session consisted of the re-administration of the d2 test in the classroom, as had been done in the initial session.

RESULTS

A prior exploratory analysis was performed to study whether the distributions presented problems of normality, heteroscedasticity, lost cases or atypical cases. No significant problems were detected, and thus, parametric techniques were implemented, namely, Student's t-test for independent or related samples, depending on which of the groups were compared. The Table 3 show the descriptive statistics.

Table 3. Descriptive statistics

	Control group		Experimental group	
	pre-test	post-test	pre-test	post-test
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
TA	249.74 (109.31)	287.43 (139.91)	261.58 (114.19)	314.33 (148.06)
TH	109.96 (21.64)	130.39 (39.23)	113.08 (38.89)	142.54 (40.64)
O	16.13 (22.60)	17.96 (25.69)	13.20 (13.76)	10.16 (12.20)
FP	10.22 (22.44)	15.96 (30.22)	13.85 (26.49)	13.54 (27.72)
TOT	239.83 (100.51)	282.22 (136.07)	253.20 (112.04)	309.37 (144.57)
CON	116.61 (47.60)	129.30 (39.49)	112.33 (38.99)	140.25 (44.11)
TA+	43.78 (29.14)	43.74 (25.47)	45.54 (30.12)	49.25 (27.52)
TA-	35.39 (33.16)	36.09 (31.48)	35.25 (34.69)	38.62 (33.09)
VAR	26.96 (829.30)	23.78 (23.82)	28.62 (29.60)	19.16 (22.19)

No significant differences were found between the experimental and control groups for any of the variables evaluated by the d2 test during the pretest. Additionally, no significant differences were found between the experimental and control groups for any of the variables

of the d2 test. Intra-group comparisons, for both the experimental and control groups (Table 4), indicated significant differences in the same variables of the d2 test. It should be noted that the effect size (ES) was large in all of the cases (greater than .80), and the power was maximal.

Table 4: Comparisons of the control/experimental variables measured using the d2 test

	Experimental group				Control group			
	t	df	ES	1-β	*t*	df	ES	1-β
TA	-3.164***	22	1.51	.99	-6.01***	23	1.49	.99
TH	-4.396***	22	1.34	.99	-6.595***	23	.91	.99
TOT	-4.187***	22	1.33	.99	-6.530***	23	.87	.98

Note. ES = effect size (Cohen's *d*). *** $p < .001$

DISCUSSION

In relation to the two objectives of this study (the first being to explore the possibilities of neurofeedback training as a procedure to improve the selective attention and concentration of school children who do not have learning problems and the second to assess the generalizability of this type of training as a useful, easy, fun and economical procedure that can be used to improve school performance), our results lead us to conclude that neurofeedback training still has several methodological problems. Therefore, despite having avoided the most common errors in this type of research (such as errors regarding the number of subjects, randomization and the control group), errors involving the measurement of attention, remain. Consequently, the second objective cannot be fulfilled at the present stage of this research.

The present work bears a clear resemblance to the study developed by Lutsyuk et al. (2006) regarding the variables that could be affecting the results from a design perspective (number and duration of sessions, etc.). The substantial difference of our work consists of the measure used to evaluate the intervention. Lutsyuk et al. used the Bourdon test (Boujon & Quaireau, 2004), while we used the d2 test because it has been tested in Spain. Lutsyuk et al. (2006) obtained results showing statistically significant differences among the groups of participants, which were attributed to the training received. In our study, we did not find such differences between the experimental and control groups, and thus, our findings do not support those of Lutsyuk et al. The reason for this discrepancy

is likely the use of different measuring instruments.

Although, as we have said, our design avoids some of the problems highlighted in the meta-analysis by Vernon (2005) (low number of participants in the trials, failure to assign subjects randomly to the experimental conditions, lack of a control group, the designs used, etc.), the results of our study cannot support the idea that this game is useful for training attentiveness and improving performance in this cognitive ability. This result is somewhat contradictory to the observations of Clogh (2009), although as noted above, Clogh (2009) did not focus specifically on an attentional mechanism as such but referred to a broader construct of «mental toughness» (involving other factors, such as achievement motivation, resilience, etc.). Thus, we can say that our results are far from conclusive in the context of Vernon (2005).

We understand that there are many unsolved problems in these types of studies. In our research, we selected the d2 test as a measuring instrument because it had been tested for Spain. This selection resulted in all of the subjects (the experimental group and the control group) obtaining similar results in the test, indicating a statistically significant improvement in both cases. This improvement is likely a result of the effect of practice because of the short time (one week) between the initial and final assessments.

This issue leads us to consider the need for a theoretical framework with clearly defined procedures to measure attention. In this context, the model of attentional networks developed by Posner & Petersen (1990; Posner & Rothbart, 2007) and their attention network test could be the

ideal candidates to define the conceptual framework and the appropriate measurements for studies with goals similar to the one here discussed.

Along with the above findings and in view of the methodological problems detected, mainly those related to the extent of selective attention, we understand that it would be useful to have some physiological measure of the dependent variable (for example, a bioelectric procedure) that enables the use of the variations in post-training attentional measures as validation criteria. This process would prevent the attentional test from being the sole criterion for assessing the intervention. It should be remembered that attentional tests, in the context of the complexity of the concept that they try to evaluate, can lead to measurements that are often heterogeneous and whose correspondence with the attentional component that one intends to measure is not clearly established.

REFERENCES

Ardila, Rosselli, Pineda, & Lopera, (1997). TDAH. Concentración y procesos atencionales [ADHD. Concentration and attention processes]. In *Neuropsicología Infantil. 2da. ed.* [*Child Neuropsychology, 2nd ed.*]. México DF: Prensa Creativa

Boujon, Ch., & Quaireau, Ch.(2004). *Atención, aprendizaje y rendimiento escolar.* [*Attention, learning and school performance*]. Barcelona: Narcea Ediciones.

Brickenkamp, R. (2002). *Test d2 «Atención Mental» [The d2 Test «Mental Attention»]*. Madrid: TEA Ediciones.

Castillo, M. D. (2009). *La atención* [*Attention*]. Madrid: Pirámide.

Gholizadeh, Z., Babapuor-Kheiraldin, J., Rostami, R., Beirami, M., & Poursharifi, H. (2011). Effects of neurofeedback on visual memory. *Behavioral Science, 4*, 285-289.

Gil, D., Palacios, M., Sánchez, R., Gómez, I., Gutiérrez, E., Ramiro, G., y Fuentecilla, A. (2012). Eficacia de un programa de entrenamiento en atención en esquizofrenia: Un estudio piloto [Efficacy of an attention training program in schizophrenia: A piloto study]. *Revista de Psicopatología y Psicología Clinica, 1,* 43-56

Haapalainen, E., Kim, S., Forlizzi, J. F., & Dey, A. K. (2010). Psycho-physiological measures for assessing cognitive load. Proceedings of the 12th AM International Conference on Ubiquitous Computing (Ubicomp'10). 26-29 Sep. Copenhagen, Denmark.

Klimesch, W., Doppelmayr, M., Schimke, H., & Ripper, B. (1997). Theta synchronisation and alpha desynchronisation in a memory task. *Psychophysiology, 34*, 169-176.

Klimesch, W., Schimke, H., Ladurner, G., & Pfurtscheller, G. (1990). Alpha frequency and memory performance. *Psychophysiology, 4,* 381-390.

Klimesch, W., Schimke, H., & Schwaiger, J. (1994). Episodic and semantic memory: An analysis in the EEG theta and alpha band. *Electroencephalography and Clinical Neurophysiology, 91*, 428-441.

Lofthouse, N., Arnold, L. E., Hersch, S., Hurt, E., & DeBeus, R. (2012) A review of neurofeedback treatment for pediatric ADHD. *Journal of Attention Disorders. 16,* 351-372.

López-Frutos, J. M., Sotillo, M., Tripicchio, P., y Campos, R. (2011). Funciones atencionales de orientación espacial, alerta y control ejecutivo en personas con trastornos del espectro autista [Attentional functions of spatial orientation, alerting and excecutive function in individuals with autism spectrum disorders]. *Revista de Psicopatología y Psicología Clínica, 16,* 101-112.

Lutsyuk, N. V., Éismont, E. V., & Pavlenko, V. B. (2006). Modulation of attention in healthy children. using a course of EEG-feedback sessions. *Neurophysiology, 38*, 458-465.

Navarro, M. I., & García-Villamisar, D. A. (2011). Funcionamiento ejecutivo en el trastorno de déficit de atención con hiperatividad: Una perspectiva ecológica de los perfiles diferenciales entre los tipos combinado e inatento [Executive functioning in attention deficit hyperactivity disorder: An ecological respective of the differential profiles between the combined and the inattentive types]. *Revista de Psicopatología y Psicología Clínica, 16,* 113-124.

Norman, P., Ingles, W., & Janet, L. (2001). Effectiveness of attention rehabilitation after an acquired brain injury: A meta-analysis. *Neuropsychology, 15,* 199-210.

Park, N. W., & Ingles, J. L. (2001). Effectiviness of attention rehabilitation after and acquired brain injury: A meta-analysis. *Neuropsychology, 15,* 199-210.

Posner, M. I., & Rothbart, M. K. (2007). Research on attention networks as a model for the integration of psychological science. *Annual Review of Psychology, 58*, 1-23.

Posner, M., & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience, 13*, 25-42.

Ríos Lago, M., Penágez, J. A., & Rodríguez, J. M. (2008). Neuropsicología de la atención (pp. 149-188) [Neuropsychology of attention]. In J. Tirapu Ustárroz, M. Ríos Lago y F. Maestú Unturbe (Eds.), M*anual de Neuropsicología* [*Handbook of neuropsychology*]. Barcelona: Viguera Press.

Seisdedos. (2002) *Adaptación Española del Test d2 «Atención Mental» de Brickenkamp.* Madrid: TEA Ediciones

Sherlin, L. H., Arns, M., Lubar, J., Heinrich, H., Kerson, C., Strehl, U., & Sterman, M. B. (2011). Neurofeedback and basic learning theory: Implications for research and practice. *Journal of Neurotherapy, 15*, 292-304.

Snyder, S. M., & Hall, J.R. (2006) A meta-analysis of quantitative EEG power associated with attention-de-ficit hyperactivity disorder. *Journal of Clinical Neurophysiology, 23,* 440-455

Vernon, D. J. (2005). Can neurofeedback training enhance performance? An evaluation of the evidence with implications for future research. *Applied Psychophysiology and Biofeedback, 30*, 347-364.