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Sex differences in response inhibition in young children

Competence in inhibiting prepotent responses has been frequently shown to be higher in females than in males in both children and adults. However, not all the inhibitory tasks seem equally sensitive to sex at each age. We investigated sex differences in two developmentally appropriate inhibitory tasks, the EYT Go/No-go and the Shape School Inhibition Condition. Our sample consisted of 160 preschool children, 85 boys and 75 girls, ranging from 4 to 6 years old. Girls' efficacy in inhibiting prepotent motor responses in the Go/No-go task was higher than boys', but not in the verbal Shape School inhibition task. Sex differences in inhibitory tasks are discussed in light of the different task requirements.

Keywords: executive functions; inhibition tasks; sex differences; preschool children.

Introduction

Response inhibition is an important component of executive functioning that deals with suppression of motor or cognitive processes that are no longer appropriate or relevant (Diamond, 2013). Sex differences in the ability of inhibiting prepotent responses are apparent as early as 22 months of age (Kochanska et al., 2000) with girls showing higher competence than boys. Nevertheless, sex effects in inhibition are inconsistently found across studies, tasks and ages (Cross, Copping, & Campbell, 2011; Grissom & Reyes, 2018; Malagoli & Usai, 2018). The main goal of this study was to explore sex differences in inhibition in preschool children and to explore the role of prepotency as a source of those differences.

Executive Function

Executive functions (EF) are a set of top-down cognitive processes that allow us to regulate our emotions, thoughts, and behavior, and are most relevant during novel situations (Gioia, Isquith, Guy, & Kenworthy, 2000; McCloskey, 2009; Miyake & Friedman, 2012). The three core, most commonly considered EF skills are inhibition, working memory or updating, and shifting or mental flexibility (Diamond, 2013; Miyake et al., 2000; Miyake & Friedman, 2012). Higher-order EF, such as problem-solving capacity and planning, are built from these core skills (Diamond, 2013). In Miyake's study, using confirmatory factor analysis (CFA) in adults, the three core skills emerged as distinct but strongly correlated EF dimensions (Miyake et al., 2000). CFA in older children and adolescents revealed similar findings (Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003). However, in early childhood and preschoolers, the findings differ, with a single (Hughes, Ensor, Wilson, & Graham, 2010; Nelson et al., 2016; Wiebe, Espy, & Charak, 2008; Wiebe et al., 2011) or two-factor models (Miller, Giesbrecht, Müller, McInerney, & Kerns, 2012) emerging as the best-fit models. In late preschool children, inhibition appears as a separate EF dimension apart from a working memory-flexibility factor (Usai, Viterbori, Traverso, & DeFranchis, 2014). Results in verbal and spatial working memory tasks are associated with inhibitory measures across the preschool years (Traverso, Mantini, Usai, & Viterbori, 2015; Wiebe, Sheffield, & Espy, 2012) but the nature of the relationship between these dimensions is not completely clear yet. Specifically, between 3 and 5 years of age, major improvements occur in both inhibition and working memory abilities (Garon et al., 2008). Hence, it seems that preschool years represent an important period for the development of EF, particularly for inhibitory control, and its relation with working memory (Carlson, 2005).

Inhibition

Inhibition enables one to control their cognitive processes, behavior, and emotions to override a prepotent response and perform a more appropriate action (Diamond, 2013). Inhibition is best seen as a family of functions (Dempster, 1991, 1992; Nigg, 2000) that emerges in early infancy and continues its development until late adolescence (Diamond, 1990; Kochanska, Murray, & Coy, 1997; Malagoli & Usai, 2018).

Response inhibition is one of the inhibitory components that first differentiates in toddlers and it is possible to evaluate these components from early ages (Gandolfi, Viterbori, Traverso, & Usai, 2014). The ability to suppress a dominant response at 22 months was linked to more regulated anger, joy, and stronger restraint at 33 months of age (Kochanska, Murray, & Harlan, 2000). Individual differences in response inhibition, in children aged 4-6 years, were significantly correlated with the children's ability to regulate their behavior and emotions (Carlson & Wang, 2007; Oeri, Voelke, & Roebers, 2018) and also influence reading comprehension through word decoding (Haft et al., 2019).

On the other hand, deficits in response inhibition are common in neurodevelopmental disorders such as attention-deficit/hyperactivity disorder (ADHD; Barkley, 1997; Nigg, 2001; Nikolas & Nigg, 2013; Schachar, Tannock, & Logan, 1993; Schachar, Tannock, Marriot, & Logan, 1995) and autistic spectrum disorders (Ciesielski & Harris, 1997). Several studies link response inhibition deficits to inattention, impulsivity, and other behavioral problems in children as well as in adolescents and adults (Bari & Robbins, 2013; Brocki, Eninger, Thorell, & Bohlin, 2010; Sjöwall et al., 2017). Thus, more profound knowledge of the responsible mechanisms for response inhibition and the relation between inhibition and other cognitive abilities, in healthy and non-healthy children, should lead to a better comprehension of these disorders.

Different inhibitory tasks depend on several inhibitory processes. As an attempt to validate previous taxonomies of inhibition functions and processes (Nigg, 2000), Friedman and Miyake (2004) did a latent variable analysis on the results of nine different inhibitory tasks performed by adults. The tasks were chosen to represent the three inhibition constructs they proposed: Prepotent Response Inhibition, the ability to intentionally suppress dominant, automatic, or prepotent responses; Resistance to Distractor Interference, the ability to resist interference from external information irrelevant to the task; and Resistance to Proactive Interference (PI), the ability to resist memory intrusions irrelevant to the task. Results suggested that Prepotent Response Inhibition and Resistance to Distractor Interference, were closely related to each other, but neither was related to Resistance to PI (Friedman & Miyake, 2004). More recently, a study tested the latent structure of inhibitory processes in children aged 24-32 and 36-48 months. In children around 4 years old, a two-factor model emerged with prepotent response inhibition and interference suppression as differentiated inhibition factors. The authors concluded that prepotent response inhibition processes are present from an early age and that the more challenging interference suppression arises later in development due to higher working memory demands (Gandolfi et al., 2014). Therefore, it is possible to gather that working memory load differentially interferes with interference suppression tasks and response inhibition tasks.

Measures of response inhibition estimate the capacity to withhold or delay a prepotent response to a presented stimulus (Schneider & Shiffrin, 1977; Simpson, Upson, & Carroll, 2017). Children become progressively capable of suppressing inappropriate prepotent responses during the preschool years (Kochanska, Murray, &

Harlan, 2000; Simpson & Riggs, 2005; Wiebe et al., 2012), showing accuracy increases of 30% between age 3 and 5 (Wiebe et al., 2012). Overcoming the prepotent responses in response inhibition tasks, usually has a cost. This cost reflects in either a longer time taken to complete the task, a decrease in response accuracy, or both (Logan & Cowan, 1984). Several studies on prepotent response inhibition in children use developmentally appropriate tasks such as Go/No-go tasks (Miller, Giesbrecht, Müller, McInerney, & Kerns, 2012; Simpson & Riggs, 2006; Wiebe et al., 2012). In these tasks, participants are asked to respond to one stimulus or class of stimuli (the Go stimulus) and to withhold the response to another stimulus (the No-go stimulus). Non-response to the No-go trials requires inhibition of a prepotent response (Livesey & Morgan, 1991). Response to the Go stimulus is made prepotent due to the higher number of Go trials presented, compared to the No-go trials, and to the time pressure to respond (Logan, 1994; Simpson & Riggs, 2006). Increasing the ratio of Go to No-go trials increases the prepotency and consequently the number of responses to No-go trials, the so-called errors of commission, reducing accuracy (Durston, Thomas, Worden, Yang, & Casey, 2002). Presentation time is also an important variable influencing the inhibition task outcome. If the amount of time given to respond is too short, participants may not have enough time to respond either to Go or to No-go trials. If the presentation time is too long then the time pressure to respond decreases and consequently, the prepotency may be easily overcome increasing accuracy (Simpson & Riggs, 2006).

Sex differences in cognition and behavior

There is abundant research on sex differences in cognitive skills. Consensus exists around some cognitive areas such as male superiority in visuospatial tasks and female advantage in verbal tasks (Halpern, 2000), including reading comprehension (Chiu & McBride-Chang, 2006) and reaction time. As with other cognitive and behavior variables, sex differences in reaction time were found in some studies but not in others (Roivainen, 2011). There are few studies with preschool and school-aged children, but differences in reaction time at these ages seem more consistent, with males showing faster RTs than females (Dykiert, Der, Starr, & Deary, 2012; Goodenough, 1935).

Sex differences in cognition and behavior might emerge from differences in brain networks and neurotransmission, as resulting from developmental factors (such as hormones), culture, and/or from evolutionary trends (Bjorklund & Kipp, 1996; Hosseini-Kamkar & Morton, 2014). As these factors all interact during development it is difficult to disentangle the role each of them has in cognitive and behavioral differences.

Studies on sex differences in brain volume have consistently found an approximate 8-10% total volume larger in males (De Bellis et al., 2001; Goldstein et al., 2001). Although males tend to have larger brains, developmental trajectories found that gray matter volume in several cortical areas, particularly the frontal lobes, peak sizes 1 to 2 years earlier in females than in males (Lenroot et al., 2007). Given the frontal lobes involvement in control and inhibition (Aron, Robbins & Poldrack, 2014) differences in cortical development could arguably be related to sex differences in control during development.

Sex differences in response inhibition

Measures of inhibitory behavior are commonly reported as being sensitive to sex differences (Bezdjian, Baker, Lozano, & Raine, 2009) although results differ across age ranges and for different inhibitory tasks (Cross, Copping, & Campbell, 2011; Grissom & Reyes, 2018). There has been significant debate regarding sex differences in inhibition in adults. Some studies find sex differences in inhibition in the adult population, with women outperforming men in tasks requiring prepotent response inhibition (Mansouri, Fehring, Gaillard, Jaberzadeh, & Parkington, 2016; Sjoberg & Cole, 2018), while others show differences in neurophysiological measures but not in behavioral responses (Li, Huang, Constable, & Sinha, 2006; Li et al., 2009) or no differences at all (Kertzman, Fluhr, Vainder, Weizman, & Dannon, 2018; Thakkar et al., 2014).

Not all response inhibition tasks seem equally sensitive to sex differences. Malagoli and Usai (2018), studied response inhibition in two samples of adolescents, 14-16 and 16-19 years old, and found that sex differences were only present in the younger sample and only in one of the tasks. At this age, girls' efficacy inhibiting a response in a Stop signal task was higher but not in a Go /No-go task.

There is substantial evidence that girls' competence in inhibiting prepotent responses is higher than boys'. Differences are apparent as early as 22 months of age (Kochanska et al., 2000). Later, during preschool and school years, boys tend to display poorer response inhibition than girls in some tasks but not in others depending on the age of the participants (Klenberg, Korkman, & Lahti-Nuuttila, 2001). Particularly in Go/No-go tasks, girls commit fewer commission errors than boys in most preschool studies (Grammer, Carrasco, Gehring, & Morrison, 2014; Liu, Xiao, & Shi, 2013; Memisevic & Biscevic, 2018; Wiebe et al., 2012). Wiebe and collaborators found an exception to this pattern in a 3-year-old sample. They tested four response inhibition tasks and sex differences were only apparent in one, the Snack delay, where children had to refrain from eating candies placed in front of them until the examiner rang a bell (Wiebe et al., 2011).

Such lack of consistency in findings, from such similar response inhibition tasks, might originate from differences in the age of the participants and/or from the task requirements and different cultures (Holding et al., 2018; Schirmbeck, Rao & Maehler, 2020). Factors affecting response inhibition tasks include parameters affecting prepotency (Simpson et al., 2017) such as the modality of response, the ratio of Go versus No-Go, the time available to respond, and working memory load (Howard, Johnson & Pascual-Leone, 2014).

Some of these factors and parameters may affect boys and girls differently. Differences in response inhibition, and also impulsivity, have been said to depend on reaction time (Bezdjian et al., 2009). Because boys have faster reaction times, premature responses to the stimulus are more likely to occur without inhibition being unleashed. Following this view, one should expect a boy's performance to suffer relatively more than a girl's in tasks where the time available to respond is shorter.

Sex-related differences in response inhibition are also evident in clinical samples. Neurodevelopmental disorders, presenting with deficits in inhibitory processing, such as ADHD, are more likely to be diagnosed in boys (Hasson & Fine, 2012; Morgan, Staff, Hillemeier, Farkas, & Maczuga, 2013). Moreover, in ADHD samples, boys demonstrate more impulsivity than girls in some (Hasson & Fine, 2012; Newcorn et al., 2001), but not all the studies published so far (Nøvik et al., 2006).

These conflicting results, both in clinical and non- clinical samples, highlight the need of finding the origin and impact of sex differences in inhibition. Knowing in which circumstances, if any, it is harder for boys to control prepotent responses and impulsivity can help us find ways to deal with it.

The present study

The main goal of this study was to explore sex differences in response inhibition in preschool children from 4 to 6 years old and analyze the possible role of prepotency as a source of those differences.

The assessment protocol for this study included two developmentally appropriate and widely used response inhibition tasks: the Go/No-go task from the Early Years Toolbox (EYT, Howard & Melhuish, 2017; Howard & Okely, 2015) and the Inhibit Condition task from the Shape School (Espy, 1997). Both these tasks have been postulated to put strong demands in inhibitory control but low demands in working memory (Wiebe et al., 2011). These two response inhibition tasks differ in the prepotency levels and elicit different responses, a motor response (Go/No-go EYT; Howard & Melhuish, 2017) and a verbal one (Shape School; Espy, 1997).

The Go/No-go (EYT) task requires participants to withhold a motor response to a stimulus presented at No-go trials ("avoid the sharks"). There is a time limit of 1000 ms to respond to the stimuli. The prepotent tendency to respond is generated by a majority of Go trials (75%) in which the child is required to respond to a certain stimulus ("catch the fish").

In the Inhibit Condition from the Shape School, the child is required to name the happy faces and to inhibit a verbal response to the sad faces and there is no time limit to do so. The prepotency of the color-naming response arises from a first condition, the Naming condition, where all the 15 stimuli presented are to be named. In the Inhibit condition, there are almost 54% (7/15) items with sad faces, the No-go trials. To the best of our knowledge, sex differences have not been reported for the Shape School task but reasons for that discrepancy with other Go/No-go tasks were not discussed previously.

Due to higher prepotency levels in the EYT Go/No-go task than in the Shape School Inhibit condition, caused by the larger proportion of Go trials and by the time constraints to answer, we expected larger sex differences in the EYT Go/No-go than in the Shape School Inhibit Condition. A visuospatial working memory task was introduced in the protocol to explore the contribution of working memory capacity in the inhibitory tasks.

Method

Participants

A sample of 191 preschoolers participated in this study. Only children that were born full-term scored above the fifth percentile on the Coloured Progressive Matrices Test (CPM; Raven et al., 2009), spoke Portuguese as a first language, and had no history of neurological or behavioral disorders were included in this study. Thirteen participants that did not meet these criteria were excluded. Data from further eighteen children were not included due to being non-responsive (Go accuracy below 20% and No-go accuracy above 80%) or indiscriminately responsive (Go accuracy exceeds 80% and No-go accuracy under 20%) in all three blocks of trials in the Go/No-go task (n=6), equipment (iPad) failure (n=4) and being non-collaborative in one or more of the tasks (n=8). Our final cohort for analysis was composed of 160 typically developing children from 6 preschools of the Lisbon metropolitan area (Portugal) with ages ranging from 4 to 6 years old (M=65.16; SD=4.84; in months), 53% (n = 85) are boys. Regarding parental education level, 74% of the participants' mothers have a high school degree, of which 21% held postgraduate degrees.

Measures

The assessment protocol was set up to measure executive functions, working memory and abstract reasoning, by including the following instruments:

Shape School (Inhibition Condition)

The Shape School test measures executive functioning in preschool-aged children (3 to 5 years old). This task was originally designed by Espy (1997) and uses a colorful storybook with figures of different colors and shapes attending a school. The language ability to name colors and understand the executive Shape School task is fully developed at these ages and should not significantly interfere in performance (Pritchard & Woodward, 2011; Rato, Ribeiro, & Castro-Caldas, 2018). The story begins by setting up the premise, showing stimulus figures playing on a playground, and then going on to different school activities throughout the story (see Espy, 1997; Espy & Bull, 2005, for a more thorough description).

The Shape School has four experimental conditions, that are presented in a fixed order: (A) control; (B) inhibit; (C) switch; and (D) both. Each test condition is preceded by a practice trial to ensure adequate rule knowledge and only the children who name the stimuli correctly, proceed to the next test trial.

In condition A (control), children are told that the names of the shape stimuli attending school are red, blue, or yellow and are asked to name the 15 stimulus figures that are arranged in three lines of five across the page. This condition serves primarily as a baseline measure of processing speed and it also creates a prepotent naming response.

In condition B (inhibit), eight of the stimulus figures are shown with happy faces, whereas the remaining seven have a sad and/or frustrated expression. Children are told that in this classroom situation, the figures with happy faces have finished their work and are ready for lunch, whereas those with unhappy faces are not. Correct responding in this condition requires a child to name the colors of the happy-faced stimuli while suppressing those associated with the unhappy faced stimuli.

For this study we only used conditions A and B. Condition A creates a prepotent naming response and sets a baseline measure for processing speed. Condition B accesses the ability to inhibit a verbal prepotent naming response.

Both the time taken to name all the stimuli in each condition and the number of stimuli correctly named are recorded. For each condition, an efficiency score is calculated by the number of correct answers on the reaction time for the condition (Efficiency = # Correct/Total Time). Here, we use the Portuguese version developed by Rato, Ribeiro & Castro-Caldas (2018), and selected the efficiency score and the percentage of correct suppression responses in Condition B as dependent variables. All the children completed the task.

Fish-Shark (Go/No-go task)

The Fish-Shark is an iPad-based assessment of children's inhibition developed by the Early Years Toolbox (EYT, Howard & Melhuish, 2017). In this task, fish and sharks swim across the screen, and children are instructed to catch the fish by tapping the screen whenever they see a fish and refrain from tapping when a shark appears, i.e., children have to avoid the sharks (Howard & Okely, 2015). Firstly, the participants are administered a brief practice session to ensure the task is fully understood. To generate a prepotent tendency to respond, 80% of the trials were Go-Fish trials (hits) and 20% were No-Go-Sharks. Each trial involves the presentation of an animated stimulus (i.e., fish or shark), in pseudo-random order, for 1,000 ms and separated by a 1,000 ms interstimulus interval. Seventy-five stimuli were applied, divided into three blocks, of 25 trials each, separated by a short break to give or reiterate instructions.

The inhibition response is assessed by the proportional accuracy on Go and No-go trials. Go accuracy is the mean proportion of correct hits and is a measure of the capacity to correctly detect a Fish and touch it during the available time. Go RT is the mean time taken to touch a detected Fish. No-go accuracy is the mean proportion of correctly non answered Sharks and is a measure of the ability to detect a stimulus and inhibit a motor response. No-go RT is the mean time taken to touch the Sharks (false alarms). Reaction time (RT) was calculated for each participant. Trials with responses faster than 300 ms were eliminated from the analysis and all blocks in which the child was largely non-responsive (Go accuracy below 20% and No-go accuracy above 80%) or indiscriminately responsive (Go accuracy exceeds 80% and No-go accuracy under 20%) were also removed. The proportion of hits (correct Go trials) and false alarms (incorrect No-go trials) were used to calculate the d' sensitivity index (Macmillan & Creelman, 2005), where higher values reflect better discrimination between two classes of stimuli. The d' is a statistic used in signal detection theory to measure the sensitivity in detecting a signal (a fish) compared to another one (a shark). The d' was calculated by subtracting the z-score value of the false alarm (commission error) rate from the z-score of the correct hit rate. Five children did not complete the task. Internal consistency was calculated with Cronbach´s alpha both for the total sample and for each group separately. The Cronbach alpha for the total sample was 0.76 which was comparable in boys (0.79) and girls (0.73).

Corsi Block-Tapping (visuospatial span task)

Working memory was assessed with the Portuguese version of the Corsi Block-Tapping test from Coimbra's Neuropsychological Assessment Battery (Simões et al., 2017). We used the classic wooden board, containing nine blue blocks placed at fixed, pseudorandom locations (Corsi, 1972). Both forward and backward conditions were applied, much like the spatial span subtest of the Wechsler Memory Scale (Wechsler, 1997). After engaging in two practice trials with two blocks, children are instructed to repeat successively larger sequences of blocks. At each difficulty level, two different trials of the same number of blocks are presented. The task ends once the child fails to successfully repeat two trials of a given sequence. Participants are given a point for each correct sequence. All the children completed the task. The use of this task will allow us to analyze the working memory contribution to the inhibition tasks under study.

Raven's Coloured Progressive Matrices

Raven's Coloured Progressive Matrices (RCPM) are widely considered as a test to measure intelligence defined as the ability to identify logical relationships within different elements and to generate the abstractive rules to organize them. The RCPM was administered individually, without time limit, in the book format, according to the manual (Raven et al., 2009). Children were asked to choose the missing element in a drawing from six options. One point was given for each correct answer, and the total score was the sum of the correct answers, with a maximum score of 36.

Procedure

This study is part of a larger research project on pre-school executive functioning approved by the Ethics Committee of the host institution. Written informed consent was obtained from parents of all participants before testing. The data collection was conducted between November 2017 and February 2019 and took place in the children's school in a room reserved for this purpose. Trained psychology graduates administered the assessment protocol and the order of the tasks was counterbalanced.

Data analysis

The data analysis was conducted with SPSS Statistics 24 for Windows (IBM Corp., Armonk, NY). Demographic and cognitive measures were analyzed between sex groups with independent two-tailed *t*-tests, Mann-Whitney U-test, and Chi-square, according to the distribution of the variables, to detect sex differences. Effect sizes (Cohen's d) are also given. To estimate possible differential effects of working memory (Corsi) in inhibitory measures where sex differences were found, Pearson's coefficient and Spearman's rank-order coefficient were used, and the correlation coefficients were compared between groups (Diedenhofen & Musch, 2015). Significance values were set at $p = 0.05$.

Results

Table 1 shows the demographic data and Raven´s CPM scores of the participants. We observed no significant differences between the two groups in terms of age, gestational age, mother's level of education, or general nonverbal abstract reasoning abilities (i.e., CPM score). Table 2 shows the descriptive statistics for both inhibitory tasks and working memory Corsi task.

-- insert Table 1 and Table 2 here --

The capacity to discriminate Go from No-go trials was higher in girls, with higher sensitivity index d' (t=-3.410, p<0.005, d= 0.53) and higher accuracy in inhibitory trials (No-go Acc; t=-6.121, p<0.001, d=0.97). Boys were more accurate at Go trials but the effect size was small (Go Acc; U= 2530.5, p=0.024, r=0.17) and they were faster than girls both in Go and No-go trials (Table 3).

Accuracy in the Shape School Inhibit Condition was very high in both sexes although boys scored slightly higher than girls (SSB%, U= 2701, p=0.037, r=0.16). There were no other significant differences in the Shape School between the two groups (Table 3).

-- insert Table 3 here –

The Efficiency (Shape School) measure was weakly correlated with the discriminative index d´ (r(157)= .232, p=.003), with the Go RT (r(157)= -.238, p=.002) and the No-go RT (r(156)=-.215, p=.007) and moderately correlated with the Go accuracy (r(157)=.348, p<.001). The percentage of correct responses in the B condition (Shape School) was weakly and negatively correlated with the accuracy in the EYT No-go trials (rs(157)= -.16, p=.044). There was no significant correlation between the SS Inhibition condition and any other EYT Go/No-go measure.

The relationship between the inhibitory tasks and working memory in each sex group was analyzed using correlation measures (Table 4 for boys and Table 5 for girls).

As the main sex differences in inhibition were in the EYT Go/No-go, we wanted to explore the association between working memory with the inhibition measures of this task, in each group, to see if this factor contributed differentially to the inhibitory control in each group. For both boys and girls success in inhibiting a No-go response is positively correlated with the time taken to respond both to Go (hits) and No-go (false positive) stimuli. There were no significant differences in these correlation coefficients in boys and girls (No-go acc vs GoRT, z=-1.00; p=.31; No-go acc vs No-go RT, z=.40, p=.68).

There was no significant correlation between visual-spatial working memory and inhibition accuracy in the Go/No-go in boys (Table 4). Results in a visuospatial working memory task showed a weak positive correlation with Go accuracy and the discriminability index only in the female group (Table 5).

-- insert Table 4 and 5 here --

Discussion

This study investigated sex differences in two developmentally appropriate inhibitory tasks, the EYT Go/No-go and the Shape School Inhibition Condition. In both tasks, participants were required to respond to a stimulus (Go trials) and withhold a response to another stimulus (No-go trials). Tasks differed in the response modality - motor or verbal: on the time constraint - limited or not limited; and on the proportion of Go to No-go trials.

Success rates were different in the two inhibition tasks. Children were better at withholding naming the color of the sad faces than at withholding catching/touching the shark. Apart from the difference in response mode, verbal for the Shape School and motor for the Go/No-go, differences in several other important parameters related to prepotency build-up, could help explain the contrasting results. In the EYT Go/No-go task, there is a time limit of 1000 ms during which the child can touch the screen and catch a fish, on the contrary, in the Shape School Inhibition condition all the faces - sad and happy - in the trial are simultaneously present and there is almost no time pressure to name them. Long presentation times reduce the inhibitory demands of prepotent response (Simpson & Riggs, 2006). So, although children are told to 'name the pupils as fast as possible', but 'without making any errors' there is no time limit in the Shape School. Response prepotency also depends on the proportion of Go vs No-go trials. In the Shape School task, an initial Naming Faces trial helps to build up the prepotency of the naming response but during the Inhibition condition, the proportion of happy to sad faces is lower than that of fish (Go trials) to sharks (No-go trials) in the EYT task. Therefore, as expected, accuracy at the EYT Go/No-go task was lower than at the Shape School Inhibition for both groups and we can consider the difficulty of the former higher compared to the latter, at this age.

Our main goal was to explore possible sex differences in response inhibition in late preschool children. As we hypothesized, girl's capacity discriminating Go and No-go trials in the EYT task was higher than boy's, they made fewer commission errors and took longer to respond to the presented stimuli.

As in other previous work with preschool children, girls were slower than boys in the Go trials (longer reaction times catching fish) but made fewer commission errors, displaying a higher sensitivity index (Liu et al., 2013; Wiebe et al., 2012). These results, slower response times, and better accuracy in inhibition are following the speed-accuracy trade-off hypothesis in decision-making. This hypothesis states that the accuracy of response varies with the time taken to produce it, one maximizes the accuracy of the speed, so decisions are made slowly with high accuracy or fast with high error rate (Heitz, 2014). The degree of trade-off depends on task complexity and the perception of difficulty or risk (Chittka, Skorupski, & Raine, 2009).

The relation between Go RT and No-go accuracy was similar in both groups. There was a positive correlation between Go reaction time and No-go accuracy suggesting that both groups benefited from slower responses. This suggests that girls are slower or slow up their responses to heighten their inhibition accuracy because they have a higher sense of the difficulty, or the risk of the task than boys have. Indeed, boys showed smaller RTs both in Go and No-go trials. This could also explain why the sex differences in accuracy in the Shape School inhibition condition were small and in the opposite direction despite similar RTs. In this task, boys were not so pressured to respond and there were no sex differences in efficiency. But the speed-accuracy trade-off must not be the only source of female superiority in interference control tasks as other studies have found better discrimination between Go and No-go trial, in females, without any differences in reaction time both in children (Grammer, 2014) and in adults (Sjoberg & Cole, 2018). Also, the findings on reaction time and inhibition may derive from different factors. Males are usually faster in simple reaction times (Dykiert et al., 2012) and girls are better in verbal tasks (Halpern, 2000; Lutchmaya, Baron-Cohen, & Raggatt, 2002) so the different pattern found in the EYT and the Shape School concerning the time taken to respond could be a reflection of these underlying sex differences in cognitive processing rather than a result of time constraints.

Another way of interpreting inhibition failures is through the race model of response inhibition (Logan & Cowan, 1984), which states that the probability of inhibiting a response depends on the outcome of a race between two opposite responses, the Go or prepotent task response and the No-go or inhibition response. According to this model, inhibitory failures or commission errors, occur when the Go response, in No-go trials, is completed early minimizing the possibility of an inhibition response. As in other studies (Rahman, Carroll, Espy, & Wiebe, 2017), the No-go RT was shorter than the Go RT but the difference between them was similar for boys and girls, suggesting that for both groups the false alarm responses were too rapid for them to inhibit.

Therefore, RT is not the only answer when it comes to justifying sex differences in inhibiting a prepotent response. Such differences might also depend on the maturation of the basal ganglia circuitry, particularly on the circuit involving the subthalamic nucleus (STN) and the anterior cingulate cortex (ACC) (Witt, 2017). Stimulating the STN, with Deep Brain Stimulation (DBS) paradigms in Parkinson's disease patients reduced the activation of the dorsal ACC. At the behavioral level, STN-DBS, impaired Go/No-go task performance, decreasing RT, and increasing the number of commission errors (Ballanger et al., 2009).

Having found sex differences in a motor response inhibition task we sought to unveil possible contributing factors. Previous work has drawn attention to the impact of intelligence, working memory, and socioeconomic factors in the developmental trajectories of inhibitory abilities (Wiebe et al., 2012). There were no significant differences between the two groups in general cognitive ability, in visuospatial working memory, or maternal educational level, that could explain differences in response inhibition. Additionally, and contrary to the findings of Wiebe and coworkers (Wiebe et al., 2012) there was no significant association between inhibition discriminability and nonverbal abstract reasoning and working memory in boys. In the girls' group, nonverbal abstract reasoning and working memory were associated with the discriminability inhibition measure (d´). It is not possible to infer any causality between these cognitive functions but all of them depend highly on the frontal lobes. Anatomical differences found in brain developmental trajectories might underlie differences found in working memory and motor inhibition at these ages (Lenroot et al., 2007). The fact that girls' brain development, in several cortical areas including the frontal lobe, peaks 1 to 2 years earlier that in boys could explain the different patterns of inhibition in younger and older children and adolescents. Sex differences in EF are not apparent in all ages for all tasks. In a previous study with 3-year-old children, there were no sex differences in the Shape School Inhibition task nor the Go No-go d' (Wiebe et al., 2011). It is possible that at 3 years inhibition of a prepotent response is equally hard for boys and girls and it gets gradually easier for girls than for boys later in preschool.

Sex differences in inhibition could partially explain the early differences found in reading. Haft and coworkers (Haft et al., 2019) have recently found that inhibition influences word decoding abilities in preschool children and so inhibition should be explored as, amongst others (Chiu & McBride-Chang, 2009; Soldhein & Lundetrae, 2018; Wagemaker, Taube, Munck, Kontogiannopoulou-Polydorides & Martin, 1996) a factor explaining sex differences in reading abilities in children and adolescents.

Both the EYT Go/No-go and the Shape School are easy to administer and children participated and enjoyed both tasks. The different patterns of results in the two tasks imply that, to detect sex differences, a response inhibition task should impose a limited period for responding like the Go/No-go. For the Portuguese preschool population, normative values are only available for the Shape School (Rato et al., 2018) so an effort should be made to provide EYT Go/No-go norms.

Although the use of different parameters in each task did harm the explanatory power of our results, they highlight the need for careful consideration in the selection of inhibition tasks for young children. Future research should explore sex differences in inhibition developmental trajectories and examine possible implications in learning and behavior.

Table 1. Demographic data and Raven´s Matrices score for participants (N=160)

	Boys (*n*= 85)	Girls (*n*=75)			
	M (SD)	M (SD)	statistical test		*p*
Age (months)	65.14 (5.08)	65.33 (4.52)	*t*	-.251	ns

Gestational age (weeks)	38.84 (1.34)	39.00 (1.46)	*U*	2727.	ns
Raven CPM	20.18 (5.27)	19.54 (4.20)	*t*	.845	ns
Mother education level			χ^2	10.97	ns
(*n*)	4	8			
Middle school	10	17			
High school	52	30			
Graduate	15	18			
Postgraduate					

Note. Raven CPM = Raven Colored Progressive Matrices.

Table 2. Descriptive statistics for Go/No-go, Shape School and working memory measures (N=160)

Tasks Dependent measures	N	M	SD	Range	Skewness	Kurtosis
Go/No-go						
Go Acc	160	.80	.11	.50 – 1.00	-.77	-.01
Go RT	160	.73	.06	.58 - .90	.15	-2.33
No-go Acc	160	.59	.19	.20 – 1.00	-.78	-.01
No-go RT	159	.63	.07	.49 - .88	.74	.76
d'	160	1.30	.79	-.10-4.00	1.20	3.66
Shape School						
SSA%	160	.99	.01	.80- 1.00	-6.20	58.02
SSA T	160	22.30	7.60	8.68 – 52.21	1.30	2.20
SSA Ef	160	.73	.22	.28- 1.72	.58	1.62
SSB %	160	.98	.05	.73-1.00	-2.21	7.01
SSB T	160	20.35	9.80	8.15- 65.30	1.99	4.76
SSB Ef	160	.82	.32	.13 – 1.80	.16	.34
WM spatial	160	7.03	2.85	1- 14	.16	-.50

Note. Go Acc = Go Accuracy; No-go Acc= No-go Accuracy; RT: Reaction Time in sec.; d'= sensitivity index; SSA and SSB = Shape School A (control) and B (inhibit) conditions - %: Correct percentage; T: Time to complete in sec.; Ef: Efficiency score; WMspatial = Working Memory – Visuospatial Corsi

Table 3. Performance on Assessment Protocol for participants (N=160)

	Boys (*n*= 85)	Girls (*n*=75)	statistical test		*p*	Effect size
	M (SD)	M (SD)				
Go Acc	.82 (.12)	.79 (.11)	*U*	2530.5	.024	0.17†
Go RT	.71 (.06)	.76 (.06)	*t*	-5.733	.000	0.90◊
No-go Acc	.52 (.18)	.69 (.17)	*t*	-6.121	.000	0.97◊
No-go RT	.62(.06)	.65(.07)	*t*	-3.181	.002	0.46◊
d’	1.11 (.67)	1.52 (.86)	*t*	-3.410	.001	0.53◊
SSA %	.99(.02)	.99(.02)	*U*	3057.0	ns	
SSA T	21.52(7.46)	23.17(7.71)	*t*	-1.373	ns	
SSA Ef	.76 (.22)	.71(.21)	*t*	1.453	ns	
SSB %	.99 (.03)	.97 (.07)	*U*	2701.	.037	0.16†
SSB T	19.62(8.75)	21.18(10.3)	*t*	-1.035	ns	
SSB Ef	.86 (.33)	.79 (.28)	*t*	1.393	ns	
WM spatial	6.98 (2.95)	7.11 (2.80)	*t*	-.257	ns	

Note. Go Acc = Go Accuracy; No-go Acc= No-go Accuracy; RT: Reaction Time in sec.; d’= sensitivity index; SSA and SSB = Shape School A (control) and B (inhibit) conditions - %: Correct percentage; T: Time to complete in sec.; Ef: Efficiency score; WMspatial = Working Memory – Visuospatial Corsi; ◊=*cohen’s d;* †= *r*.

Table 4. Correlations between Go/No-go and working memory scores for boys (n =85)

	1†	2	3	4	5	6
1. Go Acc	–					
2. Go RT	**-.20***	–				
3. No-go Acc	-.01	**.45****	–			
4. No-go RT	**-.20***	**.55****	**.32****	–		
5. Go/No-go *d′*	**.69****	.11	**.61****	.01	–	
6. WM spatial	.16	-.14	-.04	-.15	.05	–

*$p < .05$. **$p < .01$.

† = Spearman rank correlation coefficient. All other correlations are Pearson correlations.

Table 5. Correlations between Go/No-go and working memory scores for girls (n =75)

	1†	2	3	4	5	6
1. Go Acc	–					
2. Go RT	**-.39****	–				
3. No-go Acc	-.015	**.57****	–			
4. No-go RT	**-.31****	**.65****	**.26***	–		
5. Go/No-go *d′*	**.69****	.12	**.64****	-.08	–	
6. WM spatial	**.35****	-.08	.02	-.15	**.29****	–

*p < .05. **p < .01.

†= Spearman rank correlation coefficient. All other correlations are Pearson correlations.

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