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RESEARCH ARTICLE

Response-Stimulus Interval Duration Modulates Interference Effects in the Stroop Task[1]

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In the Stroop task, incongruent stimuli (e.g. "red" printed in blue) induce a robust interference effect. The impact of both the changes in the duration of the interval between the subject's response and the next stimulus (RSI) and the development from childhood to adulthood on the size of the interference have not been systematically studied. We have therefore tested the modulation of within-task RSI (from 1000 to 5000 ms) on the interference effect in 8–10 years old children and young adults. Results disclose a stronger interference effect for the shortest RSI duration (1000 ms) in both adults and children, indicating more effective inhibitory processses for longer RSI durations. Moreover, similar interference effect were found between children and adults suggesting that both groups are similarly affected by interference. Taken together, these results suggest that inhibitory processes require a certain amount of time to develop.

Introduction

The Stroop color-naming task (Stroop, 1935) is one of the most widely used paradigms to study cognitive inhibition processes (Cohen, Dunbar, & McClelland, 1990; MacLeod, 1991). In the classical version of this task, participants are presented with written words of color names; they are instructed to name as fast as possible the color of the ink in which the words are printed, independently of the meaning of the word. On congruent trials, the meaning of the word and its ink color are the same (e.g. "red" printed in red), whereas a discrepancy between the word's meaning and its ink color exists on incongruent trials (e.g. "red" printed in blue), leading to slower and less accurate responses (MacLeod, 1991). The Stroop interference effect is a robust phenomenon, commonly interpreted as the involuntary consequence of the inability to effectively inhibit automatic reading processes.

Numerous studies have been conducted using the Stroop task or its variants since the seminal publication (Stroop, 1935). Part of the considerable interest in the Stroop task stems from its growing use as a diagnostic and research tool, that aims to explore the nature of the cognitive disturbances resulting from various psychiatric or

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neurological disorders (West & Alain, 1999). Additionally, the investigation of the neural correlates of inhibitory processes in healthy controls and patients has become an important topic of research with the emergence of non-invasive functional neuroimaging techniques. In particular, epilepsy is a neurological disorder in which cognitive impairments are frequently observed in both children and adults (de Boer, Mula, & Sander, 2008), including impairments in attention, impulsivity and inhibition (Hoie et al., 2008; McDonald et al., 2006; Mitchell, Zhou, Chavez, & Guzman, 1992). However, investigations in clinical populations may be constrained by the patients' features but also by the specificities of the functional neuroimaging technique. In this respect, the inter-stimulus interval (ISI) or the response-stimulus interval (RSI) might represent a potential confounder in neuroimaging studies in which it is usually recommended to introduce random intervals (Gross et al., 2013; Picton et al., 2000; Poldrack et al., 2008). Indeed, introducing a random jitter in the ISI or RSI reduces the expectancy effects on responses, preventing an anticipation of the upcoming stimulus that modulates brain activity (Clementz, Barber, & Dzau, 2002), and avoids the accumulation of periodic interference (e.g. line noise) when averaging the responses (Gross et al., 2013). In functional neuroimaging studies in epileptic patients, flexible RSI duration could thus be useful to avoid stimuli presentation during post-interictal epileptiform discharges, known to affect performance and underlying brain activity (Seri, Cerquiglini, & Pisani, 1998).

To the best of our knowledge, no study has specifically investigated how RSI duration and variability impact the inhibitory performance in the Stroop task. Both fixed and random ISIs have been used in Stroop studies, but no systematic comparison has been conducted. In studies using fixed ISIs, the most common intervals fall within the 350–3000 ms range (up to 12 sec), with 1000, 1500 and 3000 ms being the most prevalent intervals. In studies using random ISIs, intervals vary randomly within different ranges, e.g. 400–500 ms, 1700–2000 ms (Liotti, Woldorff, Perez, & Mayberg, 2000), and 2000–2400 ms (Markela-Lerenc et al., 2004).

So far, no systematic investigation on the effects of ISI variations has been conducted in the context of the Stroop task. However, ISI variations have been shown to impact the inhibitory performance in the go-nogo task (Nakata et al., 2005; Ryan, Martin, Denckla, Mostofsky, & Mahone, 2010; Wodka, Simmonds, Mahone, & Mostofsky, 2009) and in the negative priming task (May, Kane, & Hasher, 1995). Indeed, inhibitory performance was found to be optimal with a moderate jitter (10 %, 900 – 1100 ms), even more so than with larger ISI variations (30–50 %) in the go-nogo task, indicating that moderate ISI jitter levels may improve response readiness whereas higher variation levels would interfere with the ability to maintain attention (Wodka et al., 2009). Additionally, increases in ISI durations (1 to 6 seconds) have been shown to result in longer reaction times (RTs) in a go-nogo event-related potential (ERP) study (Nakata et al., 2005).

A negative-priming (NP) effect is observed when a stimulus ignored in the previous trial becomes the target, resulting in a longer RT and/or an error. The NP effect is thought to reflect the active inhibition of distracting stimuli during the target selection process, eventually leading to a time cost due to the release of inhibition when the distractor becomes the target (Tipper & Cranston, 1985). Several studies (for a review see, May et al., 1995) have shown a suppression of the NP effect when the delay between priming and trial is extremely short (i.e. 20–50 ms), suggesting that inhibition requires some time to process (1000–2000 ms).

Taken together, these studies conducted using go-nogo and negative priming paradigms indicate that manipulating the ISI or RSI may impact inhibition processes or their expression, and may therefore exert an impact on performance in a Stroop task.

Age may also play a role in the expression of these effects. For instance, children produce more false alarms and impulsivity responses than young adults in the go-nogo task (Jonkman, Lansbergen, & Stauder, 2003), and are less efficient on item selection in negative priming tasks (Tipper, Bourque, Anderson, & Brehaut, 1989). Developmental changes in inhibitory control occur during the first 6 years of life, with a marked improvement starting at age 7, when children start learning to read (Comalli, Wapner, & Werner, 1962; Leon-Carrion, Garcia-Orza, & Perez-Santamaria, 2004; Peru, Faccioli, & Tassinari, 2006). In addition, several studies (Comalli et al., 1962; Prevor & Diamond, 2005; Wright, Waterman, Prescott, & Murdoch-Eaton, 2003) have indicated that the interference effect is stronger in children younger than 12 years than in adults. Furthermore, children with childhood developmental disorders such as attention deficit/hyperactivity disorder (ADHD) (for a review see Lansbergen et al., 2007) or benign epilepsy of childhood with centrotemporal spikes (BECTS, for a review see Deonna, 2000) tend to exhibit poorer performance levels on inhibition tasks, as compared to healthy children.

Therefore, the current study aims to systematically investigate the possible effects of RSI variations on Stroop performance in children and adults, using RSI/ISI comparable to the requirements of neuroimaging studies conducted in patient populations. We hypothesized that performance in children may be more influenced by the RSI duration than in adults, given that short RSI may impede the time needed for inhibition processes to take place. In a first experiment, we investigated the effects of three fixed RSI (1000, 1500 and 3000 ms) on performance using congruent, incongruent and neutral trials in a classical 4-colors Stroop task. In a second study, we investigated the effects of larger and less predictable RSI, varying from 2000 to 5000 ms using the same task.

Experiment 1

Method

Participants

Two groups of healthy participants were included in Experiment 1. In the adult group, 17 undergraduate individuals (11 female and 6 male; age range 18–25 years, mean age ± S.D. 19,7 ± 1,8 years) participated in exchange for an extra credit course at the Faculty of Psychological Sciences of the Université Libre de Bruxelles (ULB). One participant was excluded from the analyses due to data > ± 2 SD from the mean of each stimuli category. In the children group, 11 girls and 4 boys (age range 8 – 10 years, mean age ± S.D. 9,0 ± 0,7 years) were recruited through elementary schools. Children aged 8–10 year-old were included in this study to ensure that they possessed sufficient reading skills to be susceptible to the color-word Stroop interference effect. On the other hand, children of 12 years old were not included as they were shown to present comparable interference effects than adults (Christ, White, Mandernach, & Keys, 2001; Comalli et al., 1962; Ikeda, Okuzumi, Kokubun, & Haishi, 2011; MacLeod, 1991).

Children gave their oral consent after obtaining a written agreement from one of the parents. All participants had normal or corrected-to-normal visual acuity and presented a right-hand preference.

Stimuli and procedure

Stimuli

The Stroop task consisted of three different conditions: congruent, incongruent and neutral. In the congruent condition, the color words (red, green, blue and yellow) were printed in their respective ink color. The incongruent condition included the twelve possible different word–color pairings, for example the word "red" printed in green, yellow or blue ink, and "green" printed in blue, red or yellow ink. For the neutral condition, four neutral French words were used. Each color word was matched with a neutral word in terms of number of letters, lexical frequency, emotional valence

		3000 ms	1500 ms	1000 ms
Children	Congruent	1167 (36)	1157 (41)	1166 (40)
	Incongruent	1253 (41)	1288 (47)	1359 (46)
	Neutral	1172 (43)	1182 (43)	1189 (42)
Adults	Congruent	761 (35)	763 (40)	761 (39)
	Incongruent	927 (40)	924 (45)	941 (44)
	Neutral	766 (41)	758 (42)	781 (41)

Table 1: Experiment 1. Mean reaction time (ms) for each condition (congruent, incongruent and neutral) and each interval (3000, 1500, 1000 ms) in adults and children. (Standard Deviations are shown in parenthesis).

and imageability using the online program "Lexique 3" (http://www.lexique.org) (New, Pallier, Brysbaert, & Ferrand, 2004). Stimuli were displayed and keyboard responses collected using the Cogent 2000 software (http://www.fil.ion.ucl.ac.ulk/cogent) operated on Matlab 6.1 (www.mathworks.com).

Procedure

Participants sat in front of a 17'' computer screen at an approximate eye distance of 50 cm. Stimuli were presented in pseudo-random order to avoid negative priming effects. Indeed, the relevant stimulus dimension (color) in a congruent or incongruent trial was never the same as the irrelevant stimulus dimension (word) from the preceding trial. Neutral words were interspersed to annihilate unwanted effects. One hundred twenty congruent, 72 incongruent and 48 neutral trials were presented during the task. The RSI was manipulated so that the same number of stimuli within each category was displayed after 1000, 1500 or 3000 ms. These 3 interval windows were chosen based on their high prevalence in Stroop studies using fixed ISIs.

A central fixation cross was displayed during the RSI. Stimuli remained on screen for maximum 3000 ms or until a response was recorded. Instructions emphasized to respond using the colored button on a conventional computer keyboard that corresponded to the ink color of the words and to ignore the word's meaning. Practice trials constituted of colored ellipses were administered prior to the experiment to ensure that participants correctly learned the color-button correspondences. The training session was stopped when the correct responses rate reached 90%.

Statistical analysis

Only the RTs for correct responses were included in the statistical analysis. For each participant in each condition and each RSI, mean RT was calculated. Since error rate was very low in all conditions in both groups (< 1 %), analyses were computed on RT differences between incongruent (IC) and congruent (C) stimuli only. Repeated measures ANOVAs were conducted on mean RTs and on the relative amplitude of the interference effect (rAEI) including the within factor Interval and the between factor Group.

Results

Independent t-test analysis showed that adults and children needed approximately the same number of practice trials to reach the 90% correct responses rate criterion ($t(64) = 0{,}63$; $p = 0{,}53$)) (mean ± SD in children = 24 ± 5 trials, in adults = 23 ± 5 trials).

RTs for correct responses are shown in **Figure 1** as a function of Condition, Interval and Group (see supplemental material **Table 1** for mean RTs at each condition and each interval within both groups). A

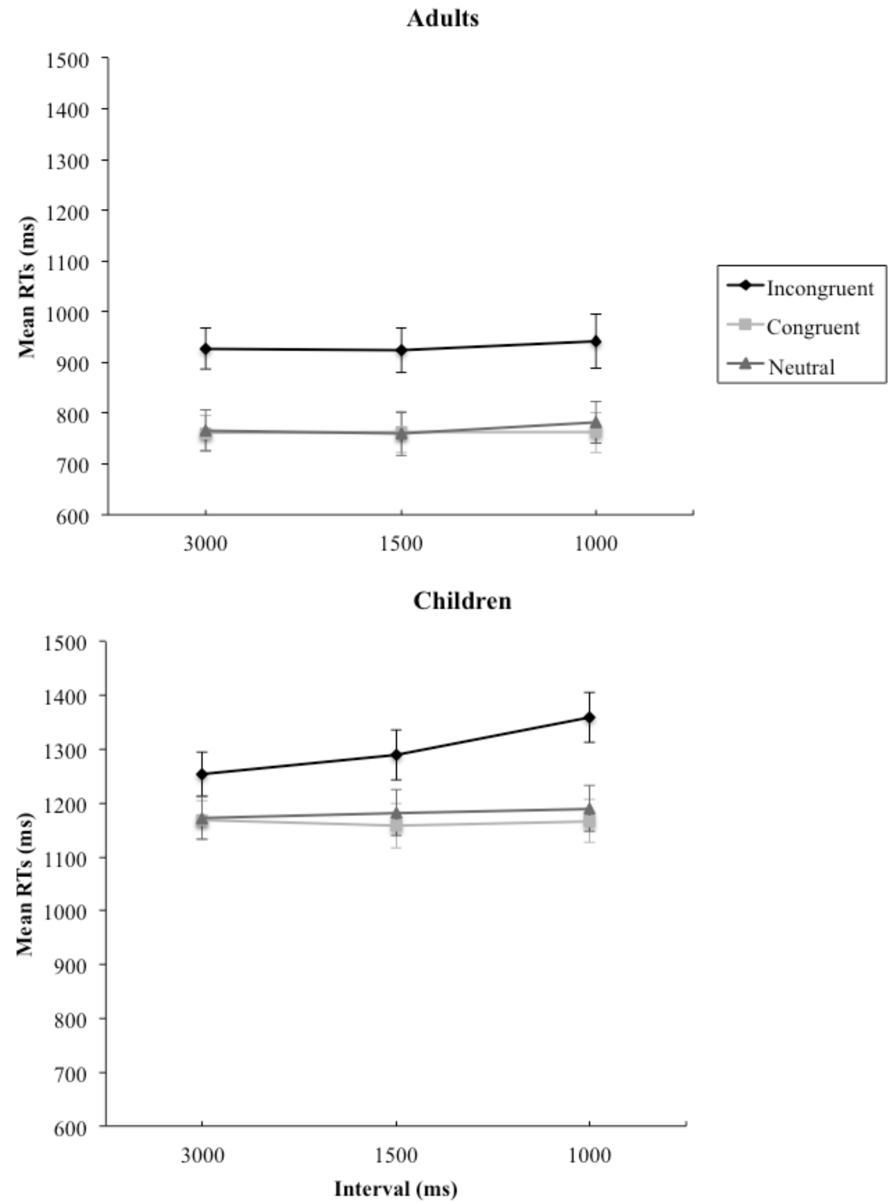

Figure 1: Experiment 1. Mean reaction times for each trial condition (congruent, incongruent, neutral) and each interval (1000, 1500, 3000 ms) within each group (adults and children). Both groups disclosed an interference effect with longer RTs for incongruent than both congruent and neutral stimuli. The children are generally slower to respond than the adults.

repeated measures ANOVA was computed on mean RTs for correct responses including the two within factors Condition (congruent, incongruent, neutral) and Interval (1000, 1500, 3000 ms) and the between factor Group (children, adults). Bonferroni corrections were applied on post-hoc t-tests. The analysis revealed a main effect of condition ($F_{(2,50)} = 80.66$; $p < 0.001$) with slower responses for incongruent than congruent (post-hoc $p < 0.001$) and neutral ($p < 0.001$) trials (incongruent mean RTs (ms) ± SD = 1116 ± 29; congruent = 962 ± 26; neutral = 975 ± 27) but no facilitation effect (i.e. no shorter RTs for congruent than neutral stimuli, $p > 0.78$). A main effect of Interval ($F_{(2,60)} = 3.88$; $p < 0.05$) was also present. Post-hoc tests revealed faster responses at 3000 ms (mean RTs ± SD = 1008 ± 26 ms) than 1000 ms (mean ± SD = 1033 ± 28 ms; $p < 0.05$). No differences were found with the 1500 ms interval (mean ± SD = 1012 ± 28 ms; ps> 0.22). There was also a main effect of Group ($F_{(1,30)} = 52.66$; $p< 0.001$) with longer RTs for children (mean ± SD = 1215 ± 39 ms) than adults (mean ± SD = 821 ± 38 ms; $p < 0.001$) (see Figure 1). Interaction effects between Condition and Group or Interval factors were not significant (Fs < 1.23, ps > 0.10), as well as the triple interaction effect ($p > 0.39$), suggesting that Interval and Condition effects were similar in both children and adults.

Additionally, we computed the relative amplitude of the interference effect (rAEI = IC-C/C)*100) in both groups. A repeated measures ANOVA was computed on the rAIE (%) including the within-subject factor Interval (1000, 1500, 3000 ms) and the between-subject factor Group (children, adults). The ANOVA revealed a main effect of Interval (F(2,58) = 4.0;7 $p < 0.05$), and post-hoc tests disclosed larger interference effects in shortest intervals (1000 ms; mean ± SD = 21 ± 2 %) than longest intervals (3000 ms; mean ± SD = 15 ± 2 %, post-hoc $p < 0.05$). No significant difference with the intermediate interval value was evidenced (i.e. 1500 ms; mean ± SD = 16 ± 1 % ; ps > 0.16). The main effect of group (p >0.28) was not significant and the interaction Interval x Group did not reach significance ($p > 0.21$).

Experiment 2

In a nutshell, results of Experiment 1 disclosed an interference effect in both children and adults, which was stronger for shortest intervals than longest intervals. The second experiment was conducted to control random RSI effects on Stroop interference. RSI values varied randomly between 2000 and 5000 ms. In this experiment, longer RSI were chosen since they are often used in functional neuroimaging Stroop studies in clinical populations and would be needed in the investigation of epileptic patients (adults and children) to avoid the effects of post-interictal epileptiform discharges on performance and brain activity, as discussed above (Seri et al., 1998).

Method

Participants

Two groups of healthy participants were included in Experiment 2. In the adult group, 21 undergraduate individuals (12 female and 9 male; age range 19–26 years, mean age ± S.D. 22.8 ± 1.7 years) participated. One participant was excluded from the analyses due to data > ± 2 SD from the mean of each stimuli category. In the children group, 9 girls and 6 boys (age range 8 – 11 years, mean age ± S.D. 9.5 ± 0.8 years) were recruited through elementary schools. One boy was excluded from the analyses due to data > ± 2 SD from the mean of each stimuli category. Children gave their oral consent after obtaining written agreement from one of the parents. All participants had normal or corrected-to-normal visual acuity and presented a right-hand preference.

		2000 – 2500 ms	2500 – 3000 ms	3000 – 3500 ms	3500 – 4000 ms	4000 – 4500 ms	4500 – 5000 ms
Children	Incongruent	1300 (58)	1399 (61)	1259 (44)	1298 (40)	1284 (57)	1269 (58)
	Congruent	1260 (41)	1214 (55)	1195 (41)	1183 (57)	1167 (41)	1200 (54)
	Neutral	1250 (41)	1198 (48)	1189 (54)	1177 (63)	1190 (55)	1154 (33)
Adults	Incongruent	938 (34)	898 (38)	881 (30)	892 (37)	891 (46)	882 (37)
	Congruent	837 (29)	831 (31)	840 (31)	811 (27)	826 (27)	819 (29)
	Neutral	828 (25)	801 (31)	786 (29)	804 (27)	788 (23)	813 (33)

Table 2: Experiment 2. Mean RTs (SD) in each group for each condition (congruent, incongruent, neutral) and each six interval categories in adults and children.

Stimuli and procedure

Stimuli were identical to those described in Experiment 1. The procedure was also identical, except for the RSI, randomly set at each trial within the 2000–5000 ms range.

Statistical analysis

RTs for correct responses were included in the statistical analysis. For each participant in each condition and each RSI category (see below), mean RT was calculated. Since error rate was very low in all conditions in both groups (≤ 1 %), analyses were computed on RTs only. Repeated measures ANOVAs were conducted on mean RTs and on the relative amplitude of the interference effect (rAEI) including the within factor Interval and the between factor Group.

Results

RTs for correct responses are shown in **Figure 2** as a function of Condition, Interval and Group (see supplemental material **Table 2** for mean RTs at each condition and each interval within both groups). A repeated measures ANOVA including the within factors Condition (congruent, incongruent and neutral) and Interval (4500–5000ms; 4000–4500ms; 3500–4000ms; 3000–3500ms, 2500–3000ms; 2000–2500ms) and the between-subject factor Group (children vs. adults) was conducted. This analysis revealed a main effect of Condition ($F(2,68) = 52.57$; $p < 0.001$), with slower responses for incongruent than congruent (post-hoc $p < 0.001$) and neutral ($p < 0.001$) trials (mean RTs ± SD for incongruent trials = 1102 ± 28 ms, congruent trials = 1018 ± 26, neutral trials = 1002 ± 25). There was also a main effect of Interval ($F(1,32) = 5.72$; $p < 0.001$). Post-hoc tests disclosed that RTs started to be faster from the 3000–3500 ms range as compared to shorter intervals (2500–3000 and 2000–2500 ms) (see Figure 2). The main effect of Group was also significant ($F(1,32) = 56.91$; $p < 0.001$) with children being slower than adults. Finally, the Interval x Group, Interval x Condition, Condition x Group and the triple interaction Interval x Group x Condition interaction failed to reach significance ($ps > 0.17$).

Like in Experiment 1, the rAEI was computed for each interval category in both groups. A repeated measures ANOVA was conducted on rAEI with Interval (4500–5000ms; 4000–4500ms; 3500–4000ms; 3000–3500ms, 2500–3000ms; 2000–2500ms) as within-subject factor and Group (children vs. adults) as between-subject factor. This analysis failed to disclose any main effects ($ps > 0.88$) or any interactions ($p > 0.11$).

General Discussion

In the present study, we conducted two experiments designed to investigate the impact of variations in RSI on interference effects thought to reflect inhibition processes in the Stroop color-word task, in both

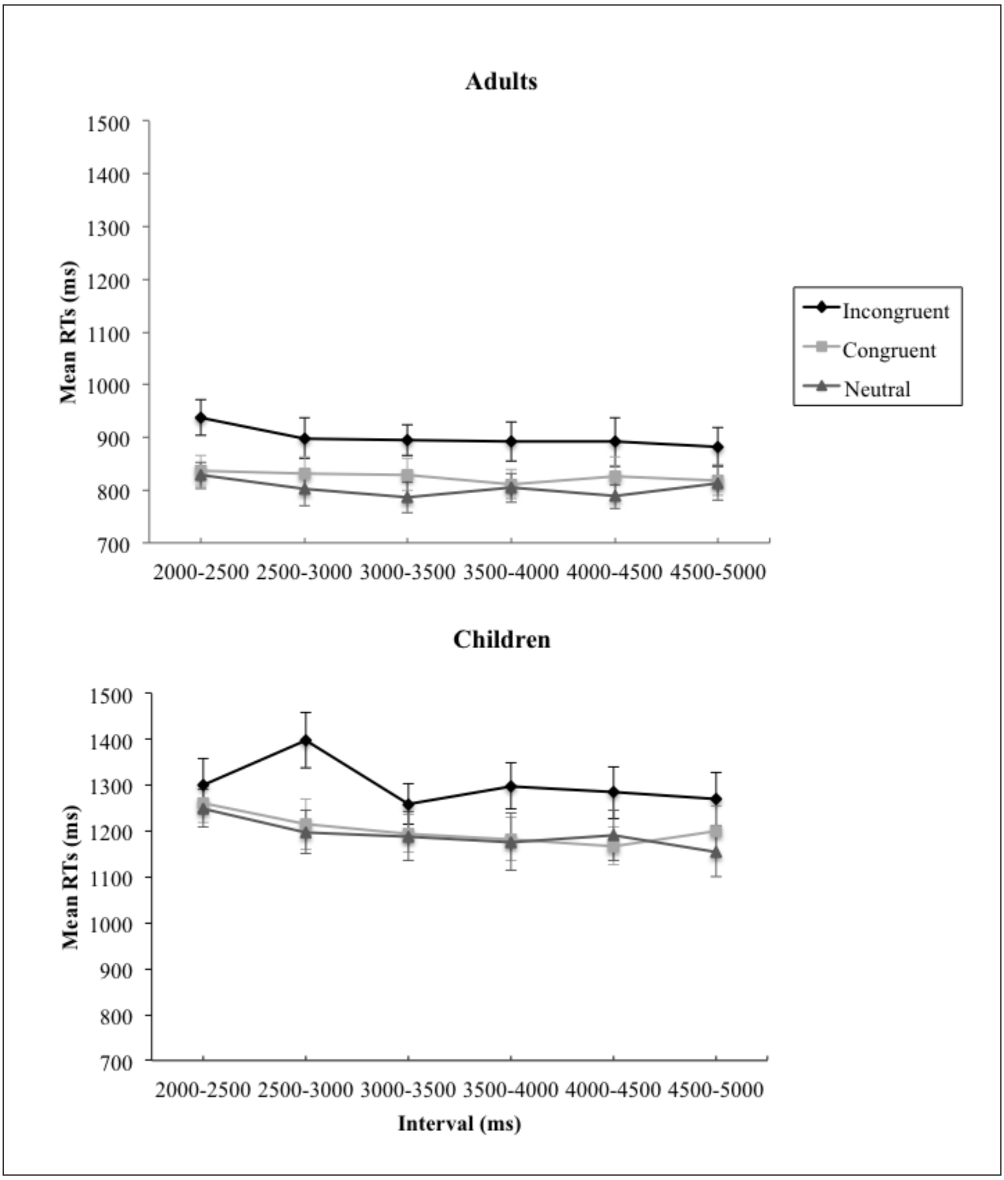

Figure 2: Experiment 2. Mean reaction times for each trial condition (congruent, incongruent, neutral) and each interval category (2000–2500; 2500–3000; 3000–3500; 4000–4500; 4500–5000 ms) within each group (adults and children). Both groups disclosed an interference effect with longer RTs for incongruent than both congruent and neutral stimuli. The children are generally slower to respond than the adults.

healthy children and adult populations, in a context compatible with functional neuroimaging and clinical studies. Experiment 1 was conducted using three fixed RSI durations, whereas RSI duration was randomly distributed in Experiment 2. Essentially these two studies led to similar results except for the relative amplitude interference effect. First, clear-cut interference effects were observed at all RSI durations in both adults and children, with slower RTs for incongruent than congruent and neutral trials, which confirms the robustness of the Stroop phenomenon. Notwithstanding this similarity, we found a larger rAEI for short (1000 ms) than long (3000 ms) RSI in Experiment 1, suggesting that the temporal interval dimension may partially modulate inhibitory processes in the Stroop task. A similar impact of the RSI duration was not observed in Experiment 2. However, intervals in the 2000–5000 ms range (in Experiment 2) are relatively long as compared to the shortest 1000 ms used in Experiment 1. Despite this larger interference effect for the 1000 ms RSI, we also found that global RTs (i.e. averaged across conditions) were systematically slower for shorter than longer RSI, and that children generally processed stimuli more slowly than adults, indicating that global reaction times but not the interference effects are modulated by age or RSI duration. However, children are less familiar with word stimuli than adults, which could be an alternative explanation for a lack of different interference effects between children and adults. Thus, it cannot be excluded that word stimuli processing would be less automatic for children, therefore leading to a reduced interference effect. Hence, our systematic comparison validates the use of large and variable RSI in functional neuroimaging and clinical studies.

Our results obtained with the Stroop task are partially discrepant with the results obtained using other inhibition paradigms. Using the go-nogo tasks, where inhibition arises from the response level, increases in ISI were associated not only with an increase in RTs but also with an increase in number of errors (Nakata et al., 2005; Ryan et al., 2010; Wodka et al., 2009). Noteworthy, differences in the design of the protocol could explain these differences. Wodka et al. (2009) and Ryan et al. (2010) introduced jitter in the ISI (from 10 to 50 %), whereas Nakata et al. (2005) used ISIs duration from 1 to 6 seconds. Likewise, negative priming studies (Lowe, 1985; May et al., 1995; Neill & Westberry, 1987) have evidenced longer RTs for previously inhibited target trials with longer ISI. Here, in contrary to the go-nogo tasks, inhibition arises from the stimulus level. These experiments have found a reduction in inhibition-related effects at very short (50–100 ms), as compared to longer but still small (1000 ms) intervals. One possible explanation for this discrepancy is that the shortest RSI (1000 ms) used in our study is considered as a long RSI in these studies. However, using a Stroop task, Neill & Westberry (1987) manipulated the RSI duration (20, 620, 1020, 2020 ms) to investigate the time effects on the distractor-suppression effect (i.e. negative priming effect when the relevant stimulus dimension [color] becomes the irrelevant stimulus dimension [word] during the next trial) and showed that suppression effects dissipate with longer RSI. Notebaert & Soetens (2006) also manipulated the RSI duration (50 and 1000 ms) using a Stroop task in which they compared Stroop effects when the irrelevant dimension (word) was repeated and when it changed. They observed that the Stroop effect disappeared when the word was repeated for short RSI, whereas the repetition of the word did not impact the Stroop effect for longer RSI. These results were interpreted in the framework of the sustained suppression hypothesis (MacLeod, 1991). According to this hypothesis, there is a selective suppression of the automatic response activation after response activation (Ridderinkhof, 2002). For short RSI, when the irrelevant information is repeated on the next trial, no Stroop effect appears since the suppression of the response is still active and need some time to dissipate (Notebaert & Soetens, 2006). Such suppression mechanism was also suggested by another Stroop study (Notebaert, Gevers, Verbruggen, & Liefooghe, 2006) in which typical conflict monitoring patterns (i.e. smaller Stroop effect after an incongruent trial than a congruent trial) were found for long RSI (200 ms), whereas it was not the case for short RSI (50 ms). Similarly, Sharma & McKenna (2001) investigated the impact of time pressure in an emotional Stroop task. They found greater emotional interference for short RSI (32 ms) than long RSI (1000 ms). They postulated that under time pressure, negative aspects of the stimulus are more salient. Nevertheless, those results can not be extrapolated to interference induced by color-words since the cognitive processes that are implicated differ.

In the studies manipulating RSI in the Stroop task, the main interest was negative priming, conflict monitoring or suppression effects and not the Stroop effect per se. Although the impact of RSI variations on interference was not directly investigated in these studies (Neill & Westberry, 1987; Notebaert & Soetens, 2006), their results suggest that effective inhibition takes time to develop.

In line with this hypothesis, we have found a higher interference effect for the 1000 ms RSI than longer RSI. The evolution of the amplitude of the interference effect could follow a linear trend, with improved efficiency peaking around 1000 ms, then slightly decreasing (e.g. around 1500 ms) to remain unchanged thereafter. This would explain why we found a modulation of the interference effect in Experiment 1 (RSI 1000 ms vs. 3000 ms) but not in Experiment 2 (RSI ranging from 2000 to 5000 ms). Taken together, those results seem to indicate that inhibitory processes take some time to develop. One possible explanation could be that for short RSI, the suppression of the automatic response activation (i.e. the word in our study) as hypothesised by Ridderkinhof (2002) takes some time to dissipate and leads to a high interference effect, whereas, for long RSI, there is more time for preparation and the suppression of the automatic response activation could begin earlier leading to efficient inhibitory processes. Another possible explanation is that for longer RSI, subjects dispose of time to allocate his attention to the task, resulting in a better response inhibition.

A significant effect of RSI duration on global RTs averaged over the 3 stimulus categories was found, with faster RTs for long than short RSI. This result is in line with the studies that have investigated the impact of RSI variations on performance in simple reaction time tasks. For instance, Tucker and colleagues (Tucker, Basner, Stern, & Rakitin, 2009) found slower responses and increased lapses (i.e. RTs > 500 ms) in adults for shorter intervals whereas faster responses and false starts were higher for longer intervals in a psychomotor vigilance task with RSI ranging from 2 to 10 seconds. In our study, we report a similar effect not only in adults but also in 8–10 years old children, who exhibited shorter RTs for longer RSI. Additionally, children responded more slowly than adults, which is also consistent with the literature. Age-related differences in speed processing have been reported in several studies (e.g. Cerella & Hale, 1994; Hale, 1990; Kail & Salthouse, 1994), including a meta-analysis (Kail, 1991) that evidenced a linear decrease in RTs with age in children and adolescents, actually similar to the children-adults difference reported in the present study.

At variance with prior studies that have reported differences between children and adults in the Stroop interference effect (Comalli et al., 1962; Leon-Carrion et al., 2004; Peru et al., 2006), we failed to evidence a stronger interference effect in children than in adults in both of our experiments, besides globally slower responses in children. This result is line with our hypothesis, as we surmise that increasing RSI duration would result in a more efficient inhibition in children. Nonetheless, whether variations in RSI duration, or alternatively the use of RSI durations above 1000 ms, may be responsible for the finding that children presented similar interference effects than adults in the present study remains to be further investigated. Children are globally slower to respond than adults, most probably due to slower speed processing and higher difficulties to allocate sustained attention to the task. Moreover, response preparation is known to be slower in children, as compared to adults (Bender, Weisbrod, Bornfleth, Resch, & Oelkers-Ax, 2005; Flores, Digiacomo, Meneres, Trigo, & Gomez, 2009; Urben, Van der Linden, & Barisnikov, 2011). Our results show that even if children are generally slower than adults, similar interference effects are observed between the 2 groups. Several studies have shown that response inhibition and processing speed can be considered as distinct abilities (Szucs, Soltesz, Jarmi, & Csepe, 2007; Urben et al., 2011). Considering the fact that children are slower in information processing and response preparation, one explanation would be that the general slowing leads to slower response time but does not worsen interference effects, as slower activation equally impacts both congruent and incongruent stimuli. As the Stroop effect is generally explained by the fact that automatic word reading interferes with less automatic color naming, we can assume that the activation of the word in children is lower due to slower speed but that this lower activation is equally implicated in both congruent and incongruent stimuli.

To sum up, the present experiments show that changes in RSI duration do not markedly impact the interference effect in the Stroop task, in both children and adults. Besides the demonstration of the robustness of the Stroop effect in various conditions and populations, our results indicate larger interference effects for RSI duration around 1000 ms as compared to longer ones in this famous inhibition task, as well as systematic effects of age and RSI duration on RTs. This systematic analysis of the impact of RSI duration in two healthy populations validates the use of larger and variable RSI in studies using the Stroop task in contexts where the experimental manipulation is constrained by a functional neuroimaging technique and/or by a clinical population.

Notes

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