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ORIGINAL

From Emotional Processing to Neurorehabilitation: Exploring Cognitive Performance and Physiological Response in Preschool Children

Del Procesamiento emocional a la Neurorehabilitación: Explorando el Rendimiento Cognitivo y la Respuesta Fisiológica en Niños en Edad Preescolar

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ABSTRACT

Introduction: in recent decades, great importance has been given to the joint study of emotional, cognitive and physiological processes. Emotions play an important role in enabling regulation and adaptation of individuals to their environment, which is crucial for their well-being, mental and physical health. However, just a few research studies analyze the integration of these processes in preschoolers. This study analyzes the emotional, cognitive and physiological processing of girls and boys aged 4 and 5 years.
Methods: 42 children aged 4 and 5 years participated in the study. They were administered a Stroop-like task under neutral or positive conditions in order to analyze the effect of emotional valence on performance and heart rate.
Results: an increase in heart rate was found during the Stroop-like task in both conditions. A decrease in heart rate was also observed in the positive condition of the task in the girl´s group and in the 5-year-old´s group. Finally, in the neutral condition, heart rate variation correlated inversely with reaction time.
Discussion: the results show that cognitive demand increases heart rate regardless of the task valence, and that positive valence produces a decrease in heart rate depending on age and gender. These findings emphasize the need to integrate individual characteristics when studying emotional, cognitive, and physiological processing during development, as well as when considering biopsychosocial health.

Keywords: Positive Emotional Valence; Well-Being; Stroop-Like Task; Heart Rate; Individual Differences.

RESUMEN

Introducción: en las últimas décadas se otorgó gran importancia al estudio conjunto de los procesos emocionales, cognitivos y fisiológicos. Las emociones desempeñan un papel importante permitiendo la regulación y adaptación de las personas al medio, lo que es clave para el bienestar y la salud mental y física. Sin embargo, pocas investigaciones analizan la integración de estos procesos en preescolares. El presente estudio analiza el procesamiento emocional, cognitivo y fisiológico de niñas y niños de 4 y 5 años.
Métodos: participaron 42 niñas/os de 4 y 5 años, y se les administró una tarea tipo Stroop bajo una condición neutra o positiva para analizar el efecto de la valencia emocional sobre el desempeño y la frecuencia cardíaca.
Resultados: se encontró un incremento de la frecuencia cardíaca durante la tarea tipo Stroop en ambas condiciones. También se observó una disminución en la frecuencia cardíaca en la condición positiva de la tarea en el grupo de nenas y en el grupo de 5 años. Por último, en la condición neutra, la variación de la frecuencia cardíaca correlacionó inversamente con el tiempo de reacción.
Discusión: los resultados muestran que la demanda cognitiva incrementa la frecuencia cardíaca más allá de la valencia de la tarea, y que la valencia positiva produce una disminución en la frecuencia cardíaca en función de la edad y el género. Estos hallazgos enfatizan la necesidad de integrar las características

individuales al estudiar el procesamiento emocional, cognitivo y fisiológico durante el desarrollo, y al pensar la salud biopsicosocial.

Palabras clave: Valencia Emocional Positiva; Bienestar; Tarea Tipo Stroop; Frecuencia Cardíaca; Diferencias Individuales.

INTRODUCTION

Emotions influence a wide variety of cognitive and physiological processes,[1,2,3] and play an important role in enabling regulation and adaptation of individuals to their environment, which is crucial for their well-being, mental and physical health.[4]

While most research focuses on the impact of negative emotions,[5] studies using positive stimuli show that they attract attention more easily than neutral ones.[6] This could happen because certain high-intensity emotional stimuli increase attention facilitating cognitive performance, since positive emotions are associated with more global and flexible cognitive processing.[7]

Specifically, there are studies that address the influence of positive stimuli on inhibitory control tasks and cognitive flexibility. Inhibitory control involves the ability to ignore distractions and avoid dominant responses in favor of more appropriate ones to meet demands [8], while cognitive flexibility refers to the ability to adapt to new demands, rules, or priorities.[9,10] Some studies indicate that positive stimuli improve performance in tasks that evaluate inhibition and cognitive flexibility,[11,12] while in other studies, the presence of emotional stimuli decreases performance and increases reaction times.[13] This decrease in performance caused by the use of emotional stimuli is called emotional interference, since the automatic processing of emotional stimuli, parallel and privileged,[14] involves a cognitive overload.

On the other hand, contradictory results are also observed regarding physiological changes related to positive emotions.[15] Heart rate (HR) is considered a robust measure of emotional reactivity.[16] Some studies suggest a pronounced decrease in HR in response to positive stimuli, compared to neutral stimuli,[2] while other studies argue that positive stimuli result in a slight acceleration in HR.[17]

Finally, the performance of tasks that require inhibition and cognitive flexibility is also related to changes in HR. Specifically, there are studies that report a decrease in HR during these tasks,[18] and interpret this variation as an expected autonomic response to demanding and novel tasks.[19]

This study

Despite the importance of the joint analysis of emotions, and cognitive and physiological processes for mental and physical health, their study in preschool populations is still underdeveloped. In addition, given the special salience with which negative emotional stimuli are processed, research of these processes has primarily focused on tasks of this valence.[20] For these reasons, the objective of this study is to explore the performance and HR of girls and boys aged 4 and 5 years during a Stroop-like task with neutral or positive valence.

Based on the literature, it is expected to find that the valence of the task (positive or neutral condition) will differentially affect the performance of girls and boys in a Stroop-like task. That is, a higher HR and a better performance in the Stroop-like task in the positive condition compared to the neutral condition. On the other hand, differences in the variables were explored according to gender, in addition to the correlations between HR and performance in the Stroop-like task.

METHODS

Participants

An incidental sample of 42 children (42,9 % girls) aged 4 years (n = 17) and 5 years (n = 25) was recruited. Participants were randomly assigned to either the neutral condition (n = 19) or the positive condition (n = 23) of the task. All participants were native Spanish speakers, and none of them had developmental disorders or were undergoing psychological, neurological or psychiatric treatment. In addition, it was ensured that all of them had normal vision or were wearing glasses (if prescribed).

Instruments

Stroop-like task

Wright et al.[21] (2014) Stroop-like task was used to evaluate inhibition and cognitive flexibility. The task includes three blocks with increasing demand. In the congruent block, participants are asked to press the button on the same side on which stimulus appears. In the incongruent block, participants are requested to press the button on the opposite side of where another stimulus appears. Finally, in the mixed block, both types of stimuli are presented, and participants are requested to apply flexibly the two previous instructions.

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For the analyzes, the variables considered were the proportion of correct trials over the total number of administered trials (Performance) and reaction time (RT) of trials that were correctly responded. The variables were calculated and analyzed for each of the task´s blocks separately.

A situation of social interaction with the participants assigned to the positive condition was performed.[22] The procedure consisted of the addition of a meaningful component that gives a purpose to the task, one that is relevant and appealing to the children (e.g., organization of a birthday). Besides, there was an interactive component which consisted of the selection of stimuli and backgrounds for the tasks, as well as other components related to the story, such as choosing a character and a pet. These components did not modify their structure or the sequence of the tests.

Pulse oximeter

A photoplethysmograph (Contec CMS50D+ model), was used to record HR as a psychophysiological variable. Recording was done throughout the evaluation session. Previously, a baseline recording was done for two minutes and an average was calculated for each participant.[23] The average HR during the task was considered as a variable.

Procedure

The principles established by the International Convention on the Rights of the Child and National Law No. 26061 (Comprehensive Protection of the Child´s Rights) were followed, and the procedures recommended by the Ethical Research Involving Children Project were adopted.[24] In order to participate, informed consents were required to be signed by a responsible adult. Likewise, the procedures implemented did not present any risks, and were approved by the Ethics Committee of CEMIC (Protocol No. 961).

Data collection was done at the Centro Cultural de la Ciencia (CABA) in the context of the proposal called *"A ciencia abierta"*, led by the Unit of Applied Neurobiology of CEMIC-CONICET. The evaluation was carried out individually. The total duration of the tasks varied between five and ten minutes, depending on the time each participant needed to perform the activity.

Data analysis

First, descriptive analyzes of the variables were performed. Since the assumptions for the use of parametric statistics were not met, non-parametric analyzes were implemented. Second, baseline HR was compared between groups to ensure their initial equivalence. To verify HR variation, HR was compared before and during the task using the Wilcoxon test of repeated measurements. Next, the performance variables in Stroop and HR between the conditions were compared using the Mann-Whitney U test. Finally, Spearman's rho correlations were performed between performance variables in Stroop and HR.

RESULTS

It was confirmed that the groups assigned to the positive condition and the neutral condition were equivalent in their baseline HR ($ps > 0,05$). On the other hand, an increase in HR was observed as a result of the performance of the Stroop-like test in both conditions (neutral: $W = 19,00$, $p = 0,001$, $r = -0,800$; positive: $W = 7,00$, $p < 0,001$, $r = -0,949$).

Descriptive information of the variables is presented in table 1.

Table 1. Descriptive statistics of the Stroop-like task variables and heart rate divided by emotional condition of the task

Variables	Neutral condition				Positive condition			
	Mean	SD	Median	IQR	Mean	SD	Median	IQR
Stroop congruent block								
Performance	0,92	0,13	1,00	0,15	0,85	0,18	0,90	0,26
RT	1492,71	384,60	1457,00	317,40	1548,15	576,65	1408,80	590,61
Stroop incongruent block								
Performance	0,91	0,14	1,00	0,10	0,86	0,21	1,00	0,21
RT	1726,70	380,57	1747,90	440,23	1555,89	432,88	1364,70	507,50
Stroop mixed block								
Performance	0,87	0,17	0,94	0,19	0,84	0,18	0,94	0,25
RT	2124,29	510,56	1964,39	292,84	1951,94	598,27	1824,50	923,56
Heart rate								
During Stroop	102,83	17,06	101,44	25,76	108,87	10,50	108,56	12,20
Variation	17,12	22,05	11,72	22,47	99,89	10,59	6,83	13,25

When comparing the variables between positive and neutral conditions in the total sample, no significant differences were observed in any of the variables. Information about comparisons between conditions is in table 2.

Table 2. Comparison of the variables of interest between the conditions of the task according to the groups of participants

Variables	Total			Genre						Age					
				Female			Male			4 years			5 years		
	U	p	R	U	p	r	U	p	r	U	p	r	U	p	r
Stroop congruent block															
Performance	161,50	0,125	0,261	39,00	0,960	0,025	41,00	0,069	0,427	27,50	0,430	0,236	50,00	0,099	0,351
RT	205,00	0,745	0,062	34,00	0,633	0,150	55,00	0,361	0,231	35,00	0,963	0,028	74,00	0,893	0,039
Stroop incongruent block															
Performance	204,00	0,701	0,066	40,00	1,00	0,000	65,50	0,740	0,084	24,50	0,281	0,319	71,50	0,739	0,071
RT	156,00	0,118	0,286	32,00	0,515	0,200	47,00	0,167	0,343	23,00	0,236	0,361	60,00	0,373	0,221
Stroop mixed block															
Performance	195,50	0,560	0,105	29,50	0,354	0,262	68,50	0,883	0,042	25,50	0,333	0,292	77,00	1,00	0,000
RT	150,00	0,086	0,314	32,00	0,515	0,200	44,00	0,119	0,385	32,00	0,743	0,111	48,00	0,120	0,377
Heart rate															
During Stroop	153,50	0,103	0,297	22,00	0,122	0,450	57,00	0,424	0,203	22,00	0,200	0,389	53,50	0,208	0,305
Variation	168,00	0,209	0,231	15,00	0,027	0,625	70,00	0,955	0,021	34,00	0,888	0,056	42,00	0,058	0,455

Note: Significant comparisons are in bold

When the sample was segmented by gender, girls assigned to the positive condition showed a lower variation in HR than those in the neutral condition (U = 15,00, p = 0,027, r = 0,625). There were no differences between the variables based on task conditions in the group of boys.

When dividing the sample by age, 4-year-old girls and boys reported no differences in any of the variables between the task conditions. In the 5-year-old group, there was a tendency for a greater variation of HR in the neutral condition compared to the positive condition (U = 42,00, p = 0,058, r = 0,455).

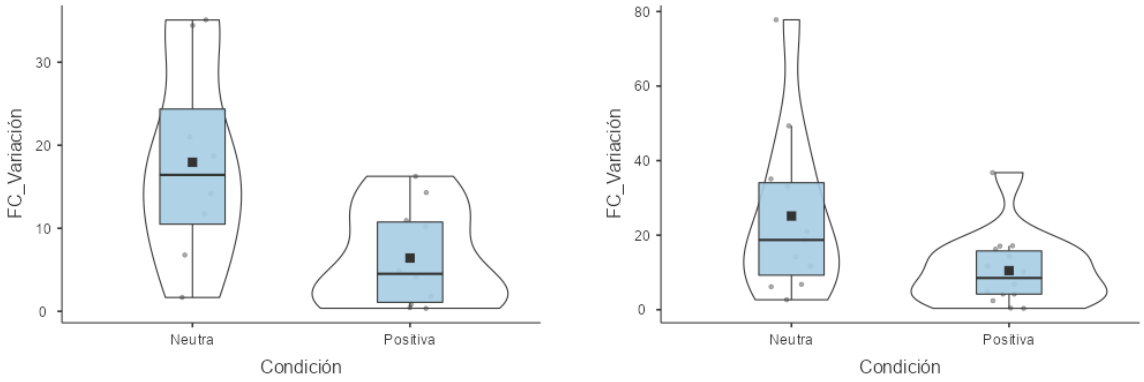

Figure 1. Comparison of heart rate variation between emotional conditions for the groups of girls (left) and 5-year-olds (right)

Regarding the correlations between the variables of interest, in the neutral condition of the task an inverse correlation was found between HR variation and RT in the incongruent block (r = -0,546, p = 0,017) and in the mixed block (r = -0,556, p = 0,015). In the positive condition of the task, there were no significant correlations between the performance and HR variables. Table 3 shows complete information on the correlations analyzed.

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Table 3. Correlations between Stroop and heart rate variables divided according to the emotional condition of the task

Stroop	Heart rate			
	Neutral condition		Positive condition	
	Stroop	Variation	Stroop	Variation
Congruent block				
Performance	-0,045	0,181	-0,034	-0,289
RT	0,333	-0,361	-0,006	-0,381
Inconsistent block				
Performance	0,060	0,351	0,247	0,028
RT	-0,151	-0,546*	0,010	-0,374
Mixed block				
Performance	0,257	0,413	-0,247	0,056
RT	-0,182	-0,556*	0,005	-0,296

Note. *$p < 0,05$.

DISCUSSION

This study analyzed the performance and HR of girls and boys aged 4 and 5 years in a Stroop-like task with neutral or positive valence. First, the initial equivalence of the experimental groups in terms of their baseline HR was confirmed. Next, the variation of HR before and during the task was explored. A higher HR was found during the Stroop-like task in both conditions.[25] This implies that cognitive effort has an increasing effect on HR, regardless its emotional valence. This aligns with other research studies postulating that various autonomic measures could be used as indicators of cognitive effort during different life stages.[18,23]

Contrary to expectations, there were no variations in performance based on task conditions. Only a higher HR was observed in the neutral condition in comparison with the positive condition in the group of girls, with a similar trend in the group aged 5 years. This could be due to controversy over the effect of emotional valence on the performance and HR of participants, and the lack of studies conducted in preschool populations. On the other hand, the gender differences found could be due to variations present in socio-emotional development, where girls usually present a greater maturation of cognitive skills related to self-regulation compared to boys.[26] The small sample used in this study makes it difficult to carry out more specific analyzes in this regard.[27] Therefore, future research could be focused on increasing the sample size in order to develop comparisons and segmentations that allow to identify the variations among the groups.

Lastly, the correlations between HR and performance in the Stroop-like task were explored. Inverse and moderate correlations were found between RT and HR variation in the incongruent and mixed blocks of the neutral condition of the task, but not of the positive condition. Other studies also found similar relationships between RT and various autonomic measures, as both are considered non-specific indicators of activation.[18,28] It is possible that the difference between the correlations found in both conditions is due to the fact that, although both showed a variation between the baseline HR and the HR reported during the task, the effect was greater in the positive condition than in the neutral condition.[29] This could result in participants experiencing a greater autonomic activation in such condition.

In conclusion, the findings of this study contribute to the ongoing debate about the impact of emotional valence on HR.[15] Additionally, they emphasize the importance of considering the individual characteristics of participants when studying the integration of cognitive, emotional and physiological processing, and when thinking about health from a biopsychosocial approach.[30] Age and gender differences should also be taken into account when conceptualizing various psychophysiological pathologies, which have traditionally been addressed primarily from a medical point of view.

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CONFLICTS OF INTEREST

There are no conflicts of interest.

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DATA AVAILABILITY

Data are not publicly available due to ethical and privacy restrictions. However, they are available upon reasonable request.

AUTHORSHIP CONTRIBUTION

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