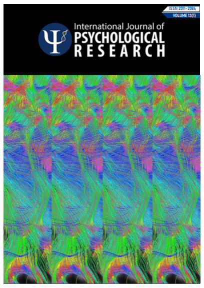

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Inhibitory Processes and Fluid Intelligence: a Performance at Early Years of Schooling

Procesos inhibitorios e inteligencia fluida: su desempeño en los primeros años de escolaridad

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Abstract.

Inhibition constitutes one of the main executive functions and it is important to more complex skills such as fluid intelligence. Actually, there is an agreement on distinguishing three inhibitory types: *perceptual, cognitive* and *response inhibition*. Several studies show the differential engagement of these inhibitory types in different skills. However, there is no registered evidence about the differential relation of inhibitory types with fluid intelligence. This inquiry is especially important during the first school years, since in this stage, inhibitory processes would already be differentiated, and inhibitory processes and fluid intelligence are linked to the performance of children in the school setting. For these reasons, the goal of this work is to study the relation and contribution of perceptual, cognitive, and response inhibition with fluid intelligence, in children in the first years of primary school. For that purpose, a sample of children from six to eight years old ($N = 178$) was tested with a perceptual inhibition task (perception of similarities and differences task); a cognitive inhibition task (proactive interference task); a response inhibition task (stop signal task); and a fluid intelligence task (progressive matrices task). We observed significant correlations between perceptual and response inhibition and fluid intelligence (controlling for age), but only perceptual inhibition explains significantly part of the performance in the fluid intelligence task. This study provides data about the specific contribution, during childhood, of an inhibitory type to fluid intelligence and contributes empirical evidence in support of the non-unitary approach of inhibition.

Resumen.

La inhibición constituye una de las principales funciones ejecutivas, siendo fundamental para otras habilidades más complejas, tales como la inteligencia fluida. Actualmente, existe acuerdo en distinguir tres procesos inhibitorios: inhibición *perceptual, cognitiva* y *de la respuesta*. Distintos estudios muestran que los tipos inhibitorios participan de manera diferencial en diversas habilidades, aunque no se registra evidencia sobre la relación diferencial de los mismos con la inteligencia fluida. Su estudio es especialmente importante durante los primeros años de la escuela primaria, donde los procesos inhibitorios estarían diferenciados y tanto ellos como la inteligencia fluida se vinculan con el desempeño de los niños en el ámbito escolar. Por estos motivos, este trabajo se propuso analizar la relación y contribución de la inhibición perceptual, cognitiva y de la respuesta con la inteligencia fluida en niños en los primeros años de la escuela primaria. Para ello, una muestra de niños de seis a ocho años de edad ($N = 178$) fue evaluada con una tarea de inhibición perceptual (test de percepción de diferencias y similitudes), una tarea de inhibición cognitiva (tarea de interferencia proactiva), una tarea de inhibición de la respuesta (basada en el paradigma *stop signal*) y una tarea de inteligencia fluida (test de matrices progresivas). Se encontraron correlaciones significativas entre la inhibición perceptual y de la respuesta con la inteligencia fluida (controlando la edad), pero solo la inhibición perceptual explica de manera significativa parte del rendimiento en la tarea de inteligencia fluida. Este estudio aporta datos específicos sobre la contribución de un tipo inhibitorio a la inteligencia fluida durante la niñez, así como evidencia empírica a favor del modelo no-unitario de la inhibición.

Keywords.

Perceptual inhibition, cognitive inhibition, response inhibition, fluid intelligence, childhood.

Palabras Clave.

Inhibición perceptual, inhibición cognitiva, inhibición de la respuesta, inteligencia fluida, niñez.

1. Introduction

Inhibition constitutes one of the main executive functions. It involves a group of cognitive processes, which are related to the control of thoughts, conducts, and emotions, during goal-directed behavior (Y. S. Aydmune, Introzzi, Zamora, & Lipina, 2016; Diamond, 2016; Friedman & Miyake, 2017). Inhibition is defined as the ability to stop the prepotent tendencies linked to emotion, thoughts, behavior, and environmental stimuli, which can interfere with the achievement of goals (Dempster, 1992; Diamond, 2013; Mann, De Ridder, & Fujita, 2013). Even though in the literature there is a consensus on the importance of inhibition –due to the findings about its participation in the development of other executive functions (e.g., flexibility and planning; Davidson, Amso, Anderson, & Diamond, 2006; Diamond, 2013, 2016) and more complex skills (e.g., reading comprehension, learning of mathematics, self-control; Blair & Razza, 2007; Borella, Carretti, & Pelegrina, 2010; Borella & De Ribaupierre, 2014; Espy et al., 2004; Hofmann, Schmeichel, & Baddeley, 2012; Pimperton & Nation, 2010), as well as its participation in the semiology of different psychopathological disorders (e.g., externalizing behaviors disorders; Volckaert & Noël, 2015, 2016)– there is an important debate about its structure (Diamond, 2016; Howard, Johnson, & Pascual-Leone, 2014; I. M. Introzzi, Canet Juric, Aydmune, & Stelzer, 2016). In this debate, different postures are observed, which can be grouped in two general categories (Diamond, 2016; Howard et al., 2014; I. M. Introzzi et al., 2016). On the one hand, the approaches understood as a unique and indivisible process, that is to say, as a one-dimensional construct (non-unitary posture; e.g., Dempster, 1992; C. MacLeod, 2007; C. M. MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003); on the other hand, the ones which argue that inhibition constitutes a multidimensional construct, raising the existence of a family of inhibitory processes (non-unitary posture, e.g., Friedman & Miyake, 2004; Howard et al., 2014; I. M. Introzzi et al., 2016). Although there are discrepancies in this framework in relation to which ones and how many processes can be identified, there is an agreement on distinguishing three inhibitory types (Friedman & Miyake, 2004), which would act at different levels of the information processing: *perceptual inhibition, cognitive inhibition and response inhibition* (the terms can vary according to the model and/or the author). Perceptual inhibition refers to the ability to reduce the interference from information in the external environment that is irrelevant to the task at hand, by facilitating attentional focus about the relevant ones. It would take place at a perceptive level, in an initial perceptual stage of processing (Diamond, 2013; Friedman & Miyake, 2004; Hasher, Lustig, & Zacks, 2007; Tiego, Testa, Bellgrove, Pantelis, & Whittle, 2018). Cognitive inhibition allows to suppress the irrelevant information of the working memory, which interferes with the actual activity. Working memory (other main executive function; Diamond, 2013) allows to hold information in mind and to manipulate it to solve a task (Conway, Jarrold, Kane, Miyake, & Towse, 2007). Irrelevant information may be information that eluded to the perceptual inhibition, but was subsequently recognized as irrelevant, or information that was relevant in a previous situation, but that is not relevant in the current one (Diamond, 2013; Friedman & Miyake, 2004; Hasher et al., 2007). It would take place at a more intermediate level. Finally, response inhibition implies the suppress of predominant but inappropriate responses, that is to say, it would correspond to a later output stage of processing in which relevant responses must be selected and incorrect ones resisted (Diamond, 2013; Friedman & Miyake, 2004; Tiego et al., 2018).

Within the main research that contributes empirical support to the non-unitary posture, studies about the particular development trajectories of inhibitory processes and studies on the differential engagement in different skills are distinguished (I. M. Introzzi et al., 2016; Friedman & Miyake, 2004). In regard to the first group of works, their results suggest that perceptual inhibition and response inhibition would emerge simultaneously in the first years of life, while cognitive inhibition would do it in the preschool years (Gandolfi, Viterbori, Traverso, & Usai, 2014). The first two inhibitory types would present important changes in the preschool and school years (Carlson, 2005; Cragg & Nation, 2008; Garon, Bryson, & Smith, 2008; I. M. Introzzi et al., 2016; I. Introzzi et al., 2016), whereas cognitive inhibition would experiment important improvements during school years (Aslan, Staudigl, Samenieh, & Bäuml, 2010; Harnishfeger & Pope, 1996; Kail, 2002; Zellner & Baüml, 2004). These three inhibitory processes would continue their maturation during adolescence (Darowski, Helder, Zacks, Hasher, & Hambrick, 2008; Huizinga, Dolan, & van der Molen, 2006; I. Introzzi et al., 2016; Kail, 2002) and, in the case of response inhibition, until early adulthood (Bezdjian, Tuvblad, Wang, Raine, & Baker, 2014; Vara, Pang, Vidal, Anagnostou, & Taylor, 2014; Van Gerven, Hurks, Bovend'Eerdt, & Adam, 2016). In short, these processes would have particular development trajectories and would experiment considerable changes during childhood and adolescence. Several authors suggest that during childhood, inhibitory processes involved independent constructs, but they are related. For example, different researchers distinguished (through confirmatory factor analysis) response inhibition and perceptual inhibition in preschool and school-children (e.g., Gandolfi et al., 2014; Traverso, Fontana, Usai, & Passolunghi, 2018; Tiego et al., 2018). Meanwhile, the authors of a revision (which contains development studies of inhibitory processes) suggest that three inhibitory processes are differentiated in the first years of school period (I. M. Introzzi et al., 2016).

In relation to the differential engagement of these processes in diverse skills along the development, it has been found that response inhibition is related to linguistic skills –lexical and syntactic– at about three years old (Cozzani, Usai, & Zanobini, 2013). Cognitive inhibition and perceptual inhibition have also been linked to reading comprehension of texts during primary school years (Borella et al., 2010; Borella & De Ribaupierre, 2014; Demagistri, Canet, Naveira, & Richard's, 2012). Finally, during primary and secondary school years, relations between perceptual inhibition and response inhibition with working memory have been observed (Canet Juric, Andrés, Demagistri, Mascarello, & Burin, 2015). However, even though the importance of the inhibition to the development and functioning of the fluid intelligence (FI) is recognized (Dempster, 1993; Diamond, 2013, 2016; Michel & Anderson, 2009), there is no registered evidence about the differential relation of inhibitory types with this capacity. FI refers to the capacity of using mental operations deliberately and in a controlled way to solve new problems, which cannot be solved automatically from prior knowledge (Cattell & Horn, 1978). These mental operations include, for example, concept formation, classification, contrast and generation of hypothesis, identification of relationships, among others (McGrew, 2009). FI emerges during the third year of life, increasing quickly during childhood (McArdle, Ferrer-Caja, Hamagami, & Woodcock, 2002). FI would act as a support for cognitive development and the learning of specific knowledge, and it is also considered a predictor of academic and job performance (Alloway & Alloway, 2010; Ferrer, O'Hare, & Bunge, 2009; Stelzer, Andés, Canet-Juric, & Introzzi, 2016).

Several authors have proposed that the changes in the efficiency of inhibitory processes explain the improvements in intelligence over the course of childhood (Dempster, 1992, 1993; Dempster & Corkhill, 1999; Michel & Anderson, 2009). However, studies in child population that explores the relation between the inhibition and FI do not consider simultaneously different inhibitory processes and, generally, they study what here is defined as response inhibition –from a non-unitary perspective, or from a unitary perspective, because it is the mechanism that many simply refer to as "inhibition" (Hasher et al., 2007). For example, Zhao, Chen, and Maes (2016) observed relations between response inhibition and FI in children in primary education. Duan, Wei, Wang, and Shi (2010) found that working memory and, as a lesser extent inhibition, predict FI in 11 to 12-year-old children. Michel and Anderson (2009) noticed that the changes in the development of inhibition are linked to the changes in FI in school children. In a different direction, Arán Filippetti, Krumm, and Raimondi (2010) did not find any association in school children but they did in teenagers. In fact, response inhibition during childhood has been trained finding in some cases some kind of effect on the resolution of FI tasks (e.g., Liu, Zhu, Ziegler, & Shi, 2015), and, in others, lack of benefits (e.g., Zhao et al., 2016).

Concerning perceptual inhibition, some studies analyzed its relationship with FI. Stelzer (2014) found that perceptual inhibition (along with working memory and planning) predicts the FI performance in children from 79 to 89 months, while Zhao and Jia (2018) did not find effects on FI after a training on perceptual inhibition in children from 10 to 12 years old.

Finally, relations between cognitive inhibition and FI in child population can be deduced from the few studies in which there was an intervention on this process, which have found effects on FI (e.g., Y. Aydmune, Introzzi, & Lipina, 2019). However, in literature there are not studies in this population that analyze specifically the relation of cognitive inhibition with FI. Available studies with adult population show different results with each other, finding in some cases a relationship between them (e.g., Burgess, Gray, Conway, & Braver, 2011), as in others it does not happen (e.g., Borella, Carretti, & Mammarella, 2006).

It is understood that the results are contradictory (Arán Filippetti et al., 2010), and, at the same time, the studies about what is defined here as response inhibition predominate. Some authors suggest that the inhibitory processes could contribute to FI in different ways (Dempster & Corkhill, 1999; Liu et al., 2015; Sala & Gobet, 2017; Stelzer et al., 2016). At a perceptual level, inhibition would allow to suppress the interference of environmental stimuli that are irrelevant for the resolution of actual problems. In turn, inhibition could suppress irrelevant information of working memory (cognitive inhibition), allowing only the maintenance and processing of relevant information for the task (for example, rules or patterns of relationships). Finally, at a behavioral level, inhibition would suppress prepotent and inappropriate behaviors for the resolution of the activity that FI demands.

Although the three inhibitory types would result important for the suitable performance in a FI task, it is possible that the relation of each one with this last one is differential. In other words, that by following the postulates of the non-unitary approach of inhibition, perhaps some is linked greater than the others. However, this remains at the hypothetical level, since there are not studies in which the relation of the three inhibitory processes with FI is analyzed simultaneously. In turn, such inquiry is especially important during the first school years, since in this stage: (a) inhibitory processes would already be differentiated (Gandolfi et al., 2014), (b) inhibitory processes and FI would experiment notable changes in their development, and (c) all of them are linked to the performance of children in the school setting (e.g., Borella et al., 2010; Ferrer et al., 2009).

For these reasons, the goal of this work is to study the relation and contribution of perceptual, cognitive, and response inhibition with FI, in children in the first years of primary school. For that purpose, a sample of children from six to eight years old was tested with inhibitory (perceptual, cognitive, and response inhibition) and FI tasks, waiting to find differential relations according to the non-unitary perspective of inhibition.

2. Method

2.1 Research Design

A non-experimental, cross-sectional, correlational-causal design wad used (Campbell & Stanley, 1995; Hernández, Fernández Collado, & Baptista Lucio, 2015).

2.2 Participants, Ethical Considerations and Procedure

A hundred ninety-seven children from six to eight years old from two primary schools of the city of Mar del Plata (Argentina) participated in this study. This work is part of one of the authors' doctoral dissertation. All the procedures were evaluated and approved by an ethics committee –Comité de Ética del Programa Temático Interdisciplinario en Bioética, Secretaría de Ciencia y Técnica del Rectorado de la Universidad Nacional de Mar del Plata (UNMdP)– and two institutional review boards –Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET); Comité del Doctorado en Psicología, Facultad de Psicología, UNMdP. Parents/caregivers had to sign an informed consent and children had to give their assent to participate. Participants were included according to the following criteria: non-repeating students, absence of developmental, psychological and/or psychiatric disorders, and with normal or corrected vision and hearing. The information was collected through a sanitary file that children's parents/caregivers completed. Nineteen cases were excluded from data analysis because they did not meet with the inclusion criteria; therefore, we worked with a sample of 178 participants (95 girls, 83 boys; age $M = 6.84$, $SD = 0.83$; primary school students from first grade $n = 67$, second grade $n = 63$, third grade $n = 48$). Sample size was calculated using G*Power and according to the lineaments that Pértegas Díaz and Pita Fernández (2002) describe. In both, the estimation was based on the following data: alpha error probability= .05; power =.80; expected Pearson's lineal correlation coefficient $r = 0.2$. A minimum of 149 participants was determined. In addition, with significant correlations, data analysis planned involved a multiple regression analysis. Consequently, sample size was calculated again using G*Power (same alpha error probability and power, three predictor, and $R^2 = 0.2$). Results indicated that sixty-one cases were necessary. In view of the above, a sample of 178 participants was appropriate. Four tasks (inhibitory tasks and a FI task; see Materials) were administrated in random order to all children, in two individual sessions, at school in an appropriate room. The researchers verified the understanding of tasks through practice trials on them.

2.3 Materials

2.3.1 Perceptual Inhibition Task

Perception of Similarities and Differences test (*Test de Percepción de Diferencias* revisado, CARAS-R; Thurstone & Yela, 2012). This is a paper and pencil task with 60 boxes, each of which contains three faces (simple drawings with elementary lines). Two faces are identical while the third is different. The participant is required to indicate with a cross, as quickly and accurately as possible, the different face in each box (during three minutes). In other words, the participants must find relevant stimulus in a larger set of stimuli that can operate as distracters. As a result, it allows to asses perceptual inhibition of the distracting information (Stelzer, 2014). Before task six practice trials are presented. Hits net –number of hits minus number of errors– was employed as dependent variable. This test showed adequate levels of reliability (internal consistency $\alpha = 0.91$), convergent and divergent validity in normative data sample (Ison & Carrada, 2012).

2.3.2 Cognitive Inhibition Task

This is a variant of the proactive interference task by Brown (1958) and Peterson and Peterson (1959). The activity employed here is an adaptation of the tasks designed by Borella, Carretti, and Lanfranchi (2013), as well as Christ, Kester, Bodner, and Miles (2011). The task has two blocks of four trials. In each of the blocks of this task, participants view four lists of four stimuli each (images with their corresponding verbal labels presented at a rate of one image every two seconds). The first three lists were taken from the same category, and the last list, which served as the "release from proactive interference" list, was taken from a different category. Between the presentation of each list and recall, participants completed a distracting task (to tell which of two numbers is the highest, during 16 s). After the distracter task, participants had to verbally recall as many of the four to-be-remembered items as possible. The words recalled are registered. In general terms, the task runs on a PowerPoint presentation. Before task a practice trial is presented. The images are standardized pictures designed specifically to be used with children. Familiar semantic categories for children were employed (e.g., animals and eating utensils). Also, familiarity and length of words were considered (Cycowicz, Friedman, Rothstein, & Snodgrass, 1997; Goikoetxea, 2000). On trails (lists) 2 and 3, participants had to overcome proactive interference associated with the semantically similar items from the previous trial. Inhibitory control was assessed by comparing memory performance on these "interference" trials with performance on trials 1 and

Table 1

Correlations between age, inhibitory processes and fluid intelligence

		Fluid intelligence	Perceptual inhibition	Cognitive inhibition (accuracy)	Cognitive inhibition (Intrusions)	Response inhibition
Age	*r*	.479	.491	-.034	.030	-.001
	p∗	.000	.000	.652	.690	.993

Note. * Level signification 0.01.

4 (which were not preceded by trials with semantically similar items). Performance was evaluated based on a participant's accuracy for items on the list (% correct) and the number of false positive (intrusion) errors. We use both variables as dependent variables. The activity fulfills the expected internal criteria according to the paradigm on which it was built (Y. S. Aydmune, Introzzi, Zamora, & Lipina, 2018) and shows adequate levels of convergent and divergent validity (Y. Aydmune et al., 2019).

2.3.3 Response Inhibition Task

This task is part of the Cognitive Self-Regulation Tasks computerized battery (*Tareas de Autorregulación Cognitiva* –TAC–; I. Introzzi & Canet Juric, 2012). It was built based on the Stop signal paradigm (Logan, Schachar, & Tannock, 1997; Verbruggen & Logan, 2009) and has two blocks. The first block has 32 *go* trials (and 10 practice trials), each trial starts with a fixation point (a cross during 500 ms) in the center of the screen, followed by an arrow pointing left or right (for 1000 ms). Participants must press a key according to the orientation of the arrow as quickly as possible. The second block has 72 trials (and 24 practice trials), 75% of them are *go* trials, and the other 25% are *stop* trials. Stop trials contain the same stimulus than the go trials, but also have a stop signal (audio signal) that indicates the participant that must inhibit the response. Stop-signal delay (the interval between the presentation of the go stimulus and the stop signal) was initially set at 250 ms and then adjusted dynamically depending on the subject's performance. The delay increased by 50 ms if the subject inhibited successfully and decreased by 50 ms if failed to inhibit. Response in stop trials might indicate that the participant –through inhibition– did not stop an ongoing response (Logan et al., 1997). The main performance index is Stop-signal reaction time (SSRT), which represents the latency of the response to the stop signal. SSRT can be calculated subtracting stop-signal delay from mean go reaction time (Schachar & Logan, 1990; Schachar, Tannock, Marriott, & Logan, 1995). The activity fulfills the expected internal criteria according to the paradigm on which it was built, and shows adequate levels of convergent and divergent validity (e.g., Richard's et al., 2017).

2.3.4 Fluid Intelligence Task

Raven's Colored Progressive Matrices Test (Raven, Court, & Raven, 1993) is made up of a series of diagrams or designs (36 designs, one per page) with a missing piece (with one practice trial). The participant is given six choices to pick from and fill in the missing piece. The dependent variable was the number of correctly solved problems. Different authors employed this test or similar as FI task (e.g., Duan et al., 2010; Liu et al., 2015; Zhao et al., 2016; Zhao & Jia, 2018). For this reason we used it here. This test shows adequate reliability (α= .898) and validity (Cayssials et al., 1993).

3. Results

Several authors suggest that three inhibitory processes and FI experience improvements in their evolution during childhood (I. M. Introzzi et al., 2016; Michel & Anderson, 2009). For this reason, first we analyzed the growth of them via correlations (Pearson's r coefficient) between age, inhibitory processes, and FI. Table 1 shows these results. Significant positive correlations between age and perceptual inhibition and between age and FI were observed. In other words, older children show better performances in perceptual inhibition and FI tasks.

Then, for the analysis of relationships between inhibitory processes and FI, we applied partial correlations (Pearson's r coefficient) controlling for age. Table 2 shows these results.

Subsequently, a multiple regression analysis, with perceptual and response inhibition (because we observed significant correlations between these inhibitory processes and FI) as predictors was applied. We did not include in the analysis the gender because a prior Student's t test showed absence of significant difference between the groups (female and male) respect to FI –t (176)= -.067; $p = .947$. Specifically, FI was entered like dependent variable, and age, perceptual inhibition, and response inhibition were entered all in once like predictor variables. A prediction statistically significant of the variables –F(3,172)=31.167, $p < .001$, $R^2 = .352$– perceptual inhibition (Beta=0.355, t=5.005, $p < .001$) and age (Beta=0.313, t=4.43, $p < .001$) was observed. Table 3 shows complete results. Before applying the statistical tests described above, we analyze the assumptions required for their implementation (Gardner, 2003).

Table 2

Partial correlations between inhibitory processes and FI controlling for age

Variables		Perceptual inhibition	Cognitive inhibition (accuracy)	Cognitive inhibition (Intrusions)	Response inhibition
Age FI	*r*	.367	.086	-.048	-.161
	p∗	.000	.129	.263	.017
	gl	173	173	173	173

Note. FI= fluid intelligence. *Level signification (unilateral) 0.05.

Type I error was controlled by the compliance with these assumptions and the control for age in correlations.

4. Discussion and Conclusions

This study aimed to analyze the relation and contribution of three inhibitory types –perceptual, cognitive and response inhibition– with FI in children in the first years of primary school. Following the postulates of the non-unitary approach of inhibition (e.g., Friedman & Miyake, 2004; I. M. Introzzi et al., 2016), it was anticipated that the contribution would be differential. The results of the correlation analysis suggest that the performance in perceptual and response inhibition is linked to the FI, while cognitive inhibition capacity is not associated with this ability. On the other hand, the regression model indicates that only the age and perceptual inhibition act as predictors of the FI performance. The finding on the age coincides with the development of this ability during primary school (Ferrer et al., 2009). The data on the contribution of perceptual inhibition coincide with the results of previous studies in children (e.g., Stelzer, 2014), and they are in line with those theoretical proposals that suggest that the ability to control interference at a perceptual level take part in the operations involved in FI (e.g., Dempster & Corkhill, 1999; McCall, 1994; McCall & Carriger, 1993; Stelzer, 2014). In this sense, inhibitory control at a perceptual level would promote the attentional focus on those elements that are relevant to the resolution of new problems, acting as the first process of voluntary control in the processing of information. However, this study is distinguished from other precedents. After analyzing simultaneously the relation of different inhibitory types with FI, it contributes empirical evidence on the specific contribution of perceptual inhibition.

In addition, although relations between response inhibition and FI were observed (e.g., Michel & Anderson, 2009; Zhao et al., 2016), the fact that response inhibition does not explain significantly part of the performance in the FI task suggests that its predictive value is low and that perceptual inhibition and age are more appropriate to predict this performance. In turn, low correlations between response inhibition and FI could be explained by the calculation of SSRT in stop signal task. There are two popular methods of estimating SSRT: mean (employed here) and integration methods. The mean method could overestimate SSRT differences between groups (Verbruggen, Chambers, & Logan, 2013). In other words, the relations between response inhibition and the groups could be spurious and integration method could be more appropriate. However, as mentioned above, the correlations are low and response inhibition does not explain significantly part of the performance in the FI task. Consequently, the overestimation bias could be low in this case. Verbruggen et al. (2013) suggest that both methods could be affected by the gradual slowing of RTs. However, in stop signal of the TAC (I. Introzzi & Canet Juric, 2012), this slowing of reaction times is reduced by clear instructions, feedback (a signal appears when the subject slows your reaction time), and the number of trials. Anyway, it is important that futures studies use the integration method to compare results.

Given the link raised between FI and working memory (e.g., Duan et al., 2010; Sala & Gobet, 2017), and being cognitive inhibition a process that contributes to the optimal performance of this last one (Diamond, 2013, 2016; Friedman & Miyake, 2004; Hasher et al., 2007), it was expected to find relations between cognitive inhibition and FI. Contrary to expectations, relations between them were not observed. Perhaps the results are due to a real lack of relations between cognitive inhibition and FI.

In any case, given that this work results unique in the study of the differential relations of three inhibitory processes with FI in child population, it seems necessary to continue with this inquiry. Thus, future investigations could use other tasks to measure each process studied in order to analyze if the results found are kept. In this sense, an alternative explanation for contribution from perceptual inhibition to FI is the similarity of the two tasks: both require observation of line features and they are paper and pencil tasks. In turn, the materials and task requirements of cognitive and response inhibitions are more different from FI task (e.g., the inhibitory tasks are computerized and response inhibition index involves RTs).

Table 3

Partial correlations between inhibitory processes and FI controlling for age

Model	R	R^2	R^2 corrected	Variables	Beta	t	$p*$
	593	.352	.341	(Constant)		2.540	.012
				Perceptual inhibition	.355	5.005	.000
				Response inhibition	-.106	-1.724	.087
				Age	.313	4.430	.000

Note. Dependent variable: Fluid Intelligence; predictor variables: Perceptual Inhibition, Response Inhibition and Age.
*Level Signification 0.05

Also, here a measure of FI derived from standardized tests was used. This test is away from the children's everyday life (McCoy, 2019). It is a common limit to different studies (e.g., Liu et al., 2015; Zhao et al., 2016; Zhao & Jia, 2018). For this reason, the knowledge about the relationships between inhibition and FI in the daily life of children is still insufficient, and it is fundamental to the development and incorporation of these measures in futures studies. Likewise, the analysis of different levels of organization could be incorporated –for example, neural and cognitive (e.g., Liu et al., 2015)–, which would contribute to the understanding of the underlying mechanisms.

It is also important to replicate the study with samples from different contexts, and to analyze if the results can be generalized.

In summary, beyond these limitations, this work contributes in several ways. Firstly, it gives evidence on the relation of inhibition with FI in childhood, which is discussed given the contradiction of some results (Arán Filippetti et al., 2010). Secondly, this study provides data about the specific contribution, during childhood, of an inhibitory type –perceptual inhibition– to FI. According to literature, both experience changes during this stage, and at the same time they are important for children's performance, for example, in the school setting (Diamond, 2013, 2016; Ferrer et al., 2009; Michel & Anderson, 2009). Then, the understanding of the relation and specific contribution with FI can lead to the development of interventions on this process, aimed at preventing difficulties associated to FI and other related abilities (Arán Filippetti et al., 2010; Y. Aydmune, Lipina, & Introzzi, 2017; Sheese & Lipina, 2011). Thirdly, the study contributes empirical evidence in support of the non-unitary approach of inhibition, since perceptual inhibition, unlike cognitive and response inhibition, would explain partly the development of FI. These results are in line with a group of findings about differential participations of inhibitory processes in other executive functions and more complex skills (Friedman & Miyake, 2004; I. M. Introzzi et al., 2016).

It is expected that future research can go more deeply into knowledge about inhibitory processes in childhood, since they constitute essential components for the development and functioning of other skills, important for children's daily performance.

5. Disclosure of interest

The authors report no conflict of interest.

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