ARTÍCULO ORIGINAL

Inhibitory Control And Symptomatology Of Attention Deficit Hyperactivity Disorder

El Control Inhibitorio y la Sintomatología Del Trastorno Por Déficit de Atención Con Hiperactividad

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Abstract

Background. Inhibitory control has been described as a factor causing difficulties in the regulation present in the ADHD. **Objective**. The aim was to analyze the relationship between inhibitory control and symptoms of ADHD in a sample of 81 subjects diagnosed with ADHD (*Mage*=10.05, *SD*=2.53). **Methods**. A quantitative, cross-sectional and correlational scope research was carried out. The instruments used were the ADHD RS IV and SIMON experiment. Correlation inferential statistical regression and regression processes were applied. **Results**. Three regression models were tested, where inhibitory control presents a significant prediction with the (a) attention deficit $F_{(1,79)}$=20.69, p=<.001, R^2=.21, (b) hyperactivity and impulsivity $F_{(1,79)}$=5.90, p=.01, R^2=.07 and (c) the combination of both (a+b) $F_{(1,79)}$=13.25, p=< .01, R^2=.14. **Conclusions**. The findings suggest that inhibitory control is one of the main executive functions that determines the degree of affectation of the symptomatology of the child population with ADHD.

Keywords: attention deficit, executive functions, hyperactivity, impulsivity, inhibitory control.

Resumen

Antecedentes. El control inhibitorio ha sido descrito como un factor causal que genera problemas de déficit de atención, impulsividad e hiperactividad que engloban la sintomatología del TDAH. **Objetivo**. El fin de esta investigación fue analizar la relación entre el control inhibitorio y los síntomas del TDAH en una muestra de 81 sujetos diagnosticados con TDAH (*Medad*=10.05, *DE*=2.53). **Método**. Se ejecutó una investigación cuantitativa, transversal y alcance correlacional. Los instrumentos utilizados fueron ADHD RS IV y el experimento SIMON. Se aplicaron procesos de análisis estadístico inferencial correlacional y regresión. **Resultados**. Tres modelos de regression fueron testeados, donde el control inhibitorio present una relación significativa, prediciendo (a) el déficit de atención $F_{(1,79)}$=20.69, p=<.001, R^2=.21, (b) hiperactividad e impulsividad $F_{(1,79)}$= 5.90, p=.01, R^2=.07 y (c) la combinación de ambos (a+b) $F_{(1,79)}$=13.25, p=< .01, R^2=.14. **Conclusiones**. Los hallazgos encontrados sugieren que el control inhibitorio es una de las funciones ejecutivas principales que determina el grado de afectación de la sintomatología de la población infantil con ADHD.

Palabras clave: déficit de atención, funciones ejecutivas funciones, hiperactividad, impulsividad, control inhibitorio.

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Introduction

Damasio,[1] Goldberg[2] and Lezak,[3] among others, have stated that executive functions are superior mental abilities of highest complexity for cognitive development, and among those, it is possible to find inhibitory control as one of the most important and determining functions for a human being to be able to have a behavior that fits social standards.

Inhibitory control has been described as an executive function that allows an individual to regulate consciously his or her behavior. This function has the capacity to control the presence of automatic or impulsive responses, to control interference and to stop automatic responses in progress and when this executive function is diminished it

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would produce a classic symptomatology present in attention deficit hyperactivity disorder – ADHD.[4]

The development of inhibitory control can be seen since early stages of human ontology. For example, a nine-month-old baby shows difficulties to inhibit previously learned responses. On the other hand, a twelve-month-old baby is already capable to suppress certain behaviors and change them into new responses. A three-year-old toddler is capable to inhibit instinctive responses. At the age of six, a child shows a better impulse control, which improves significantly by the time that he or she reaches nine. Nevertheless, at the beginning of his or her teen years, there seems to be a transition period where an increase of impulsivity is present.[5,6,7] In general terms, diverse authors stressed that, starting at the age of twelve, inhibitory control tends to be similar to the one a person will have as an adult.[8,9]

Several instruments and techniques are used to test inhibitory control, for example, computer experiments where an automatic response must be inhibited, such as experimental tasks Go/No-Go or SIMON, behavior observation scales, such as BRIEF scale and EFECO,[10,11] and classic neuropsychology tasks such as Stroop.[12]

A variety of studies have reported that, the existence of a deficit in inhibitory control would produce classic ADHD symptomatology, where presented signs and symptoms such as difficulties to control impulses, regulate attention processes, control emotions, high levels of impulsivity, difficulties to finish tasks, problems to follow directions, aggressive behavior, problems when interacting within educational or familiar environments, among other issues that constitutes ADHD as one of the most important neurodevelopmental disorders for the neuropsychology area.[13,14]

These empirical findings have led to state that inhibitory control is the central and most important executive function for the regulation of conscious behavior in ADHD.[4] However, the field of research of inhibitory control and the rest of executive functions is still in development. Other perspectives have been developed such as the one written by Brown[15] and Gioia et al.[11] who affirm that inhibitory control would not be the axis of executive control as it has been proposed by Barkley,[4] but, it will act at the same level as the rest of executive functions, supporting behavioral regulation and cognition.

As it has been described, it is theoretically hypothesized that inhibitory control deficit produces behavioral difficulties, and from this affirmation is raised the need to develop a research study where it is possible to analyze inhibitory control prediction over ADHD symptomatology.[16] In this sense, this study objective is to determine the level of prediction of inhibitory control over attention deficit hyperactivity disorder and impulsivity on a sample of students with ADHD.

Method

Participants

The study included 81 students who had a diagnosis of ADHD, this diagnosis was made once the psychologists working in the Student Counseling Department of each educational institute participating in this study detected some possible cases of ADHD and sent them to get a complete evaluation by a psychologist or psychiatric specialist outside the school and asked for the report confirming this condition and this data was kept in the health department of the institution. This sample was composed of 47 males (58%) and 34 females (42%). Participants' age was between six and fifteen years old (*Mage* = 10.05, SD = 2.53). Prospective participants were included if they met the following criteria: to have a diagnosis of ADHD combined subtype confirmed by the Student Counseling Department data and not be taking any pharmaceutical treatment at the moment of the study. Prospective participants were excluded if presenting any hearing, visual, motor or intellectual disabilities, having a diagnosis of neurodevelopmental disorders others than ADHD, taking medication for a cognitive or behavioral difficulty, being unwilling to participate in the research.

Measures

The questionnaire used for this research was the ADHD Rating Scale IV version for teachers,[17] which allows testing of three variables: (a) attention deficit measured with 9 items; (b) hyperactivity/impulsivity measured with 9 items; and (c) the total scale that combines attention deficit with hyperactivity/impulsivity measured with 18 items; these alignments are based on the current proposal of ADHD described in the DSM-5.[16] Prior research suggests that psychometric properties for the attention deficit scale is $\alpha = .95$ and for hyperactivity/impulsivity $\alpha = .94$.[18] The current study found an internal consistency of the subscale attention deficit (items 1-9) of $\alpha = .96$ and the correlation between its items was among $r = .68$ and .89. In the subscale of hyperactivity/impulsivity (items 10-18), the internal consistency was $\alpha = .96$, and the correlation between its items was $r = .59$ and .85. For the total ADHD subscale conformed by 18 items the internal consistency found was $\alpha = .97$ and the correlation between its items was $r = .66$ and .85. In every subscale it was not necessary to eliminate any item because Cronbach's Alpha coefficients did not get better when doing so, because of it, every item was used as the next analysis describes.

The SIMON experiment was used from the Psychology Experiment Building Language (PEBL),[19,26] which consists on a cognitive task to inhibit the tendency of a response.[20] Barkley[21] affirms that while performing this task, humans have the automatic tendency to respond to the hemifield in which a stimulus is present and when this response tendency stops, then, brain structures from the frontal lobe get activated allowing inhibitory control to act.

During the experiment, the screen shows a red circle (which must be clicked with the left hand) and a blue one (which triggers a response with the right hand), one at a time (see figure 1). Between the display of each circle, a cross is displayed (which disappears after 500ms. and then the next stimulus is shown) in the middle of the screen dividing it on a right and left hemifields. Once the blue or red circles are shown there is no time limit and the circle does not automatically disappear, unless the participant inputs an answer.

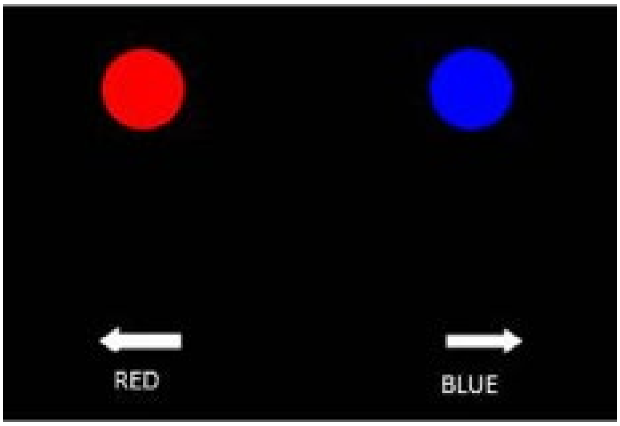

Figure 1. Screenshot of the experiment SIMON.[26]

During the task two types of trials are presented: (a) congruent trials, where the circle is displayed in its corresponding hemifield, blue circles are displayed on the right or red ones on the left side of the screen; and (b) incongruent trials, which display the circles on the wrong side of the screen to trigger the inhibition of a response, blue circles are displayed on the left and the subject needs to respond with the right hand, and where red ones are shown on the right hemifield and the right answer has to be pressed with the left hand. Congruent and incongruent stimuli are displayed on a 50/50 ratio.

Each test includes 140 trials displayed at random. In terms of position, where the circles are shown, each circle can be displayed on the right side of the screen (42%), left side (42%) or in the middle (16%) of the screen. Because of it, responses counted as errors of inhibitory control included the number of replies for which the participant did not inhibit the automatic response tendency; meaning that, when a blue circle was displayed on the left hemifield, the subject replied with his or her left hand instead of his or her right one; likewise when the red circle was displayed on the right side of the screen and the reply was done with the right hand instead of the left one. Throughout the experiments, mistakes were quantified as the number of errors when exposed to the stimuli for which inhibitory control needed to be executed.

Data Analyses

Statistics were run using the SPSS statistical software package version 20. The analyses started with a descriptive statistical procedure of the variables. The second step was to make a correlational analysis, and then, a linear regression using three models. For the first model, inhibitory control was set as the predicting variable (independent) and attention deficit as the criterion variable (dependent). The second model set the inhibitory control as the predicting variable and hyperactivity/impulsivity as the criteria variable. The third model, took the inhibitory control variable as the predicting variable and the combination of attention deficit with hyperactivity/ impulsivity as the criterion variable.

Procedure

Our research began with the approval of the Ethics and Research Committee of Concepcion University of Chile. Before beginning, permission to conduct the experiment was requested to educative authorities. Then, permission consent from the student's representative was required and a writing approval by the participant was asked as well. Once all the permissions where in order, the SIMON experiment was conducted. This process was performed individually and, in a distraction, free-setting. ADHD questionnaires were completed by the participant´s teachers. Once the database of the experiment and the questionnaires were built, the statistical analyses were run. The study was designed with a non-experimental, quantitative model, cross-sectional, correlational and with a causality reach through the application of predictive techniques to determine the causal impact of the inhibitory control over ADHD's symptomatology. It is important to mention that throughout the study all ethics standards related to human research declared in Helsinki were respected at all times.[22]

Results

Hypothesized Model 1

In the correlation analysis for the first hypothesized model, it was found that inhibitory control relates mildly $r = .46$, $p = < .001$ with the attention deficit variable. The linear regression found a significant prediction of inhibitory control over attention deficit $F_{(1,79)}$=20.69, p=< .001, R^2=.21.

Figure 2 shows a tested model with its respective regression typified coefficient. The resulting regression equation is $Y = B_0 + (B_1 * X)$, where $Y = 4.352 + (.487 * X)$. For this equation, bear in mind that X values corresponding to the independent variable and where the number of mistakes that took place during the SIMON experiment predicted the attention deficit score. For example, a student having 10 SIMON errors will obtain 9.22 points on the attention deficit scale.

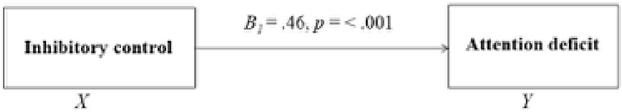

Figure 2. First model tested on the current research.

Hypothesized Model 2

The second tested model found a medium magnitude correlation between inhibitory control, and the hyperactivity/impulsivity variable r = .26, p = .01. The regression analysis found that the prediction of inhibitory control over hyperactivity/impulsivity is significant $F_{(1, 79)} = 5.90$, p = .01, R^2 = .07. Figure 3 shows a tested model with its corresponding regression typified coefficient. The resulting regression equation is Y = 5.346 + (.301 *X), which means that a student can present 8 SIMON experiment errors and obtain 7.75 points on the hyperactivity/impulsivity scale.

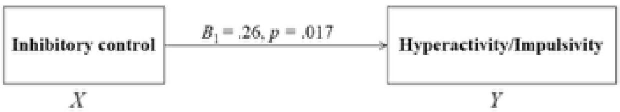

Figure 3. Second model tested on the current research.

Hypothesized Model 3

The third model also found a medium correlation between the inhibitory control variable and the combined variable of attention deficit with hyperactivity/impulsivity r= .38, p= < .001. The regression analysis found a significant prediction of inhibitory control over the attention deficit with hyperactivity/impulsivity variable $F_{(1, 79)}$=13.25, p = < .01, $R2$ = .14. Figure 4 shows this tested model. The regression equation has the following data Y = 9.70 + (.79*X), which means that if a student has 3 mistakes on the SIMON experiment, he will obtain 12.07 points on the total combined scale of attention deficit with hyperactivity/impulsivity.

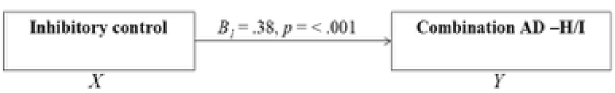

Figure 4. Third model tested on the current research.

Discussion

This research aimed to analyze the prediction of inhibitory control on attention deficit and hyperactivity/impulsivity on a sample of students diagnosed with ADHD.

The correlation coefficients allowed to state that there is a directly proportional relationship between the studied variables. This means that, while higher the number of mistakes on inhibitory control, greater the score will be obtained for the scale of attention deficit, hyperactivity/impulsivity and the combination of both.

Furthermore, these findings show that inhibitory control is a predicting variable for behavioral factors described above. For the attention deficit prediction, it was found that inhibitory control explains 21% of its variance, while hyperactivity/impulsivity it predicts 7% of its variance, and for the prediction of the combined variable of attention deficit with hyperactivity/impulsivity, inhibitory control explains 14% of its variance. Based on these results, it is possible to conclude that even when inhibitory control is a causing factor of hyperactivity/impulsivity and attention deficit on students presenting ADHD, there are other etiological factors that would explain the rest of the variance percentage of ADHD symptomatology.

Data found on this study is related to those found by Barkley,[4,27] who stated that a deficit of inhibitory control is the principal cause of general executive functioning and alterations in behavioral regulation present on ADHD (impulsiveness, excessive motor activity, difficulty in responding to behavioral norms, etc.).

Additionally, the obtained results may be contrasted with prior findings reported,[23] there are reports with which the results from this study could be contrasted, because previous studies[24,25] have reported that attention deficit would not be related with inhibitory control of patients diagnosed with ADHD inattentive subtype, however, the results of the present research suggest that the attention deficit component would be related to a deficit of inhibitory control that is present on ADHD combined subtype patients.

There are multiple reasons that can explain this lack of agreement, reasons that could be related to the sample and instruments applied, but it is also possible as stated by Howard et al.[8] that the inhibitory control construct can take different forms, and, at the same time, these forms may imply a relationship with other behavior or cognitive variables. Nevertheless, to own judgment, this data shows a strong relationship among inhibitory control and attention deficit; which leads thinking that, in a clinical and scholar contexts, inhibitory control would be an important factor to take into consideration in the intervention with ADHD combined subtype patients, to develop adequate abilities to regulate their cognition and behavior.

For clinical practice, findings of the current research have an interesting contribution since they present a regression equation that allows identifying how the number of inhibitory control mistakes can predict attention deficit and hyperactivity/impulsivity of students with ADHD. In this way, treatment of students presenting the above-mentioned behavioral issues must be focused on the inhibitory control intervention; it could be possible to measure the efficacy of the intervention in the reduction of mistakes on inhibitory control and through a mathematical calculation of regression equation could be predicted the reduction of ADHD behavioral symptomatology.

As a limiting factor, it must be reported that, the students with ADHD combined subtype of this study belong to determined city of South America, which must be consider at the moment of the interpretation of the data, however, the characteristics of the country where this study took place, leads for the favorable and possible use of these results and conclusions in other similar contexts.

Finally, as additional research line to be developed in future from this study is to execute experimental type investigations where it would be possible to improve the performance of control inhibition in patients with and without an ADHD diagnosis and to analyze its impact on attention deficit, hyperactivity and impulsivity symptomatology present in this neurodevelopmental disorder.

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