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Corrective Feedback Makes a Difference in Preadolescents with ADHD: A Pilot Study in Basic Cognitive Tasks

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ABSTRACT

The literature has shown that preadolescents with ADHD might benefit from specific actions such as the presence of corrective feedback during a task. In order to examine these effects, a sample of preadolescents was selected and divided into two groups: a control group and a target group with ADHD. Participants had to perform a decision-making task, with a counterbalanced design, presented in blocks with and without corrective feedback. Two different analysis procedures were carried out: the traditional student's t-test and an ex-Gaussian fit. The reaction times were much lower for in the feedback block than in the control blocks, as well as in the control group than in the adolescents with ADHD. The difference in feedback reached or approached a statistically significant level, however, the difference between the control and ADHD group did not show statistical significance (except for accuracy under feedback condition). In terms of component distribution analysis, a specific parameter, named τ, was much lower for the feedback condition and for the control group.

Keywords: ADHD; corrective feedback; distribution components.

RESUMO – *Feedback* Corretivo em Pré-Adolescentes com TDAH: Um Estudo Piloto em Tarefas Cognitivas Básicas

Pré-adolescentes com TDAH podem se beneficiar com *feedback* corretivo durante uma tarefa. Para examinar esses efeitos, selecionou-se uma amostra de pré-adolescentes dividida em dois grupos: um controle e um experimental com TDAH. Os participantes realizaram uma tarefa de tomada de decisão com e sem *feedback* corretivo. Dois procedimentos de análise foram realizados: o teste *t* de Student e um modelo gaussiano. Os tempos de reação foram menores para o grupo que recebeu o *feedback* corretivo, bem como para o grupo de adolescentes com TDAH. A diferença no *feedback* atingiu o nível estatístico ou se aproximou dele, porém a diferença entre o grupo controle e de pré-adolescentes com TDAH não atingiu a significância estatística (exceto para a precisão na condição *feedback*). Quanto à análise de distribuição de componentes, o parâmetro τ foi muito inferior para a condição de *feedback* e para o grupo controle.

Palavras-chave: TDAH; retroalimentação corretiva; distribuição de componentes.

RESUMEN – La Retroalimentación Correctiva Marca la Diferencia en Preadolescentes con TDAH: Un Estudio Piloto Sobre Tareas Cognitivas Básicas

Preadolescentes con TDAH pueden beneficiarse de variables específicas, como la retroalimentación correctiva durante una tarea. Se seleccionó una muestra de preadolescentes dividida en dos grupos para examinar estos efectos. Los participantes realizaron una tarea de toma de decisiones, presentado en bloques con y sin retroalimentación correctiva. Se llevaron a cabo dos procedimientos de análisis diferentes: la prueba *t* de Student y un modelo gaussiano. Los tiempos de reacción fueron más bajos para el bloque con retroalimentación correctiva, así como para el grupo de adolescentes con TDAH. La diferencia en la retroalimentación alcanzó o se acercó al nivel estadístico, pero la diferencia entre el grupo de control y los preadolescentes con TDAH no alcanzó la significación estadística (excepto por la precisión en la condición de retroalimentación). En términos del análisis de distribución de componentes, un parámetro τ fue menor para los grupos de retroalimentación y control.

Palabras clave: TDAH; retroalimentación correctiva; distribución de componentes.

Attention Deficit/Hyperactivity Disorder (ADHD) has raised interest in the scientific community in the last decade. One spread model that tries to understand this disorder was developed by Barkley in 1998. The author denominated it "Hybrid Model of Executive Functions" and it emphasizes the role of self-control and executive functions on attentional demands. In particular, the model stipulates four executive functions that appear to be related to the performance of teenagers with ADHD: working memory, self-directed speech, motivation/emotion regulation and alertness, and reconstitution process (which consists of two threads: the fragmentation of the observed behaviours, and the ability to command parts differently). Furthermore, according to this model, ADHD is a disorder characterized by a deficit in inhibition and functioning of the executive functions (Barkley, 2001). In this way, normal adolescence is a intricate period of life, where inappropriate risk-taking and novelty seeking might

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appear. These could be even more complex for students with ADHD, who often show self-regulatory problems (Brocki et al., 2019; Burnette et al., 2020; Rosello et al., 2020) and they might also disperse relatively easily. It is commonly said that they find it hard to maintain focus, usually have limited resources to select and process relevant information, and moreover, they have difficulties in following rules and instructions. Consequently, they find it difficult to organize themselves to achieve objectives or plan tasks and strategies. Moreover, they often show low intrinsic motivation, among other conditions, which hinders their proper development within the classroom (Boot et al., 2020; Miranda, 2011).

For everything mentioned previously, the students with ADHD have special educational needs, to be covered. For example, some behaviour strategies in the classroom are recommendable, e.g. reinforcement and punishment. These might establish or increase appropriate behaviours, as well as reduce or eliminate inappropriate behaviour. Focusing on these variables, a useful tool might be the presence of feedback. According to the traditional Bandura's theory (1982), the feedback that a child receives modifies their self, and affects their motivation. However, this only might occur when the feedback that is provided is informative (non-punitive), thus enhancing intrinsic motivation (Romero Ayuso, 2006; Sato, & Loewen, 2018). Another interesting effect of the feedback is that it helps to guide future actions, and thereby can reduce errors in the future.

Under the variables of interest, the informational component that corrective feedback has provides information about the action that takes place (Fernández-Abuín, 2005). According to the above theoretical framework, it is expected that the completion of tasks with feedback in children and adolescents with ADHD could provide better results than performing the same task without feedback. With regards to this point, the variables most used in laboratory tasks employ reaction times and percentage of errors or successes. This first variable, the reaction times (RT), usually has a high sensitivity to a cognitive process, so it is not surprising that it has been used widely in cognitive science as a variable star. However, the RT is often characterized by a large positive asymmetry which hinders their analysis (Navarro-Pardo et al., 2013).

On this point, we have selected an ex-Gaussian fit, which might provide very accurate distribution of RT adjustments (Balota, & Spieler, 1999). This function is the convolution of two processes: a normal Gaussian function and an exponential function. An ex-Gaussian fit can be performed through three parameters μ, σ and τ, since the Gaussian distribution can be represented by the parameters μ and σ (corresponding to the mean and standard deviation of the Gaussian component, respectively), whereas the exponential distribution for the τ parameter (which corresponds to the trend). The most important point about the ex-Gaussian function may be that the different parameters described could be related to underlying cognitive processes. Leth-Steensen et al. (2000) found that children with ADHD differed from controls in the parameter τ. Thus, it is not surprising that this parameter has been related to attentional processes. In the previously mentioned study, the authors report significant differences in τ. Even if similar results have been found under the presence of corrective feedback in University students, caution is advised in the parameter interpretation (Moret-Tatay et al., 2016).

The general objective of this research is to examine the differences between a group of preadolescents with ADHD and a control group in terms of distribution components or processing (particularly in the parameter τ). We have chosen the preadolescence as a critical time in development for ADHD. On the other hand, the specific objective is to evaluate the effects of the informational feedback applied immediately after the participant's performance.

Method

Participants

A sample of 12 secondary school students from a private school was selected. Six of the subjects who took part in this investigation were diagnosed with ADHD. The ages of the students were between 12 and 14 years. The group without ADHD diagnosis (control group) consisted of 3 males and 3 females (mean age = 13.17, *SD*=1.47), and the ADHD group of 4 boys and 2 girls (mean age = 13.67, *SD*=1.63). All students participated voluntarily (after prior approval of the institution) and received an unexpected reward for their participation at the end of the experiment.

The exclusion criteria used for the control group were: the presence of any disorder or mental illness, learning difficulties, low IQ, complicated family situation, existence of academic and behavioural problems within the school or any problems that might interfere with the test. The variable age was the main inclusion criterion. Moreover, in the ADHD case group, participants had to be diagnosed with ADHD (under medical criteria). All participants with ADHD are medicated and undergoing treatment.

Materials

The presentation of stimuli and recording of response times were controlled by a Windows operating system through the DMDX software (Forster, & Forster, 2003). The test consisted of the appearance of different stimuli, which were red or blue geometric figures, in the centre of the screen, appearing randomly. The test consisted of two parts: one part without feedback (control condition) and the other part with feedback (target condition). The experiment consisted of the random presentation of 112 stimuli (56 corresponding to red, and 56 corresponding to blue, all of them in the form of

different geometric figures). Each image was presented until the participant issued a response with a maximum of 2000 ms.

Participants were instructed to press a button (labelled "Yes") to indicate that the presented stimulus was red, and press another button (labelled "No") if the stimulus presented was blue. Participants were instructed to respond as quickly as possible while maintaining a reasonable level of accuracy. The session lasted approximately 20 minutes.

Design

For the analysis of the results and hypothesis testing, research features 2 independent variables and 2 dependent variables. The independent variables are, on the one hand, the absence or presence of feedback, and on the other hand, the presence or absence of ADHD in participants. The dependent variables are reaction times and accuracy. To avoid bias, such as fatigue, each block of the test was switched over. The counterbalancing technique is based on the existence of a linear relationship between progressive error and the order of each experimental condition within the sequence. By changing the task order for each group, we try to control the order presentation effect.

Procedure

To not to have any distractions, such as noise, the test was administered in an isolated room, where participants entered individually. To perform the test, only the laptop, a table, a chair and the person responsible for implementing it were included. The instructions given to participants in the part without feedback were: "In the centre of the screen different geometric figures will appear, either red or blue; if it is red you must press the "M" key and press the "Z" key for blue. You should try to answer as quickly as you can, but not so fast as to make mistakes.

For the feedback part the instructions were: "In the centre of the screen different geometric figures will appear, either red or blue; you must press the "M" key for red, and the "Z" key for blue. You should try to answer as quickly as you can, but not so fast as to make mistakes. Each time you give your answer, the word "Error" or "Correct" will appear under the picture, as applicable. If a correct answer is given, the number of milliseconds taken to answer will appear." After a brief practice session of 16 trials in each block, once there is evidence that the subject has understood the task, they are invited to start the first part of the test (with or without feedback, depending on the case). Once this is finished, the second instructions are given, the participant is invited to start with the second part.

Data Analysis

Two types of data analysis were carried out. Firstly, a classic analysis by intra student t-test and between groups. This analysis was performed under a previous cut-off data technique, as is usually done in the literature. These statistical analyses were performed using the statistical software SPSS version 20.

In a second instance, we chose an alternative strategy, as was indicated in the introduction: the adjustment of empirical data into an ex-Gaussian distribution. This allowed us to use all the scores (unlike the classical analysis where a cut-off or cut technique of data was performed, as discussed above). Both fit distributions like these graphics were made through exGUtils, specific statistical module developed in Python language (Moret-Tatay et al., 2018).

The goodness of fit was examined through the residual variance (the most used method in behavioural sciences that is χ^2), ie, through the parameters exGUtils provides for each setting and its respective χ^2/gl ratio, which indicates optimal values when it is less than 2. Unfortunately, exGUtils doesn´t offer a graphical environment, so the graphics were developed in GNUplot 4.6.

Ethics

The experimental studies were carried out in accordance with the Declaration of Helsinki and approved by the centre committee (*PRUCV2015630*). The parents of participants gave written consent to participate in the study.

Results

Table 1 shows the average reaction times, and as expected, reaction times were lower in the presence of feedback blocks.

Prior to the analysis, a cut-off of lower response times of 250 ms and above 1500 ms is performed. This cut-off was adopted for consistency with earlier studies in the field (Moret-Tatay & Perea, 2011; Perea et al., 2011). In addition, incorrect responses were excluded from the first analysis.

In figure I, we can observe the box and whisker plot of both groups in both conditions, with the presence of feedback and no feedback; these results are useful in terms of measures of central tendency and amplitude. In the first place, classical analyses between groups and within-subjects through the student t test were performed. Thus, first the differences between the control group and the case (ADHD) group were analysed. In the statistical analysis, the assumption of homogeneity of variance, applying the Levene test ($p>0.05$) was fulfilled. However, no statistically significant differences were found in terms of reaction times and percentage of correct answers, except for errors in the presence of feedback condition: $t_{(10)}=3.01$; $p<.05$.

With regards to differences versus controls blocks and blocks with presence of feedback, we found that these reached the level of statistical significance for the group case (ADHD): $t_{(5)}=4.41$, $p<0.01$. Control group

was around statistical significance; $p=.06$. As for the hit rate, there were no statistically significant differences for ADHD group, but for the control group there was a statistical significance: $t_{(5)}=3.87$; $p<.05$.

As we mentioned in the introduction, we proceeded to characterize the reaction times by an ex-Gaussian fit. Table 2 shows the different parameters obtained by fitting into an ex-Gaussian and, in Figure 1 representing the different conditions (data adjustment made to fit each group and condition) is shown.

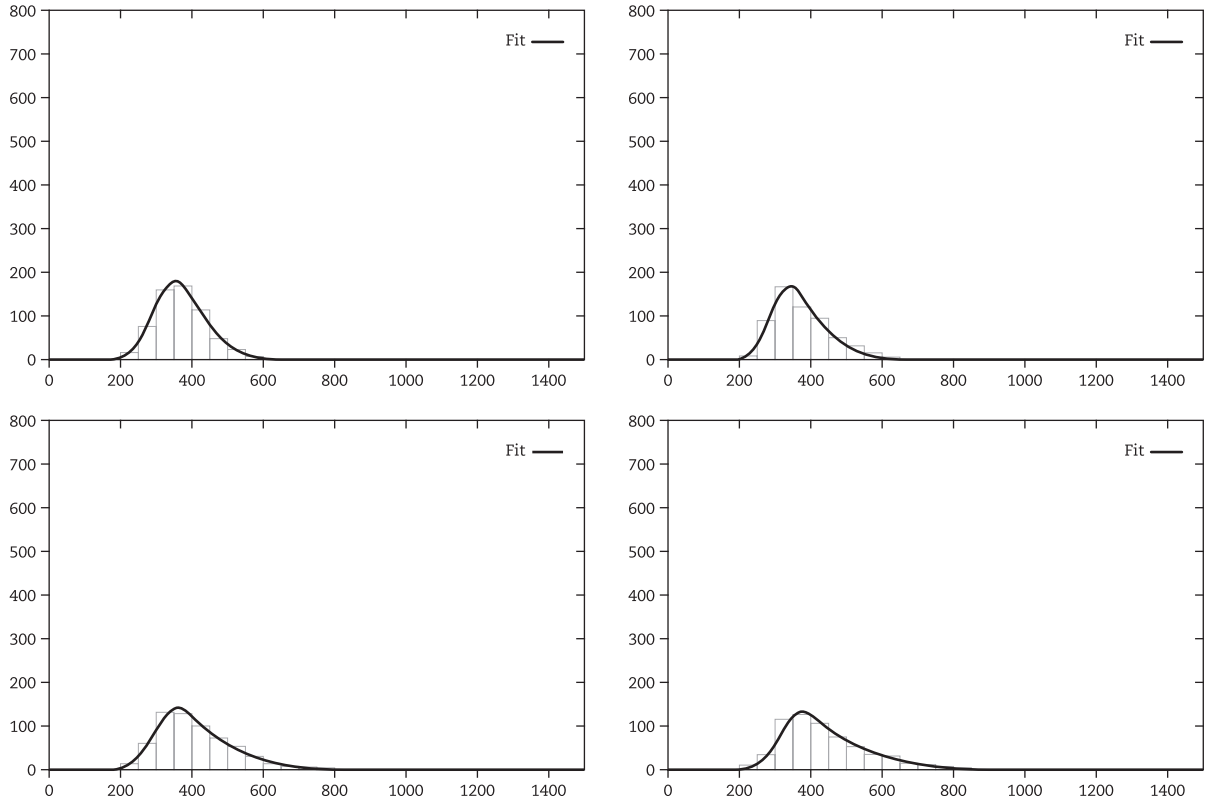
Table 1
Averages, Standard Deviation and Percentage of Correct Answers for Each Group (Case and Control) in the Different Experimental Conditions (Presence and Absence of Feedback)

Group	Condition	Averages	SD	%Correct
ADHD	Control	456.40	83.87	96%
	Feedback	386.18	54.49	94%
Control	Control	432.23	66.66	97%
	Feedback	389.42	33.63	97%

Table 2
Parameters Obtained by Fitting Data into an ex-Gaussian Function (μ, τ and σ) Freedom Degrees (fd) and Goodness of Fit (χ^2/fd) for Each Group (Case and Control) in the Different Experimental Conditions (with Presence and Absence of Feedback)

Group	Condition	μ	σ	τ	*fd*	χ^2/fd
ADHD	Control	314.79 ± 3.80	45.41 ± 3.28	137.72 ± 5.55	16	0.53
	Feedback	291.68 ± 5.59	41.48 ± 4.37	87.85 ± 6.73	12	1.65
Control	Control	301.77 ± 5.37	48.13 ± 4.54	119.75 ± 7.49	14	1.01
	Feedback	309.57 ± 4.67	50.94 ± 3.09	67.40 ± 5.18	15	0.84

Figure 1
Fit Into an ex-Gaussian Function in Order to the Different Experimental Conditions and Groups. Above: Feedback Condition. Bottom: Control Condition (No Feedback). Right: Case Group (ADHD). Left: Control Group



With regards to the hypothesis about the differences between the control group and ADHD group, in Table 3, we note differences in the average of the distribution and the τ parameter (e.g., feedback vs. control group vs group data event control) are higher than the sum of the uncertainties.

Finally, with regards to the hypothesis on the effect of feedback, in Table 4, we note differences in the average of the distribution and the parameter τ, are higher than the sum of the uncertainties (except for the average distribution in the feedback condition).

Table 3
Differences between ADHD Group and Control Group Averaged Distribution (μ + τ) and τ Parameter . Between Parenthesis Uncertainties Summatory

Group	Condition	Differences in μ*	Differences in τ
ADHD	Control vs *Feedback* (Σ uncertainties)	72.98 (21.67)	49.87 (12.28)
Control	Control vs *Feedback* (Σ uncertainties)	44.55 (22.71)	52.35 (12.67)

*(μ+ τ)

Table 4
Differences between the Control Condition and Status Feedback Averaged Distribution (μ + τ) and τ Parameter. Between Parenthesis Uncertainties Summatory

Condition	Grupo	Diferences in μ*	Diferences in τ
Control	Control vs ADHD (Σ uncertainties)	30.99 (22.21)	17.97 (13.04)
Feedback	Control vs ADHD (Σ uncertainties)	2.56 (22.17)	20.45 (11.91)

*(μ+ τ)

Discussion and Conclusion

The aim of this study was to examine the differences between teenagers with ADHD (target group) and teenagers without ADHD (control group) in terms of processing components (particularly in the τ parameter). Moreover, the specific aim was to assess the effects of the informational feedback on the performance of both groups, applied immediately after the action. For this, a sample of 6 secondary students diagnosed with ADHD compared to a sample of 6 students without ADHD, were selected. The task was to press a key or another depending on the stimulus (geometric figure) they saw on the screen, receiving, or not, feedback following its decision. Reaction times and percentage of correct answers in all conditions were measured. We observed, firstly, that the difference between the blocks with feedback and controls was greater than the sum of their uncertainties, both for control children, and children with ADHD in the middle of the distribution ex-Gaussian ($\mu + \tau$) and τ component. As for the differences between the control and group of children diagnosed with ADHD, these were greater than the sum of the uncertainties in both the mean ex-Gaussian distribution ($\mu + \tau$), and for τ component, except the mean of the distribution in the condition with feedback.

As for the results, no statistically significant differences between the control children and the group of children diagnosed with ADHD (in terms of reaction times, or percentage of hits were found except for the errors in the condition with presence of feedback). Moreover, with regards to the differences of the controls blocks against the blocks with the presence of feedback, we found statistically significant differences in reaction times in the case group, and statistical significance was around in the control group. The differences in the hit rate only reached statistical significance for the control group.

This study shows evidence for the effect of feedback in terms of processing parameters. As we could observe in the results section, differences were found, although the control was around the statistical significance. These differences are supported in the literature (Moret-Tatay et al., 2015, 2016).

The fact that differences in the control group did not reach the level could be due to a problem of statistical power, however, remember that for the purpose of eliminating noise in the analysis (since the mean is very sensitive to extremes), a technique of data trimming (cut-off) was performed. The innovative nature of this work is to develop an analysis component, through the fit to an ex-Gaussian distribution. Bear in mind that in

the literature, one of the ex-Gaussian distribution parameters (Leth-Steensen et al., 2000; Navarro-Pardo et al., 2013), the parameter τ, could be related to executive functions. Therefore, higher values of this parameter would present a worse performance. At this point, we observed, as in the work of Leth-Steensen et al. (2000), that children controls showed lower values in these parameters compared to children with ADHD. This same pattern was found for the presence of feedback blocks, compared to the absence thereof. Ultimately, this shows an argument for the theory of Kluger and DeNisi (1996), which proposes that the feedback improves attentional focus, as shown by the differences in the τ parameter. Furthermore, these findings support the recommendations of Miranda (2011) on the importance of self-regulation instruction for children with ADHD.

The implications of this type of study are clear and visible. The parameterization of the children's responses could be a very useful tool in the implementation of the diagnosis of ADHD, as well as cognitive stimulation programs. However, more research on the ecological validity of these emerging lines of research is needed (Smith et al., 2020). In addition to the aforementioned, this research is a case for the techniques used to determine reaction times. This allows us to obtain parameters that facilitate the analysis and at the same time, supports the inclusion of all data collected during the investigation (without which any information that may be valuable for obtaining results is lost). It is important to note that the classical techniques of analysis of variance are influenced by the presence of outliers. For future research, it would be interesting to develop a series of experiments to evaluate the τ parameter in other stimuli and situations. Moreover, the possibility of using other types of feedback, to thereby learn more about how to benefit from its application to school-age children, especially those with a diagnosis of ADHD, would be of interest.

Definitely, we believe that it would be interesting to extend the sample size of the present study, as in this way the statistical significance of the application of feedback on task performance could be observed more strongly, not only in the case group, but also in the control group. The sample size (6 subjects with ADHD and 6 subjects without ADHD) is one of the limitations that can be observed in this investigation. Likewise, it would be interesting to replicate this study in children with ADHD who are not under the influence of medication at the time of testing, as we have seen that medication can make them more attentive, although we are not sure that they become less impulsive when making a decision to a given stimulus. In fact, this would explain the difference found between the case and control group regarding the number of errors made on the feedback condition.

Finally, it would be of great interest to study the differences between ADHD subtypes (inattentive, hyperactive and combined) for future research in this area. However, in the literature reviewed this separation has not been made as such. It is relevant to mention that the ADHD group showed a lower tolerance for frustration (when wrong) and greater anxiety about making mistakes and doing it wrong, causing very obviously a greater source of stress than the case group. This variable was not recorded during this study, but we believe it could also be a factor to consider in future research, and could even become one of the most important variables.

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Author contributions

We declare that all authors participated in the preparation of the manuscript. Specifically, authors Carmen Moret-Tatay and Edurne Iniesta-Cristobal participated in the initial writing of the study – conceptualization, investigation, visualization, authors Carmen Moret-Tatay and Edurne Iniesta-Cristobal participated in the data analysis, and authors Carmen Moret-Tatay and Edurne Iniesta-Cristobal participated in the final writing of the work – proofreading and editing.

Availability of data and materials

All data and syntax generated and analyzed during this research will be treated with complete confidentiality due to the requirements of the Ethics Committee for Research in Human Beings. However, the dataset and syntax that support the conclusions of this article are available upon reasonable request to the main author of the study.

Conflict of interests

The authors declare that there are no conflicts of interest.

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