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MULTIMODAL INTERVENTION PROGRAMME FOR THE IMPROVEMENT OF ATTENTION DEFICITS

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Can attention be learned? The purpose of this article is to report on the development, administration and assessment of an intervention programme for the improvement of selective and sustained attention in school students aged 5 to 19 with difficulties for learning the academic material corresponding to their age group. Two groups participated in the study: one with difficulties in selective attention and the other with difficulties in sustained attention. The group with selective attention difficulties was made up of 102 students, of whom 59 were in the experimental group and 43 in the control group. The group with difficulties in sustained attention numbered 106, of whom 58 were in the experimental group and 48 in the control group. The results suggest that this kind of intervention programme (which combines visual therapy, cortical activation and training with activity banks) is effective for improving deficits in both selective attention and sustained attention.
Keywords: *Attention deficit, visual therapy, cortical activation, activity banks*

¿Es posible aprender a atender? En el presente artículo se informa del desarrollo, aplicación y contrastación de un programa de intervención para la mejora de la atención selectiva y sostenida en estudiantes de 5 a 19 años, todos escolarizados y con dificultades para la realización de los aprendizajes escolares correspondientes a su edad. En el estudio participaron dos grupos de estudiantes: uno con dificultades en atención selectiva y otro con dificultades en atención sostenida. El grupo de dificultades en atención selectiva estuvo formado por 102 sujetos, de los cuales 59 constituyeron el grupo experimental y 43 el grupo control. El grupo de estudiantes con dificultades en atención sostenida estuvo formado por 106 sujetos, de los cuales 58 participaron como grupo experimental y 48 como grupo control. Los resultados indican que este tipo de intervenciones (en las que se combina terapia visual, activación cortical y entrenamiento con bancos de actividades), son eficaces para la mejora de los déficits de atención, tanto selectiva como sostenida.
Palabras clave: *Déficit de atención, terapia visual, activación cortical, banco de actividades.*

Attentional models have evolved from the classic stimulus selection (Broadbent, 1958; Treisman, 1960; Hoffman, 1986) and limited resources models (Kanheman, 1973) to the more current activation models (Toomin, 2000; Angelakis, Lubar & Stathopoulou, 2004). These new models do not share the traditional idea of limited attentional capacity, since attention, on working as an active and constructive mechanism, is modified with practice, so that subjects generate their own attentional potential. Such potential will be determined not only by cognitive elements, but also by conative and affective elements, whose interaction is described in the first neoconnexionist model of attention (Phaf, Van der Heijden & Hudson, 1990), the *Slam* model, which demonstrates changes in attentional capacity through continued practice. Such changes occur in processes of both selective and sustained attention.

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Selective attention

Selective attention processes begin with a spatial selection phase (Ericksen & Webb, 1989; Madden, 1992; Henderson & MacQuistan, 1993), which is followed by a phase based on the characteristics of the object (Vázquez, Vaquero, Cardoso & Gómez, 2001; Roselló, 1997; Barbero, 2005). However, these two phases can coexist, since, as various authors have shown through the visual evoked potentials (VEP) technique, the P1 and N1 potentials can be modulated, both by attention based on the stimulus field (Méndez, Ponce, Jiménez & Sampedro, 2001) and by attention based on specific stimuli (Valdés-Sosa, Bobes, Rodríguez & Pinilla, 1998). This coexistence involves correct binocular coordination, which permits error-free image processing, via two distinct pathways: the magnocellular pathway (which channels static information) and the parvocellular pathway (which channels information in motion). This process is of enormous relevance to reading, since in this type of recognition what matters is not only the extent of the peripheral field, but also the quantity and quality of the fixations carried out, which favours the passage of the stimulus from the retina to the visual cortex. In subjects with dyslexia (Stein, 2001), the passage of information from the retina to the lateral geniculate body occurs at a normal pace via the parvocellular pathways, and very slowly via the magnocellular pathways. The deterioration of these pathways gives rise to errors in recognition of the written word. It is therefore necessary to develop discrimination skills (ocular motility, accommodation and fixation) to overcome this deficit. Thus, the goal of the present study, once discriminatory ability has been assessed with the D-2 (TOT) (see below) and monitored in the classroom through reading error rate (TALE test, see below), is to develop skills for the control and recognition of written information with visual therapy, and to put these into practice with computerized adaptive tasks (TAI, see below). Improvement in these tasks should have an effect on discriminatory ability, and hence on the reduction of reading errors.

Sustained attention

Students with sustained attention deficit tend to have specific problems with learning to read (25-40%, according to Willcutt & Pennington, 2000) and with mathematics (24-60%, according to Barkley, 1998), problems which cannot be remedied exclusively through the use of medication, given the faults in the executive network (Duncan & Owen, 2000) and the vigilance network (Merrell & Tymms, 2001; Roselló, 2002). The executive network is responsible for voluntary control of working memory and the selection and identification of stimuli (Posner & Dehaene, 1994; Posner & DiGirolamo, 1998), wereas the vigilance network is associated more with the degree of activation necessary for executing a task. This level of activation may vary according to task difficulty (May, 1999), and can be measured, following Álvarez, González-Castro, Soler, González-Pienda and Núñez (2004), through beta-theta activity changes, which are closely linked to brain metabolism and blood supply. An increase in beta or a decrease in theta would be associated with relatively inactive brain regions, so that the beta/theta ratio would serve as an excellent indicator of cortical activity. Other brainwaves, such as alpha, also tend to be good indicators (Angelakis et al., 2004; Angelakis, Lubar, Stathopoulou & Kounios, 2004; Swartwood, Swartwood, Lubar & Timmerman, 2003), though less accurate ones. Activation levels will therefore condition concentration ability, so that this study sets out, once sustained attention has been assessed via the beta-theta ratio and D-2 (CON), to increase cortical activation with EEG neurofeedback, and to carry out a practical assessment using the computerized adaptive tasks. The improvement in activation should influence concentration ability, and in turn, task performance.

METHOD

Design

Taking into account the goals of the present study, the research design proposed is of a quasi-experimental type, with non-equivalent control group. This type of design is widely used in the Educational Psychology, given the frequent impossibility of assigning subjects randomly. Furthermore, we measured age and IQ, using them as covariates in the data analysis, since these variables can presumably affect the assessment of the intervention programme's efficacy based on the post-test measures.

Participants

Participants in the present study were two groups of students, one with selective attention difficulties and the other with sustained attention problems. The group with selective attention problems was made up of 102 participants, of whom 59 were in the experimental group in 43 were in the control group. The group with sustained attention was made up of 106 students, of whom 58 were in the experimental group and 48 were in the control group. Age ranges of the four groups were 5 to 17 (selective attention) and 5 to 19 (sustained attention). We excluded from the sample some students who showed intellectual deficits at the beginning of the study, the final sample covering an IQ range of 70 to 132.

Participants, all from schools in the Asturias region of northern Spain, were selected on the basis of a prior request for examination, signed by parents or form teachers, in the wake of behaviour they perceived as possibly associated with attentional deficit. We excluded from the sustained attention group those students who were on medication, or began taking medication during the study period, in either the experimental or the control group. We excluded from the selective attention group those students who were initially unable to read.

Assignment to the study groups was made according to the type of problem presented by the student (selective or sustained), and for the distribution among experimental and control groups we took into account parents' readiness for their children to participate in the intervention and their commitment for them to do so for 1 hour, three days a week over a period of three months.

Assessment instruments

– The "Reading and Writing Analysis Test" (*Test de Análisis de Lectoescritura*, TALE), by Toro and Cervera (1984), identifies reading errors (loss of line, inversion, confusion, hesitation, supposition, omission, addition and syllabification) using texts adapted to each participant's age and level.
– The Worth Sensory Binocular Fusion Test *(Worth, www.promocionoptometrica.com*) is a test for assessing central fixation and ocular dominance. It consists of four images: two green crosses, a red diamond and a white circle. If participants, with a red filter in the right eye and a green filter in the left, discern a red diamond, two green crosses and a diffuse red-green circle, they will present errors in the recognition of written information.
– The D2 Test of Attention (Brickenkamp, 2001) is a test that can be applied individually or in groups from the age of 8, and takes 8 to 10 minutes. This instrument provides an accurate measure of the speed and quality of processing (TOT) and the quality and quantity of concentration (CON).
– The *Biocomp 2010* (The Biofeedback Institute of Los Angeles) is an EEG system, adapted by Toomin (2002), which provides cortical activation levels through the beta/theta ratio. When the ratio is under 50% in Cz it is associated with an attention deficit, and when it is under 50% in Fp1 the attention deficit may be related to hyperactivity.

Training material

– The *Computerized adaptive tasks* (*Tareas adaptativas informatizadas,* TAI), by Álvarez, González-Castro, Redondo and Busquets (2004), are banks of activities on four CDs corresponding to four intervention levels: level 1 (age 6-7), level 2 (age 8-9), level 3 (age 10-11) and level 4 (aged 12 and over). The activities on each CD are organized around five objectives for selective attention and four for sustained attention, which are achieved when 80% of their activities have been carried out successfully. Although the number of activities for each objective is finite, it is possible to create new ones using the "Clic" program (*clic.xtec.net/es/index.htm*), found on each one of the CDs.
– *Vectograms (www.promocionoptometrica.com*) are designed to improve binocular fixation through stimulation of positive and negative fusional vergences. They are made up of two transparent sheets, one bearing a green drawing and the other a red one. The idea is to place one sheet on top of the other and progressively increase their separation to introduce stronger and stronger lenses and increase the difficulty. For these exercises it is necessary to use anaglyphs.
– *Marsden's ball and Hart's cards* (*www.promocionoptometrica.com*). The objective of these materials is to improve ocular motility. In the case of the ball, the participant must follow different movements with the eyes, without moving the head. With the cards, the participant fixates on distant stimuli to increase peripheral vision.
– The *EEG Spectrum* (*www.neurocybernetics.com*) is made up of two pieces of equipment: one for the instructor and another for the trainee. The instructor monitors brainwave activity and sets the goals, wereas the participant observes the feedback via a game. As participants modify their activation levels, the instructor adapts the demand thresholds. At the end of each session a graph appears which summarizes the activation, anxiety and motivation levels obtained over the course of that session.

Intervention programme

The training was divided into three modules: computer language activities, visual therapy and stimulation of cortical activity. In the first module each participant carries out some 100 selective attention activities, at a rate of three per day, three days a week for three months. Each activity lasts about 7 minutes. All the activities are designed with the *Clic* program and organized by age and educational level, so that, as a whole, they constitute an activity bank with internal characteristics very similar to those of item banks. In the second module, participants train in their most deficient visual abilities. If the problem lies in control abilities they work on ocular motility (Marsden's ball and Hart's cards) and accommodation, for three minutes, three days a week over a three-month period; if the difficulty lies in recognition abilities, they work on fixation (vectograms). Finally, in the third model, each participant with sustained attention problems plays games on the *EEG spectrum* to increase cortical activation, for three minutes, three days per week over three months. When the intervention period is over, the assessment is carried out again with the instruments described so as to determine the effects of the programme. Despite the control group students' training being delayed in order to obtain a valid reference, in line with ethical considerations they were trained appropriately once the work with the experimental group was completed.

Hypotheses

Considering the nature of the intervention programme, and once it had been applied, the experimental group students were expected to improve: a) the mechanics of their reading (fewer lost lines, greater reading speed, fewer repetitions, inversions, confusions, hesitations, suppositions, omissions and additions, and less syllabification); b) central fixation and sensory fusion, eliminating stimulus recognition problems; c) quantity and quality of concentration, increasing total effectiveness of sustained attention and reducing the number of commissions; d) cortical activation, both in the central and left prefrontal cortices.

RESULTS

A) SELECTIVE ATTENTION

Reading errors

Table 1 shows the means and standard deviations for the variables related to reading errors that were assessed.

The multivariate contrasts corresponding to the *pre-test* measures show that there are statistically significant differences between the two groups, in general (λ= 0.751; $F_{10,72}$= 2.383; p=0.017; η^2= 0.249), and at a specific level in *hesitations* ($F_{1,81}$=6.412; p= 0.013; η^2= 0.073) and *syllabification* ($F_{1,81}$= 4.039; p= 0.048; η^2=0.047). Given that the groups are not homogeneous before the intervention, the analysis of the post-test differences was made taking the pre-test measures as covariates. This procedure permits us to obtain information about differences in the post-test taking into account the differences prior to the intervention.

As regards the analysis of the post-test differences, the results indicate statistically significant differences between the two groups of participants (λ= 0.394; $F_{10,73}$=11.236; p= 0.000; η^2= 0.606). Considering the dependent variables one by one, we observed that in all cases there were statistically significant differences, except for the variables *repetitions* and *hesitations*: [*line losses* ($F_{1,82}$= 46.900; p=0.000; η^2= 0.364), *reading speed* ($F_{1,82}$= 25.081; p= 0.000; η^2=0.234), *inversions* (F1,82= 17.025; p= 0.000; η^2= 0.172), *confusions* ($F_{1,82}$= 21.321; p= 0.000; η^2= 0.206), *suppositions* ($F_{1,82}$= 55.598; p= 0.000; η^2= 0.404), *omissions* ($F_{1,82}$= 10.647; p= 0.002; η^2= 0.115) *additions* ($F_{1,82}$= 8.857; p= 0.004; η^2= 0.097), *syllabification* ($F_{1,82}$= 14.385; p= 0.000; η^2= 0.149), *repetitions* ($F_{1,82}$= 2.337; p= 0.130; η^2= 0.028) and *hesitations* ($F_{1,82}$= 2.049; p= 0.156; η^2= 0.024). It should be pointed out that the differences, in all cases, are in the direction of supporting the effectiveness of the intervention programme. Thus, it is observed after the intervention that the experimental group, with respect to the control group, shows fewer losses of line, greater reading speed, fewer inversions, confusions, suppositions, omissions and additions, and less syllabification.

Table 1
Descriptive statistics of control and experimental groups corresponding to reading errors in the pre-test and post-test

	PRE-TEST				POST-TEST			
	Control Group		Experimental Group		Control Group		Experimental Group	
	M	SD	M	SD	M	SD	M	SD
Loss of line	0,94	0,76	1,1	1,01	0,86	0,75	0,04	0,28
Reading speed	77,77	44,84	97,16	51,05	87,89	46,2	139,64	62
Nº repetitions	2,74	3	2,32	2,96	2,08	2,68	1,29	2,19
Nº inversions	0,71	0,93	0,62	1,12	0,73	1,04	0,06	0,24
Nº confusions	1,49	1,58	1,56	1,63	1,46	1,69	0,22	0,51
Nº hesitations	1,29	3,06	2,9	3,3	1,49	3,68	0,59	1,21
Nº suppositions	1,71	1,5	1,52	2,05	2,68	1,86	0,49	0,68
Nº omissions	0,63	1,6	0,86	1,16	0,62	1,09	0,08	0,28
Nº additions	0,57	0,85	0,78	0,99	0,57	0,93	0,16	0,43
Syllabification	1,03	1,1	1,3	0,99	0,92	0,9	0,33	0,47

Visual abilities

Table 2 shows the means and standard deviations corresponding to the assessment of the visual abilities in the experimental and control groups, before and after the intervention.

Once more, the multivariate contrasts corresponding to the *pre-test* reveal statistically significant differences between the two groups at an overall level (λ= 0.638; $F_{7,23}$= 1.863; p= 0.123; η^2= 0.762), wereas at the specific level these differences are only found in the dependent variable *convergence* ($F_{1,29}$=6.750; p= 0.015; η^2= 0.189). Therefore, in this case we also carried out covariance analyses (with the pre-test measures as covariates).

The results obtained in the post-test reveal statistically significant differences between the students in the experimental and control groups (λ= 0.275; $F_{7,28}$= 10.526; p= 0.000; η^2=0.725). Considering the dependent variables one by one, we find statistically significant differences for *saccadic movement*, *fixation* and *Worth* ($F_{1,34}$= 30.943; p= 0.000; η^2=0.476), ($F_{1,34}$= 33.550; p= 0.000; η^2= 0.497) and ($F_{1,34}$= 6.417; p=0.016; η^2= 0.159). It should be pointed out that these differences are in the direction of supporting the effectiveness of the intervention programme applied. Thus, we find after the intervention that the experimental group, compared to the control group, shows an improvement in saccadic movement, fixation and Worth. In the case of the dependent variable D2 (TOT), although there are no statistically significant differences in the pre-test or in the post-test, when the pre-test score differences are taken as covariant, significant differences appear in the post-test ($F_{1,36}$= 51.552; p= 0.000; η^2= 0.589).

B) SUSTAINED ATTENTION

Cortical activation (Biocomp) and concentration (D2)

The means and standard deviations corresponding to these variables, for the experimental and control groups, in the pre-test and post-test, can be found in Table 3.

After examination of the pre-test scores, the corresponding multivariate contrasts indicate no statistically significant differences between the two groups, either at the general level (λ= 0.928; $F_{3,49}$= 1.259; p= 0.299; η^2= 0.072) or at the specific level. Therefore, we can assume that the two groups are homogeneous.

As regards the results obtained after the intervention, at a general level they reveal statistically significant differences between the two groups of participants (λ= 0.467; $F_{3,48}$=18.273; p= 0.000; η^2= 0.533). Considering the dependent variables one by one, it is observed that in all cases there are statistically significant differences [*Cz* ($F_{1,50}$= 30.851; p=0.000; η^2= 0.382), *Fp1* (F1,50= 22.751; p= 0.000; η^2= 0.313), *D2*$_{Con}$ ($F_{1,50}$= 28.194; p= 0.000; η^2= 0.361). It should also be pointed out that differences, in all cases, are in the direction of supporting the effectiveness of the intervention programme. Thus, it is observed after the intervention that the experimental group, with respect to the control group, shows greater central cortical activation (Cz) and left prefrontal activation (Fp1), and greater concentration capacity (*D2*$_{Con}$).

DISCUSSION AND CONCLUSIONS

Approaching attentional problems in an overall fashion is not an easy task. Therefore, this study is based on a model in which binocular fixation is taken as the axis of selective attention (Stein & Walsh, 1999; Stein, 2001) and cortical activation as the axis of sustained attention (Rossiter, 2004; Toomin, 2002). But the first problem considered was how to assess each of these areas with tests that were simple but at the same time sufficiently objective and easy to apply. The decision taken, in the case of selective attention, was to assess sensory binocular fusion through the Worth, to identify omissions and commissions through the *D2*, and to assess the general and applied functioning of visual control and recognition abilities through assessment with the *TALE* test. When visual abilities improve, fewer reading errors are committed (differences are observed with respect to the control group in inversions, confusions, suppositions, omissions, additions and syllabification), and this clearly has an influence on school performance. This change was significant in recognition abilities (fixation and sensory fusion), and its importance is evident in participants' performance of discrimination tasks of the D2 type, in which the differences are significant for both omissions and commissions.

Table 2
Descriptive statistics of control and experimental groups corresponding to visual abilities in the pre-test and post-test

	PRE-TEST				POST-TEST			
	Control Group		Experimental Group		Control Group		Experimental Group	
	M	SD	M	SD	M	SD	M	SD
Tracking	1,33	0,29	1,35	0,3	1,53	0,12	1,62	0,13
Saccadic movement	1,45	0,37	1,46	0,33	1,38	0,3	1,88	0,21
Accommodation	1,64	0,5	1,73	0,46	1,8	0,41	2,04	0,47
Fixation	1,93	0,16	1,99	0,21	1,68	0,15	1,92	0,12
D2TOT	50,73	28,72	39,54	23,39	51,87	27,79	68,13	24,3
Convergence	1,91	0,3	1,45	0,51	51,87	27,79	68,13	24,3
Worth	2,18	1,4	1,59	1,18	1,87	0,35	2	0

Table 3
Descriptive statistics, pre-test and post-test, for control group (GC) and experimental group (GE) corresponding to Biocomp and D2, in the sustained attention group.
EEG-A [Cz]= Central cortical activation; EEG-A [FP-1]= Left prefrontal activation; D2$_{Con}$= Concentration ability

	PRE-TEST				POST-TEST			
	Control Group		Experimental Group		Control Group		Experimental Group	
	M	SD	M	SD	M	SD	M	SD
EEG-A [Cz]	4,54	1,53	4,61	1,64	3,59	1,71	5,81	1,25
EEG-A [Fp1]	4,77	1,38	4,3	1,88	3,77	1,44	5,72	1,49
D2Con	49,91	24,62	40,18	24,3	44,77	23,19	75,84	21,51

The same did not occur in visual control abilities (tracking, convergence and accommodation), abilities which do not present statistically significant differences in the post-test, except for the case of saccadic movement. This may be due to the fact that the recordings used were qualitative (they do not take into account the dioptres of accommodation or convergence, nor the number of tracking losses) and/or the age range was very broad (students aged 5 to 17; would the results be the same working with primary school pupils, where reading deficits can be most crucial?). Future research should consider such questions, though in any case, in the present study the key to improvement appears to reside in the type of intervention carried out. In this regard, it is clear that the improvement of selective attention cannot be achieved with a training programme focused exclusively on the development of visual abilities; it is necessary in addition to employ specific activities and tasks (computerized adaptive tasks). This is why the experimental group students, compared to those in the control group, show greater effectiveness in total performance for the D2 test (TOT). It would be advantageous, furthermore, to make comparisons with teachers' observations (Amador, Forns, Guàrdia & Peiró, 2006), with a view to assessing the generalization of these changes within the school context.

As regards sustained attention, since the study is based on a model of cortical activation, the assessment system chosen is the beta/theta ratio (Biocomp) and its checking with the D2 (CON). This research line had already been begun in the 1980s, at the Biofeedback Institute of Los Angeles, with excellent results (Toomin, 2002). Such results are confirmed in this study not only from the assessment point of view (beta/theta ratio in Cz and Fp1 below 50%, as indicators of deficit), but also from that of intervention. Cortical activation improves not only with specific training (neurofeedback EEG), but also with specific activities and tasks, well adapted to the profile of each student and his or her effort level. When programming of tasks takes into account times and changes of activity, this is reflected in increased concentration. Moreover, continuous effort is an effective stimulant for increasing activation levels; hence the effectiveness of the computerized adaptive tasks.

The instruments Biocomp and D2 are both highly sensitive to this training package; in the case of the Biocomp the experimental group obtains significant differences in Cz and Fp1 with respect to the control group, and in that of the D2 the experimental group obtains significant differences in concentration with respect to the control group, total number of correct solutions is increased and errors are reduced. Thus, this could constitute an effective way of increasing attentional capacity and improving concentration quality. In any case, in order to draw more objective conclusions in this direction it would be necessary to undertake new research in which a longer period of concentration was demanded, since the monitoring of concentration with the D2 does not exceed 7 or 8 minutes. What would be needed is a more stringent test, such as the TOVA (Test of Variables of Attention; Greenberg, 1996), which assesses performance quantity and quality for over 20 minutes. It would also be necessary to take into account the type of sample chosen, focusing exclusively on secondary-school students, since this is the stage at which teachers detect the greatest attentional deficit.

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