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The components of attention and cognitive flexibility in juvenile delinquents

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Abstract

Objective: *The objective of this study was to analyze the components of attention and the cognitive flexibility of juvenile delinquents.* **Methods:** *These processes were assessed through a continuous performance task and the Wisconsin Card Sorting Test in three groups (n = 29 each) of males (17.46 ± 1.60 years old): a juvenile delinquent inmate group (JDG), an age-paired group (APG), and an age- and education-paired group (AEPG), since juvenile delinquents had an average of 7.5 years of education. Family violence, Attention Deficit Hyperactivity Disorder (ADHD) symptoms, drug use, and socioeconomic status (SES) were also recorded through questionnaires.* **Results:** *Juvenile delinquents, compared to non-delinquents, had less correct responses on tonic alertness, the capacity to respond to stimuli in general. The JDG reported more family violence and more ADHD symptoms than non-delinquents. Low-education groups (JDG, AEPG) had less correct responses in the other components of attention, and more perseverative responses (index of cognitive flexibility), as well as lower SES and more drug use compared to the APG. Such deficits in cognitive performance seem to relate to education, not legal status.* **Conclusions:** *Juvenile delinquents have deficits in tonic alertness, a basic component of attention that could impact their school and work performance, which had never been reported in this population before; they also experience more family violence and report more ADHD symptoms.*

Keywords: *Juvenile delinquents. Adolescents. Executive functions. Attention.*

Los componentes de la atención y la flexibilidad cognoscitiva en delincuentes juveniles

Resumen

Objetivo: *El objetivo de este estudio fue analizar los componentes de la atención y la flexibilidad cognoscitiva de un grupo de delincuentes juveniles.* **Métodos:** *Estos procesos fueron evaluados mediante una Tarea de ejecución continua (TEC) y el Test de Acomodo de Tarjetas de Wisconsin en tres grupos (n = 29) de varones (17.46 ± 1.60 años): un grupo de delincuentes juveniles (GDJ), un grupo apareado por edad (GAE) y un grupo apareado por edad y escolaridad (GAEE), ya que los delincuentes juveniles tenían en promedio 7.5 años de educación. La violencia familiar, los síntomas de TDAH, el uso de drogas y el estrato socioeconómico también fueron registrados a través de cuestionarios.* **Resultados:** *Los delincuentes juveniles comparados a los no-delincuentes tenían menos respuestas en alerta tónica, la capacidad de responder a estímulos en general. El GDJ reportó más violencia familiar y más síntomas de TDAH que los no-delincuentes. Los grupos de baja*

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escolaridad (GDJ y GAEE) tenían menos respuestas correctas en los otros componentes de la atención y más respuestas perseverativas (índice de flexibilidad cognitiva), así como un menor estrato socioeconómico y más uso de drogas comparados al GAEE. Estos déficits en ejecución cognitiva parecen relacionarse a la educación, no al estatus legal. **Conclusiones:** *Los delincuentes juveniles tienen déficits en alerta tónica, un componente básico de la atención que podría impactar su ejecución en la escuela o el trabajo, lo cual nunca había sido reportado en esta población antes; además experimentan más violencia familiar y reportan más síntomas de TDAH.*

Palabras clave: *Delincuentes juveniles. Adolescentes. Funciones ejecutivas. Atención.*

Introduction

Juvenile delinquency is a serious problem in Mexico[1], where ten thousand minors are incarcerated annually for serious crimes, such as homicide, kidnapping, and sexual offenses[2,3]. These adolescents report low education, high drug use, exposure to violence, and a high prevalence of Attention Deficit Hyperactivity Disorder (ADHD)[4,5], which are risk factors for prefrontal cortex developmental delay. This delay manifests as deficits in attention and executive functions[6-8] and is related to academic difficulties and school dropout[9,10].

Attention is better defined by its four components. Tonic alertness is the capacity to respond to general stimuli. Phasic alertness is the increased capacity to respond after a warning. Selective attention is the capacity to give specific responses to specific stimuli. Sustained attention is the capacity to maintain the same level of response during prolonged periods[11,12]. There are no studies on the analysis of tonic or phasic alertness of juvenile delinquents. Only a few studies have used neuropsychological tasks to analyze selective and sustained attention in juvenile delinquents, and those studies did find deficits in these components[13-15].

Cognitive flexibility, a component of executive functions, is the capacity to adjust behavior to changes in the environment[16]. Juvenile delinquents are reported to have lower cognitive flexibility compared to control groups paired by age, race, sex, and socioeconomic status (SES)[14,17,18]. Nevertheless, none of the studies that report cognitive deficits in juvenile delinquents controlled for education; therefore, it is not clear if the deficits found in the components of attention or in cognitive flexibility are related to their legal status or to their low education.

Therefore, the objective of this study was to analyze the components of attention and cognitive flexibility in juvenile delinquents, controlling age and education. Prefrontal developmental delay risk factors, such as family violence, ADHD symptoms, low SES, and drug use, were also analyzed.

Methods

This study is a transversal non-experimental design with human participants. Its procedures were all in line with the principles of the Helsinki Declaration.

Participants

Eighty-seven male adolescents of 17.87 ± 1.54 years of age (mean ± standard deviation) participated; all resided in the state of Nuevo León, México. Participants were excluded for auditory or visual impairments, risk of severe brain damage, and for being under medication that influences neuropsychological assessment. All participants interned in the institution were invited without exception, and those who accepted were included. The controls were looked for based on the particular characteristics of the juvenile delinquents; therefore, it was a non-probabilistic sample, and the final sample consisted of those who agreed to participate voluntarily.

There were three groups of participants (n = 29 each group), the juvenile delinquent group (JDG), recruited at a detention facility for adolescents who committed serious crimes (homicide, sexual assault, kidnapping). These participants had dropped out of school before their arrest and therefore had low education (7.55 ± 1.37 years of education) for their age (17.97 ± 1.64 years) (Table 1). The age-paired group (APG) was recruited at high schools and universities; each participant was paired by age with a participant from the JDG; this group had the highest education possible for their age (11.10 ± 1.26 years). The age- and education-paired group (AEPG) was recruited at technical training institutes and night-shift schools to find low-education adolescents and pair them with a participant from the JDG of the same age and years of education (Table 1). The APG and the AEPG cannot be considered as one group divided in two because, to have a group of low education non-delinquents, it was necessary to look for them in particular spaces, therefore they derive form radically

Table 1. Age, education, and drug use in the juvenile delinquent group (JDG), the age-paired group (APG), and the age- and education-paired group (AEPG)

Variables	JDG (n = 29)	APG (n = 29)	AEPG (n = 29)	*Statistical test*	*JDG vs AEPG*	*JDG vs APG*	*AEPG vs APG*
				F			
Age in years[a] Mean (SD)	17.97 (1.64)	17.89 (1.41)	17.80 (1.67)	0.13			
Years of education[b] Mean (SD)	7.55 (1.37)	11.10 (1.26)	8.7 (1.39)	59.64***	–2.66	–2.66***	–2.27***
SES score	14.00 (1.64)	31.72 (12.56)	20.38 (12.44)	16.39***	–1.56	–1.56***	–0.91**
				χ^2			
Number of reported drug users[c]	18	6	11	10.70**			

Age and education values are shown as mean (standard deviation).
*p < 0.05.
**p < 0.01.
***p < 0.001.
[a]Comparisons were made with repeated measures analysis of variance. The values in the post hoc comparisons are Cohen's d effect size with the significance of the Tukey's test.
[b]Range: 5-13 years of education.
[c]Comparisons were made using χ^2.

different contexts, and no participant from one group could have gone into the other.

Through this protocol, it was possible to determine if a low performance on the neuropsychological tasks was related to legal status (i.e. the JDG has more difficulties than the non-delinquent groups, education is not a factor) or to education (i.e. the JDG and AEPG have more difficulties than the APG, legal status is not a factor).

Instruments

Questionnaires

A General Information Questionnaire was used to collect information on brain damage risk, past drug use, criminal history, age, and education of the participants, as well as the education and occupation of their parents to determine SES[19].

To assess family violence, the Intimate Partner Violence Scale and the Child Punishment Scale were translated and adapted to a ten-point response scale (0 = it never happens; 10 = it always happens)[20]. On the first scale, the participant reports the frequency of violent interactions between his parents. On the second scale, the participant reports the frequency in which disciplinary methods are used at home, which go from verbal reprimands to beatings.

The ADHD index scale from the Conner's 3rd Edition – Self Report (Conner's 3-SR)[21], which includes questions about the severity of ADHD symptoms, was translated to Spanish and adapted to a ten-point response scale (0 = not true/never happens, 10 = quite true/happens a lot).

Tasks

A modified version of the Continuous Performance Task (CPT)[22] was used to assess the components of attention. In this task, participants have to press key number 1 on a computer keypad to any number except "9", press 2 when a "9" appears, and press 3 when a number "4" appears after a "9". There are 540 stimuli in total, divided in 27 blocks of 20 stimuli each with 14 numbers different from "9," four numbers "9," and two "9-4" sequences; total task duration is 11 min and 42 s. Stimuli were randomized within and between blocks. Responses to numbers different from "9" were taken as indices of tonic alertness, responses to "9" were taken as indices of selective attention, and responses to "4" after "9" were taken as indices of phasic alertness. For sustained attention, short-term stability was measured through the mean length of hit runs, that is, any group of two or more correct responses in sequence[23].

The Wisconsin Card Sorting Test (WCST)[24] was used to assess cognitive flexibility. The participant sorts a deck of 128 cards, and an examiner informs if each sort is correct, using a criterion unknown to the participant; after some correct sorts, the criterion inadvertently changes, and the participant must try a different

strategy. The number of cards that the participant sorted using a strategy that had already been marked as incorrect, known as perseverative responses, was taken as an index for cognitive flexibility.

Procedure

Ethical considerations guided all the decisions regarding the protocol, since some participants are underage and all of them are institutionalized. Great care was given to consent, risk minimization, and also confidentiality and anonymity were paramount. First, a judge (acting as the legal guardian of the adolescents) granted permission to enter the juvenile delinquent institution, as also did the authorities of the schools that participated. In the case of underage participants, their legal guardians also signed an informed consent letter; in the schools, this letter was sent to parents through the children. For the institutionalized adolescents, the legal guardians were asked for their consent and signed the letter on the day they visited the institution. The participants were asked for their consent in an individual interview, explicitly explaining there was no compensation or obligation, explaining all the procedures and tests, always indicating that there was no obligation to respond or continue with the protocol if they did not want to, being free to retire in any moment. The JGD participants gave their consent only after it was reassured that researchers had no relationship to the justice system and that no information would be shared with the authorities. After this explanation, all participants signed an informed consent letter. All records are kept anonymous and are guarded by the researchers.

Participants reported no use of drugs or medication in the previous 24 h. All questionnaires and tasks were administered individually inside a quiet room with no one else but the researcher and the participant. Questionnaires were read to the participant, who had a printed card with the response scale, and his answer was recorded by the examiner.

Data analysis

The text and tables display descriptive statistics as (mean ± standard deviation). Repeated measures analysis of variance (ANOVA) (*F*) was used to compare age, education, the questionnaire scores, the CPT, and the WCST performance indices between the three groups. Tukey's test was used as the *post hoc* pairwise analysis. The effect sizes were calculated using Cohen's *d'*, only on significant *post hoc* comparisons. The number of participants who reported drug use was compared using a Chi-square test (χ^2). A factorial ANOVA was used to analyze the effect of drugs and SES on performance. The p-values lower than 0.05 were considered significant. All analyses were made using STATISTICA[25].

Results

There were no age differences between groups (F = 0.13, NS). On education, the APG had more years of education (11.21 ± 1.37 school years) than both the JDG (7.55 ± 1.38 school years) and the AEPG (8.07 ± 1.39 school years); these low-education groups had no differences on education (F = 59.64, p < 0.001) (Table 1). The JDG reported dropping out of school due to academic and discipline problems at least 2 years before arrest.

The components of attention

On the CPT, the ANOVA showed differences in the percentage of correct responses of all components of attention. There were no differences in reaction time, meaning that all participants responded at a similar speed, but some groups had less correct responses.

The percentage of correct responses on tonic alertness (responses to every number except 9) showed differences between the three groups (F = 11.77, p < 0.001) and the *post hoc* analysis shows that the JDG had a lower percentage of correct responses (73.93 ± 22.38%), compared to the non-delinquent groups (APG: 95.70 ± 6.35%, AEPG: 85.86 ± 18.34%) who had no differences between them (Fig. 1A and Table 2). This was the only neuropsychological index in which juvenile delinquents had a particularly low performance.

In contrast, on selective attention (responses to number 9) (F = 14.15, p < 0.001), the APG, the most educated group, had more correct responses (78.32 ± 14.94%) than the groups with lower education (JDG: 48.69 ± 26.57%, AEPG: 60.92 ± 20.48%) (Fig. 1B and Table 2). On phasic alertness (responses to a 4 after a 9), (F = 11.03, p < 0.001) the APG also had more correct responses (85.70 ± 13.57), compared to the low-education groups (JDG: 55.36 ± 32.59%, AEPG: 65.77 ± 25.05%) who had no differences between them (Fig. 1C and Table 2).

A similar pattern was observed regarding sustained attention (F = 9.48, p < 0.001); the APG had an average hit run length of 22.75 responses in sequence, which means the most educated participants were able to respond without a mistake or an omission for approximately 29 s. This is about three times more than the

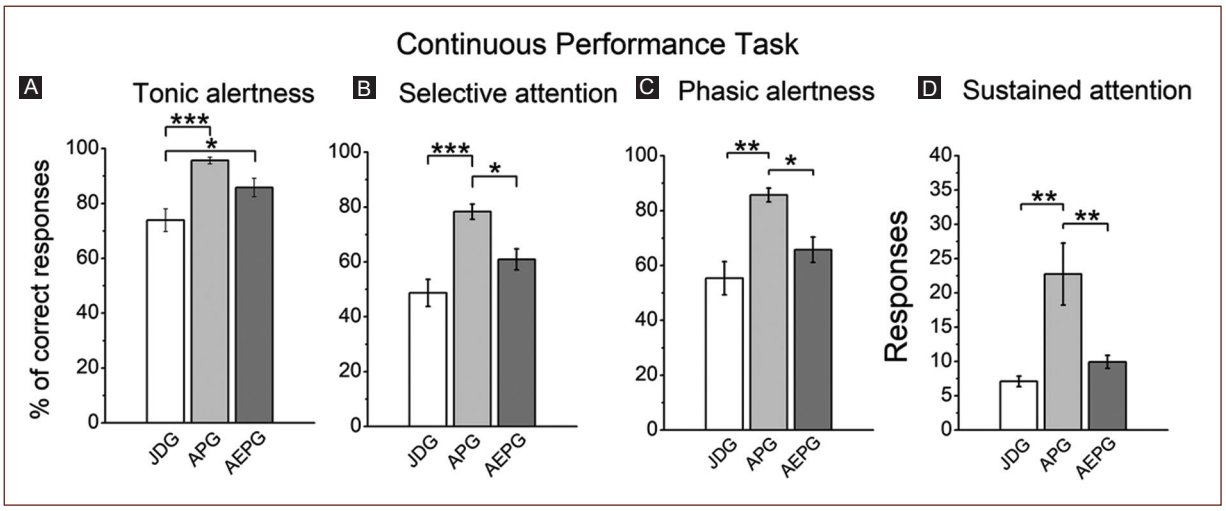


Figure 1. Differences on the components of attention between the juvenile delinquent group, the age-paired group, and the age and education-paired group. Columns represent mean ± standard error. *p < 0.05; **p < 0.01; ***p < 0.001.

Table 2. Neuropsychological tasks in the juvenile delinquent in the juvenile delinquent group (JDG), the age-paired group (APG), and the age- and education-paired group (AEPG)

Tasks	JD (n = 29)	APG (n = 29)	AEPG (n = 29)	F	JGD versus AEPG	JGD versus APG	AEPG versus APG
CPT							
Tonic alertness	73.93 (22.38)	95.70 (6.35)	85.86 (18.34)	11.77***	–0.58*	–1.32***	–0.27***
Selective attention	48.69 (26.57)	78.32 (14.94)	60.92 (3.87)	14.15***	–0.51	–1.37***	–0.96*
Phasic alertness	55.36 (32.59)	85.70 (13.57)	65.77 (25.05)	11.03***	–0.36	–1.22**	–0.99*
Sustained attention	7.11 (4.14)	22.75 (24.38)	9.94 (5.12)	9.48***	–0.61	–0.89**	0.73**
WCST							
Completed categories	2.86 (2.31)	5.76 (0.83)	3.97 (1.92)	19.6***	–0.52	–1.67**	–1.21**
Perseverative responses	28.79 (19.23)	10.97 (7.78)	21.48 (9.55)	13.39***	0.48	1.22***	1.21*

Mean (standard deviation). The values for tonic alertness, selective attention, and phasic alertness are the percentage of correct responses, sustained attention is in the number of correct responses in sequence. Comparisons were made with repeated measures analysis of variance. The values in the *post hoc* comparisons are Cohen's d effect size with the significance of the Tukey's test.
*p < 0.05.
**p < 0.01.
***p < 0.001.
CPT: continuous performance task; WCST: Wisconsin card sorting test.

JDG average hit run of 7.11 responses (9 s of uninterrupted correct responses) and significantly more than the AEPG hit run mean length of 9.94 responses (12 s of uninterrupted correct responses). The low-education groups had no differences between them (Fig. 1D and Table 2).

Cognitive flexibility (a component of executive functions)

The two indices from the WCST showed group differences on the ANOVA, the number of completed categories (F = 19.16, p < 0.001), and the index for cognitive inhibition: perseverative responses: F = 13.39, p < 0.001). The *post hoc* comparisons showed that the less educated groups completed less than four categories (JDG: 2.86 ± 2.31 categories, AEPG: 3.97 ± 1.91 categories) compared to the APG, who completed 5.76 ± 0.86 categories (Table 2). Similarly, the low education groups made more perseverative responses (JDG: 28.79 ± 19.23 responses, AEPG: 21.48 ± 9.55 responses) than the APG, who had 10.97 ± 7.78 perseverative responses. The low education groups had no differences between them (Fig. 2).

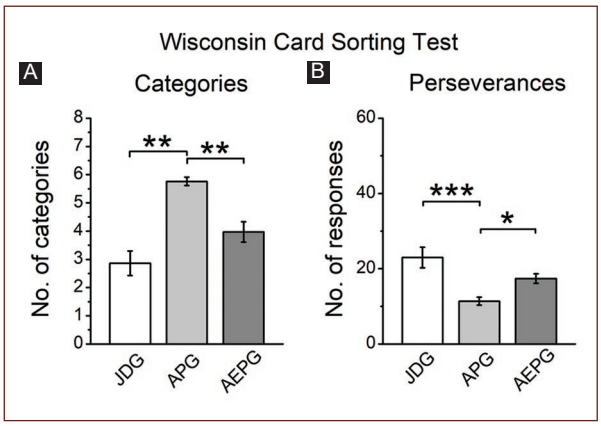


Figure 2. Differences in the **A:** number of categories, and **B:** perseverative responses on the Wisconsin Card Sorting Test, between the juvenile delinquent group, the age-paired group, and the age and education-paired group. Columns represent mean ± standard error. *p < 0.05; **p < 0.01; ***p < 0.001.

Family violence, ADHD symptoms, drug use, and SES

The ANOVA showed group differences on the Intimate Partner Violence Scale (F = 7.44, p < 0.01), The JDG reported more frequent and more serious intimate partner violence between their parents, in comparison to non-delinquent groups which had no differences between them (Fig. 3). There were no group differences on the child punishment scale (F = 2.11, NS). On the ADHD subscales (F = 4.93, p < 0.01), the JDG had higher scores (41.07 ± 24.69) compared to the non-delinquent groups, who had no differences between them (APG: 27.21 ± 14.20; AEPG: 27.59 ± 16.98) (Table 3).

The prevalence of drug use (percentage of participants who reported ever having use a substance) was higher in the JDG (62%) compared to the non-delinquent groups (38%) (Table 1), nevertheless, none of the variables from task performance or questionnaires showed significant effects on the factorial ANOVA for Drug or for Group × Drug.

SES was higher in the APG compared to the JDG and the AEPG, with no differences between low education groups (Table 1), but again, the task performance and questionnaires did not show an effect of SES, or an effect of group × SES, on factorial ANOVA.

All these comparisons would benefit of a larger number of participants, which would likely yield higher effect sizes and lower p-values, but as they are, they are sufficient to be interpreted as follows.

Discussion

Juvenile delinquents showed a deficit in tonic alertness, lower SES, more family violence, and more ADHD symptoms in comparison to other adolescents of the same age, the same SES, and the same education.

Tonic alertness is the most basic form of attention, and it was the only cognitive process to be particularly affected in juvenile delinquents, compared to adolescents paired by age and education. Previous studies have found that, after controlling for education, the differences between juvenile delinquents and similar education adolescents disappear, so this could be the first study to report that juvenile delinquents show a deficit in tonic alertness. Such a deficit implies a lower capacity to respond to any stimuli, which manifests as less correct responses and more omissions, and could be related to the development of the ascending reticular activating system. The presence of a tonic alertness deficit suggests that the development of the connections between the reticular system and the prefrontal cortex area might have been disrupted. In the school environment, such a deficit would make a student seem lethargic, sleepy, or inattentive, and demanding academic activities, such as tests, represent a huge challenge. Therefore, the tonic alertness deficit found in juvenile delinquents implies they have a high risk for academic problems and school dropout.

A deficit on tonic alertness impairs performance on many tasks, including neuropsychological tasks. Therefore, the results of past studies need to be reevaluated considering the tonic alertness deficit reported here.

The rest of the components of attention, and the executive functions component of cognitive flexibility, all showed deficits, but these deficits are not particular to the juvenile delinquent population, since other low-education non-delinquents have very similar deficiencies. Therefore, a tonic alertness deficit is an important characteristic in the complex causal chain that leads to delinquency, while the other deficits are also part of this causal chain but in a more indirect way. Nevertheless, these young people do have these deficits and must deal with the difficulties they produce, even if they are not exclusive to them.

Juvenile delinquents and low-education adolescents showed worse performance on phasic alertness, which implies that they do not benefit from warning signals in order to elevate their response capacity, for example, when a teacher asks students to direct their attention

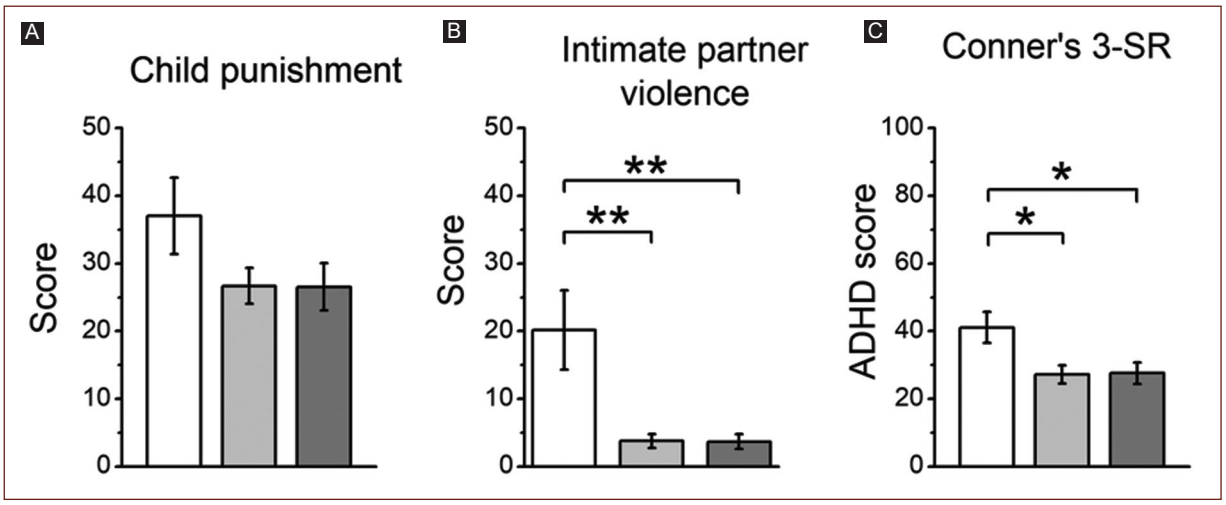


Figure 3. Differences for the **A:** child punishment scale, the **B:** intimate partner violence scale, and **C:** the Conner's 3-SR scores for attention deficit hyperactivity disorder, between the juvenile delinquent group, the age-paired group, and the age and education-paired group. *p < 0.05; **p < 0.01.

Table 3. Family violence scales and Conner's 3rd ADHD scale in the juvenile delinquent group (JDG), the age-paired group (APG), and the age- and education-paired group (AEPG)

Questionnaires	JDG (n = 29)	APG (n = 29)	AEPG (n = 29)	F	JGD versus AEPG	JGD versus APG	AEPG versus APG
Family violence							
Intimate Partner Violence	20.17 (31.51)	3.76 (5.46)	3.66 (5.89)	7.44**	0.73**	0.73**	–0.02
Child Punishment	37.03 (30.30)	26.69 (14.94)	26.55 (18.71)	2.11			
Conner's 3rd ADHD	41.07 (24.69)	27.21 (14.20)	27.59 (16.98)	4.93*	0.64*	0.69*	0.02

Mean (standard deviation). All values are the scores obtained in each scale.
Comparisons were made with repeated measures analysis of variance. The values in the *post hoc* comparisons are Cohen's d effect size with the significance of the Tukey's test.
*p < 0.05.
**p < 0.01.
***p < 0.001.
JDG: juvenile delinquent group; APG: age paired group; AEPG: age and education paired group, ADHD: attention deficit hyperactivity disorder.

to a certain stimulus in the classroom or wait for an instruction to begin a task.

The present study replicated the selective attention deficits previously reported when comparing juvenile delinquents to normal-education adolescents[14,15,26], but in this case, selective attention seemed to be particularly affected in juvenile delinquents and low-education adolescents; they failed to give a specific response to half the stimuli that required it, 30% less than their more educated counterparts. This form of attention is crucial for learning and schoolwork, for example, responding to the voice of the teacher over distractors.

Deficits in sustained attention had been reported as a decrement in performance using the time-on-task index[13], but the present study found deficits using the short-term stability of performance index (hit runs), which indicates that juvenile delinquents, and low-education adolescents, have a lower capacity to perform without omissions or mistakes, compared to more educated adolescents. This capacity is important to have a stable performance during prolonged activities such as tests, even if the questions are easy.

Juvenile delinquents and low-education adolescents also showed cognitive flexibility deficits, in comparison to more educated non-delinquents, confirming what some other studies have reported[14,17,18]. Cognitive flexibility deficits reduce the capacity to adapt a response strategy to environmental changes[16,27], which can produce academic difficulties in math and language[28]. The juvenile delinquents and non-delinquents of low

education also had less completed categories in the WCST, which suggests these youngsters could have deficits in other components of executive functions that are not being addressed in this study.

The fact that non-delinquent low-education adolescents have similar deficits to those of juvenile delinquents contradicts the hypothesis that juvenile delinquents commit crimes because they are not able to control their actions due to executive function deficits, since other adolescents with similar deficits have no criminal record. The deficits previously reported in juvenile delinquents are probably due to the differences in tonic alertness or in education, but not due to legal status. In contrast, our results suggest that such cognitive deficits could be the cause of school failure and dropout, and also suggest that once these youth are out of school, other social variables and their tonic alertness deficits could increase their risk for juvenile delinquency[29].

The only way to arrive at this conclusion was through the inclusion of an education-paired group to compare with juvenile delinquents; similar strategies are crucial for future studies on this subject. In any case, the presence of these cognitive deficits in juvenile delinquents is evidence that there is a delay in the development of prefrontal functions of these adolescents. Nevertheless, even if the executive functions and attention deficits are not the direct cause of their criminal behavior (because they are not exclusive of this group), the tonic alertness deficit shown here could be an explanation for the school dropout and the subsequent criminal involvement of these interned youngsters. There are few articles in the literature that document these variables adequately, so there are not many studies to compare our results with.

Other factors known to increase the risk for a brain developmental delay were also graver in the juvenile delinquents of this study. These youngsters reported to have witnessed more and more serious parental violence, compared to that experienced by other adolescents, which coincides with other reports[30] and with the evidence that a stable family environment has a protective effect against involvement in juvenile delinquency[31]. Apparently, this violence at home was not directed towards the minors themselves (there were no differences in child punishment between juveniles and other adolescents), but living in a household where violence occurs increases the possibility of receiving more blows to the head, and therefore, of having brain concussions that hamper brain development[7].

Juvenile delinquents also reported more ADHD symptoms than other non-delinquents, even though their task performance in attention and executive functions is similar to that of non-delinquents of similar education. This suggests that juvenile delinquents perceive their difficulties as more incapacitating and problematic than non-delinquents. This perception of attention difficulties in juvenile delinquents could be due to their lower tonic alertness, although their performance on selective and sustained attention (components that are more related to ADHD) was comparable to that of other adolescents. Another issue that should be factored in is the social stigma that people in the penitentiary system suffer.

On the other hand, SES followed education, since it was higher in more educated adolescents, nevertheless, when used as a factor on the ANOVA, it showed no effect on neuropsychological performance, which means that controlling for SES is not equivalent to controlling for education as other studies propose, probably because education has a greater effect on neuropsychological assessment than SES itself.

This juvenile delinquent sample had a similar drug use prevalence compared to other studies[32], but this did not seem to have an observable effect on neuropsychological performance, probably due to the fact that they had been on an abstinence period of about a year, which could partially revert the effects of substance use[33]. Since 45.7% of the juvenile delinquent sample were polysubstance users with very different history of use, it was impossible to further analyze drug use. More studies on this issue are needed.

These findings show that juvenile delinquents live in a precarious situation in terms of health, education, and SES, which are all factors that affect brain development. Nevertheless, children and adolescents can be protected from these risk factors by ensuring their human rights. For example, preventing brain developmental delays includes helping families provide adequate housing, care, and recreation for their children. Drug use, head trauma, and family violence can be prevented by providing better physical and mental health services for children and their families. School dropout can be prevented by ensuring that schools are able to provide education for all children, including those with developmental disorders, and by improving living conditions in general. Finally, criminal activity becomes less attractive for young people when opportunities for training and formal employment are available and fit for low-education adolescents[34].

Conclusion

Juvenile delinquents have a deficit in tonic alertness, the most basic form of attention, which depends on the reticular activating system and its ascendant connections to the rest of the brain; this network could be compromised in these adolescents.

Deficits were also found on phasic alertness, selective attention, sustained attention, and cognitive flexibility, which suggest a developmental delay in the prefrontal cortex. These cognitive deficits are present in juvenile delinquents and other low-education adolescents; therefore, these cognitive deficits cannot be the cause of juvenile delinquency.

It was also found that juvenile delinquents have a lower SES, they witness more family violence, and have more ADHD symptoms than other adolescents.

In sum, juvenile delinquents have deficits in attention and cognitive flexibility as well as a difficult socioeconomic and family situation. A program designed to prevent juvenile delinquency must consider these deficits and provide proper conditions to promote the development of these neuropsychological functions during childhood.

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Conflicts of interest

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Ethical considerations

Protection of human subjects and animals. The authors declare that the procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation and with the World Medical Association and the Declaration of Helsinki. The procedures were authorized by the Institutional Ethics Committee.

Confidentiality, informed consent, and ethical approval. The authors have followed their institution's confidentiality protocols, obtained informed consent from all patients, and secured approval from the Ethics Committee. SAGER guidelines have been followed as applicable to the nature of the study.

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References

1. Smith P, Harrendorf S. Responses of the criminal justice system. In: International Statistics on Crime and Justice. Helsinki: HEUNI-UNODC; 2010. p. 87-112.
2. Instituto Nacional de Estadística y Geografía (INEGI). Censo Nacional de Gobierno, Seguridad Pública y Sistema Penitenciario Estatales 2020. México: INEGI; 2020. Available from: https://www.inegi.org.mx/programas/cngspspe/2020/#datos_abiertos [Last accessed on 2022 Feb 23].
3. Instituto Nacional de Estadística y Geografía (INEGI). Anuario Estadístico Y Geográfico Por Entidad Federativa 2020. México: INEGI; 2020. p. 625. Available from: https://www.inegi.org.mx/app/biblioteca/ficha.html?upc=702825197513 [Last accessed on 2022 Feb 28].
4. Cauffman E, Steinberg L, Piquero AR. Psychological, neuropsychological and physiological correlates of serious antisocial behavior in adolescence: the role of self-control. Criminology. 2005;43:133-76.
5. Moffitt TE. The neuropsychology of juvenile delinquency: a critical review. Crime Justice. 1990;12:99-169.
6. Barkley RA, Biederman J. Toward a broader definition of the age-of-onset criterion for attention-deficit hyperactivity disorder. J Am Acad Child Adolesc Psychiatry. 1997;36:1204-10.
7. Lewis DO, Shanok SS, Balla DA. Perinatal difficulties, head and face trauma, and child abuse in the medical histories of seriously delinquent children. Am J Psychiatry. 1979;136:419-23.
8. Banich MT. Executive function: the search for an integrated account. Curr Dir Psychol Sci. 2009;18:89-94.
9. Latzman RD. Interrelations among Youth Temperament, Executive Functions, and Externalizing Behaviors [Dissertation on the Internet]. Iowa City: University of Iowa; 2009. Available from: https://iro.uiowa.edu/esploro/outputs/doctoral/9983776706002771 [Last accessed on 2022 Feb 17].
10. Vries AM, Liem M. Recidivism of juvenile homicide offenders. Behav Sci Law. 2011;29:483-98.
11. Posner MI, Rafal RD. Cognitive theories of attention and the rehabilitation of attentional deficits. In: Neuropsychological Rehabilitation. New York: Guilford Press; 1987. p. 182-201.
12. Valdez P, Ramírez C, García A, Talamantes J, Armijo P, Borrani J. Circadian rhythms in components of attention. Biol Rhythm Res. 2005;36:57-65.
13. Chae PK, Jung HO, Noh KS. Attention deficit hyperactivity disorder in Korean juvenile delinquents. Adolescence. 2001;36:707-25.
14. Olvera RL, Semrud-Clikeman M, Pliszka SR, O'Donnell L. Neuropsychological deficits in adolescents with conduct disorder and comorbid bipolar disorder: a pilot study. Bipolar Disord. 2005;7:57-67.
15. Wolff PH, Waber D, Bauermeister M, Cohen C, Ferber R. The neuropsychological status of adolescent delinquent boys. J Child Psychol Psychiatry. 1982;23:267-79.
16. Davidson MC, Amso D, Anderson LC, Diamond A. Development of cognitive control and executive functions from 4 to 13 years: evidence from manipulations of memory, inhibition, and task switching. Neuropsychologia. 2006;44:2037-78.
17. Abdou A, Amer D, Sadek M. Gender differences in personality characteristics and cognitive abilities in adolescents admitted in correctional institutes in Egypt. Egypt J Psychiatry. 2012;33:9-14.
18. Appellof E. Prefrontal Functions in Juvenile Delinquents [Dissertation on the Internet]. Syracuse: Syracuse University; 1985. Available from: https://surface.syr.edu/psy_etd/112 [Last accessed on 2022 Feb 17].

19. Adler N, Boyce T, Chesney M, Cohen S, Folkman S, Kahn RL, et al. Socioeconomic Status and Health: The Challenge of the Gradient; 1994. Available from: https://kilthub.cmu.edu/articles/journal_contribution/Socioeconomic_status_and_health_The_challenge_of_the_gradient/6618173/1 [Last accessed on 2022 Feb 17].
20. Straus MA. Conflict tactics scales. In: Handbook of Measurements for Marriage and Family Therapy. New York: Routledge; 2013. p. 159-63.
21. Conners CK, Pitkanen J, Rzepa SR. Conners. In: Encyclopedia of Clinical Neuropsychology. 3rd ed. New York: Springer; 2008.
22. Riccio CA, Reynolds CR, Lowe P, Moore JJ. The continuous performance test: a window on the neural substrates for attention? Arch Clin Neuropsychol. 2002;17:235-72.
23. Valdez P, Ramírez C, García A, Talamantes J, Cortez J. Circadian and homeostatic variation in sustained attention. Chronobiol Int. 2010;27:393-416.
24. Heaton RK, Chelune GJ, Talley JL, Kay GG, Curtiss G. Wisconsin Card Sorting Test Manual. Odessa (FL): Psychological Assessment Resources; 1993.
25. StatSoft Inc. STATISTICA (Data Analysis Software System), Version 7. Tulsa (OK): StatSoft Inc.; 2004.
26. Hurt J, Naglieri JA. Performance of delinquent and nondelinquent males on planning, attention, simultaneous, and successive cognitive processing tasks. J Clin Psychol. 1992;48:120-8.
27. Anacker C, Hen R. Adult hippocampal neurogenesis and cognitive flexibility: linking memory and mood. Nat Rev Neurosci. 2017;18:335-46.
28. Bull R, Johnston RS, Roy JA. Exploring the roles of the visual-spatial sketch pad and central executive in children's arithmetical skills. Dev Neuropsychol. 1999;15:421-42.
29. Yeudall LT, Fromm-Auch D, Davies P. Neuropsychological impairment of persistent delinquency. J Nerv Ment Dis. 1982;170:257-65.
30. Pagani LS. The influence of family context on the development and persistence of antisocial behavior. In: The Development of Persistent Criminality. New York: Oxford University Press; 2009. p. 37-53.
31. United Nations General Assembly. United Nations Guidelines for the Prevention of Juvenile Delinquency (The Riyadh Guidelines); 1991. Available from: https://digitallibrary.un.org/record/105349 [Last accessed on 2022 Feb 23].
32. Teplin LA, Abram KM, McClelland GM, Mericle AA, Dulcan MK, Washburn JJ. Psychiatric Disorders of Youth in Detention. Juvenile Justice Bulletin. Washington, DC: Office of Juvenile Justice and Delinquency Prevention; 2006. Available from: https://eric.ed.gov/?id=ED495787 [Last accessed on 2022 Feb 28].
33. Verdejo-García A, Bechara A, Recknor EC, Pérez-García M. Executive dysfunction in substance dependent individuals during drug use and abstinence. J Int Neuropsychol Soc. 2006;12:405-15.
34. United Nations. United Nations guidelines for the prevention of juvenile delinquency (The Riyadh Guidelines). In: Prevention of and Responses to Violence against Children within the Juvenile Justice System. United Nations; 2021. p. 39-44. Available from: https://www.un-ilibrary.org/content/books/9789210582872c009 [Last accessed on 2022 Feb 17].