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Spatial incompatibility training can prevent the occurrence of the enhanced Simon effect in elderly

Treinamento de incompatibilidade espacial pode prevenir a ocorrência do efeito Simon ampliado em idosos

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Abstract

The Simon effect is typically larger for older people than for young adults, maybe due to age-related decline in inhibitory capabilities. 32 right-handed aged people (5 male, 27 female; mean of 67,1 years ± 5,5) participated in this study. In screening were used the Mini-Mental State Examination and the Center for Epidemiological Study Depression Scale. Then, half of the participants practiced the spatial incompatibility task before the Simon task and the other group was only tested on the Simon task. The analysis of variance considering practice (incompatible, no-practice group) and correspondence (corresponding, non-corresponding) revealed a two-way interaction ($F = 7.07$; $p = 0.012$; $\eta p^2 = 0.191$) showing that the Simon effect was eliminated in the incompatible practice group, but remained intact in the group with no previous practice. These results indicated that cognitive processes required to the transfer of learning are preserved in elderly, being potentially useful to influence spatial inhibitory capabilities.

Keywords: Ageing; Inhibitory control; Spatial perception; Transfer of learning.

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Resumo

O efeito Simon é tipicamente maior em pessoas idosas do que em adultos jovens, talvez devido ao declínio de capacidades inibitórias em função da idade. Participaram deste estudo 32 pessoas idosas e destras (5 homens e 27 mulheres; média de 67,1 anos ± 5,5). Para rastreio, foram usados o Mini Exame do Estado Mental e a escala de depressão do Center for Epidemiological Studies. Metade dos participantes praticou a tarefa de incompatibilidade espacial antes da tarefa de Simon e o outro grupo foi testado apenas na tarefa de Simon. A análise de variância, considerando a prática prévia (incompatível ou sem prática) e correspondência (correspondente, não correspondente), indicou uma interação dupla ($F = 7{,}07$; $p = 0{,}012$; $\eta p^2 = 0{,}191$), demonstrando que o efeito Simon foi eliminado no grupo de prática incompatível, mas permaneceu ampliado no grupo sem prática anterior. Esses resultados indicaram que os processos cognitivos necessários para transferir a aprendizagem estão preservados em idosos, sendo potencialmente úteis para influenciar as capacidades inibitórias espaciais.

Palavras-chave: *Envelhecimento; Controle inibitório; Percepção espacial; Transferência de aprendizagem.*

The spatial correspondence between stimulus and response can influence manual Reaction Time (RT) in different paradigms, such as in the Spatial Compatibility and Simon tasks (Miles & Vu, 2021; Proctor & Vu, 2006). The RT are faster in both tasks when stimulus location and response are spatially correspondent than when they are on opposite sides (Cespón et al., 2020). The stimulus location in spatial compatibility tasks is a relevant attribute for response selection (Proctor & Vu, 2006), while stimulus position in the Simon task is irrelevant, and responses are selected according to an intrinsic stimulus attribute (e.g. shape or color), irrespective of its spatial location (D'Ascenzo et al., 2021; Verghese et al., 2018).

In the Simon task, the difference between the corresponding (stimulus and response at the same side) and non-corresponding (stimulus and response on opposite sides) conditions is named Simon effect (Hommel, 2011). This effect has been related to the response selection level, requiring cognitive control to process the relevant (e.g. the shape) against the irrelevant (spatial) stimulus attribute (D'Ascenzo et al., 2021). Different perspectives have been used to explain this phenomenon, as the attention shift account (Rizzolatti et al., 1987; Rizzolatti et al., 1994), the referential coding account (Hommel et al., 2001; Hommel & Lippa, 1995), and the dual-route model (Luo & Proctor, 2019) among others (Melara et al., 2008).

Functional magnetic resonance imaging studies have suggested that attention control in the Simon task involves activation of the dorsal premotor, lateral prefrontal and anterior cingulate cortices, in addition to posterior and superior parietal areas (Liu et al., 2004; Peterson et al., 2002). These areas seem to be involved in suppressing the irrelevant spatial information present in Simon tasks and in selectively orienting attention to the relevant task attribute, and are also considered the neuronal circuit related to the conflict monitoring (for spatial demands) that is necessary to perform the Simon task (Kawai et al., 2012). In a meta-analysis conducted by Cespón et al. (2020), were found at least four main clusters related to the Simon effect, including one extending from the right superior parietal lobule to the inferior parietal lobule and precuneus; from Supplementary Motor Area (SMA) and pre-SMA to cingulate gyri; a posterior cluster linking the right middle temporal gyri to the inferior temporal and middle occipital gyri; and finally, another extending from the left middle frontal to the precentral gyri. For authors, the inferior parietal lobule must be an important role in the interference found during the Simon task.

Researchers have described a larger Simon effect and slower RT in older adult volunteers when compared to young adults (Kawai et al., 2012; Kubo-Kawai & Kawai, 2010; Scrivano & Kieffaber, 2021; Van der Lubbe & Verleger, 2002). Some authors have suggested that an age-related cognitive decline impairs the suppression of automatic response activation to the irrelevant spatial attribute, leading to an enlarged Simon effect (Van der Lubbe & Verleger, 2002; Kubo-Kawai & Kawai, 2010; Kawai et al., 2012). Kawai et al. (2012) showed that older participants had stronger bilateral activation in the superior frontal gyri while performing the Simon task when compared to young participants, indicating that these circuits may be more vulnerable during aging. In fact it is known that gradual and natural cognitive decline is related to specific synaptic changes in the hippocampus and prefrontal cortex (Morrison & Baxter, 2012). Neuroanatomical changes have also been reported in the gray matter, including reduced volume and thinning of the cortex, especially in the Prefrontal Cortex (PFC) circuits (Fjell et al., 2009; Grady, 2012). In addition, Aisenberg et al. (2018) showed different patterns of BOLD responses in the right cerebellum, when compared young and older participants.

However, evidences indicate that the Simon effect can be modulated by an incompatibility previous practice in the Spatial Compatibility task (Conde et al., 2015; Verghese et al., 2018; D'Ascenzo et al., 2021), in which participants are instructed to respond using their contralateral hand to stimulus presentation. This modulation of the Simon effect by an incompatible previous practice is named the transfer-of-learning effect, and was first explained based on possible interactions between Long-Term (LTM) and Short-Term Memory links (STM) (Tagliabue et al., 2000; Wang & Weekes, 2014). More specifically, was proposed that STM links during the spatial incompatibility task would be established following the instruction to contralaterally respond to the stimuli and should only relevant in that practice. In contrast, LTM links are over-learned sensorimotor skills consolidated along the participants' lifetimes and do not depend on task instructions (Tagliabue et al., 2000). The LTM and STM seem to underlie the Simon effect and other spatial compatibility phenomenon, since that the transfer-of-learning effect might occur due to effects of previously acquired rules in STM links on a LTM pattern. Accordingly, the learning to respond opposite, obtained during the spatial incompatibility task could remain active and influence the performance in the following Simon task through short-term memory links (Ambrosecchia et al., 2015; Creekmur & Vu, 2011; Marini et al., 2011; Ottoboni et al., 2013; Tagliabue et al., 2000; Vu, 2007; Soetens et al., 2010).

Considering the abovementioned aspects and the fact that we did not found extant publications about these transfer effects in aged populations, the present work aimed to investigate if the enlarged Simon effect observed in older adults can be modulated after the spatial incompatibility training. In order to answer this question, two groups of older adults were tested: the first performed the spatial incompatibility task before the Simon task, while the second group was only assessed by the Simon task, without previously performing the spatial incompatibility task. The design of the present work was planned to test two premises. The first one predicted that the incompatibility training could prevent the enlargement of the Simon effect. This premise is consistent with other evidences supporting that the Simon effect is modulated by incompatibility practices in children and young adults (Iani et al., 2009; Soetens et al., 2010; Tagliabue et al., 2000; Verghese et al., 2018). This hypothetic assumption also takes in consideration some indications that procedural memory can be preserved in older people (Ward et al., 2013), and also that sensorimotor and cognitive training can have significant effects in this population (Vermeij et al., 2016).

The other premise assumes that the transfer effects will be impaired in older adults because it requires cognitive operations that may have declined in normal aging (Cabeza et al., 2016; Nagy et al., 2020; Wang et al., 2011). This perspective is based on researches that indicated cognitive declines in this population and poor executive performance through different cognitive tasks (Van der Lubbe & Verleger, 2002; MacPherson et al., 2002; Kawai et al., 2012). Thus, if these functions are really impaired in older adults, the Simon effect would not be affected by the previous incompatibility practice and would remain amplified.

Methods

Participants

The Recruitment was done by the researcher invitation, during a preliminary meeting with participants enrolled in the project "Healthy Aging". This extensionist project is a systematized and supervised physical activity program offered to older adults by the Department of Physical Education of the Federal University of Pernambuco. All participants were retired and residing in the Recife city, Pernambuco state, Brazil.

The sample size was calculated in G*Power 3.1.9.2 software (Faul et al., 2007) to achieve 80% of power to detect a significant interaction between 2 groups (Incompatible and No-practice group) × 2 correspondences (corresponding and non-corresponding) using the a priori power analysis. Considering that some works (Millner et al., 2012, Verghese et al., 2018) indicate that sensorimotor training effects have medium to large effect size, it was used an $f = 0.3$ (Cohen, 2013; Verghese et al., 2018) as parameter. The power calculation recommended 24 participants as the total sample size. Considering imprecision in the effect-size estimation by the software that do not consider relevant characteristics of the participants, we decide to use the total sample available.

In this perspective, the experiment involved 32 elderly participants (5 men and 27 women), with ages ranging from 60 to 89 years old (average of 67,1±5,5). The t-test revealed that there was no significant difference ($p = 0.427$; Cohen's $d = 0.29$) in age between control (66.2 years old, *SD* = 6,2) and experimental (68 years old, *SD* = 5,6) groups. The control group was tested with the Simon task without any previous practice, while the experimental group made the incompatibility training before the Simon task. All of them were not engaged in physical activity for at least 12 months. They did not receive any kind of reward for participate in the study.

To control possible intervening variables, were used as screening tools: the Mini-Mental State Examination (MMSE) (Folstein et al., 1975); the Center for Epidemiological Study Depression Scale (CES-D) (Radloff, 1977); and the Edinburgh Handedness Inventory, to assess handedness (Espírito-Santo et al., 2017; Oldfield, 1971). All participants were right-handed, had normal or corrected-to-normal vision and were unaware about the purpose of the experiment. All reported being in good health, with no neurological disorders and free of medications that could influence the central nervous system functions.

Informed consent was individually obtained for all participants included in the study. All the procedures were in accordance with ethical standards and were approved by the institutional research committee (Process nº #031744/2016).

Instruments

Mini-Mental State Exam (MMSE): The Folstein Mini-Mental State Examination (MMSE) is a broadly accepted screening tool for cognitive impairment assessment (Folstein et al., 1975). The MMSE have 30 questions that evaluates several domains of cognitive functions as language, memory, registration, recall, calculation. Psychometric characteristics of the MMSE have been examined considering its several adaptations and translations to another countries and languages, including Brazil (Melo & Barbosa, 2015; Melo et al., 2020).

Center for Epidemiological Study Depression Scale (CES-D): CES-D is a self-report instrument commonly used to assess depressive symptoms (Radloff, 1977). The CES-D is composed by 20 items about depressive symptoms, with 3 response levels in each question. Psychometric studies concerning the CES-D to elderly population in Brazil revealed acceptable indices of internal reliability and Construct (Batistoni et al., 2010).

Edinburgh Handedness Inventory – (Oldfield, 1971): This inventory is composed by 10 items about handedness, asking about the dominant hand in 10 items as throwing, cut with a scissors, writing, drawing, striking, using a toothbrush, knife (without fork), spoon, the upper hand used in broom and to open a box (Espírito-Santo et al., 2017; Oldfield, 1971).

Simon Task: The Simon task is a classical neuropsychological tool commonly used to assess cognitive processing during a Manual RT task (Cespón et al., 2020). The Simon effect is the RT difference when stimulus and response spatially correspond than when they are no correspondent, and reflect inhibitory capabilities to its spatial location (irrelevant attribute).

Apparatus and stimuli

The experiment was performed in a dimly lit and sound-proof chamber. Participants sat in front of a monitor at a viewing distance of approximately 57 cm. The head of the participants was positioned in a forehead-and-chin rest. A personal computer was used both for stimulus presentation and recording the response. The E-Prime software (version 2.0) was used to determine events sequences and to measure response latency. In the Spatial Compatibility task (incompatible practice session), the imperative stimulus was a solid black disk with 0.5° in diameter randomly presented at 6° (left or right) from the Fixation Point (FP). In the Simon task, there were two imperative stimuli: an empty circle or square that were randomly presented at 6.5° (left or right) from the fixation point. The square was 1° × 1° in size and the circle 1° in diameter. The screen was light gray and the stimuli were black. The FP was a cross with 0.7° × 0.7°.

The response-window interval varies in literature (Bae et al., 2009; Conde et al., 2015; Iani et al., 2009; Tagliabue et al., 2000; Zhong et al., 2018). Some works used varied intervals (Grabbe & Allen, 2012; Van der Lubbe & Verleger, 2002) while others used static intervals (Bialystok et al., 2004; Hommel et al., 2004). In fact, Ivanoff (2003) showed that the Simon effect was not influenced by the arrangement of intervals adopted, neither by a distributional perspective between faster to slower response times. Here, the task was programmed to keep the stimulus on the screen for 1000 ms or until the response, and the trial terminated if the participants did not respond within 1000 ms (Conde et al., 2015; Conde et al., 2017; Iani et al., 2009). The interval between the response and the beginning of the next trial was set in 2000 ms.

The RT was measured from stimulus onset to the execution of the manual response. Responses were made with the index fingers positioned on the left (the letter "A") and right (the number "6" on the numerical keypad) keys of a computer keyboard in front of the participant. Responses quicker than 100 ms were considered anticipations and longer than 1000 ms, omissions. Errors (key-pressing errors, omissions and anticipations) were replaced at the end of the session until complete 80 correct trials. The experimental design was tested in a pilot study with young adults and reproduced the expected Simon effect for the No practice Group and its absence for the Incompatible practice group.

Procedures

Before the behavioral task, participants read/signed a written informed consent form and responded to the Oldfield inventory (1971) to verify the manual dominance. Then, they were invited to the experimental setting and were randomly assigned to one of the two groups, without any other consideration or criteria. The experimental group was composed by half of the subjects (n = 16, 5 males and 11 females) which performed the spatial incompatibility training before the Simon task. In this first task, they were instructed to respond to the visual stimulus by pressing the key located on the opposite side (using the right key to respond for the left stimuli and the left key to respond for the right stimuli). The session consisted of 80 correct trials and the subsequent Simon task was conducted after a delay of 5 min. During this interval, participants remained seated in the experimental room and waited for the subsequent test. In the Simon task, participants were instructed to respond (also with the right or left keys) when the stimulus (circle or square) appeared on the screen. Half of them responded with the right key for the circle and with the left key for the square and the others executed the opposite pairing. In the Simon task, only the geometric form was relevant for response selection. The Simon task session consisted of 80 correct trials. The control group (n = 16 females) did not practice the incompatibility task, performing directly the Simon task. Both tasks were preceded by 20 training trials.

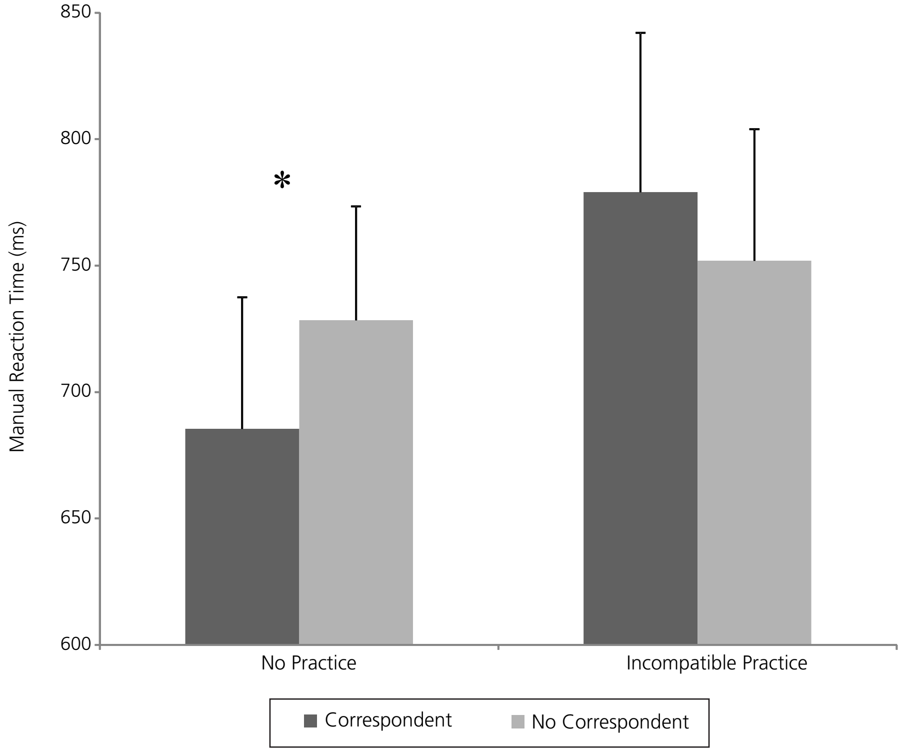
Means of correct RTs and errors percentage in the Simon task were analyzed by two ANOVA having *Previous Practice* (Incompatible and No-practice group) as between-subject factor and Correspondence (corresponding and non-corresponding) as within-subject factors. Moreover, the Partial eta-squared (ηp^2) was calculated as an estimate of effect size, and the Newman–Keuls method was used in the post-hoc analyses. Training data and incompatible practice data were not analyzed. Finally, a *t*-test was also used to study age differences between the two groups. Statistical significance was set at $p < 0.05$.

Results

An estimate of 12.5 years of education (*SD* = 4.1) was reported by the control group which did not differ ($p = 0.165$) to what was reported by the experimental group (10.3; *SD* = 4.6). Moreover, scores on the MMSE (Folstein et al., 1975) were not different ($p = 0.936$) between the two groups (control: 24.9; *SD* = 2.5 and experimental: 24.8; *SD* = 3.3). Finally, control (mean of 12.9 points; *SD* = 12.7) and experimental (13.6; *SD* = 7.3) groups did not differ in depressive symptoms ($p = 0.838$), measured by the CES-D scale (Radloff, 1977).

The RT ANOVA showed that Previous practice ($F = 0.64$; $p = 0.429$; $\eta p^2 = 0.021$) and Correspondence ($F = 0.36$; $p = 0.551$; $\eta p^2 = 0.012$) did not reach significance, but a significant two-way interaction ($F = 7.07$; $p = 0.012$; $\eta p^2 = 0.191$) occurred between them. The post-hoc comparisons revealed a regular Simon effect for the group without previous practice: corresponding trials (686 ms, SE = 52) differed from non-corresponding ones (728 ms, SE = 45; $p = 0.028$), a 42 ms regular Simon effect. For the Incompatible Practice group, a non-significant reversed Simon effect (-27 ms) was found ($p = 0.16$): RTs average was 779 ms (SE = 63 ms) for corresponding trials and 752 ms (SE = 52 ms) for non-corresponding ones (Figure 1)

Figure 1
Averages obtained in the Simon task for corresponding and non-corresponding trials for each group



Note: Bars represent the standard error and the asterisk (*****) indicates the significant difference ($p < 0.05$).

The error ANOVA showed that Previous practice ($F = 3.68$; $p = 0.065$; $\eta p^2 = 0.113$) and Correspondence ($F = 2.79$; $p = 0.105$; $\eta p^2 = 0.088$) did not reach significance, but a significant two-way interaction ($F = 6.74$; $p = 0.015$; $\eta p^2 = 0.189$) occurred. The post-hoc comparisons showed that the error rates obtained for corresponding and non-corresponding trials did not differ in both experimental (0.92% and 0.59%, respectively; $p = 0.627$) and control groups (1.26% and 2.52%, respectively; $p = 0.267$). However, error rate was significantly smaller for the non-corresponding condition of the experimental group than for both corresponding ($p = 0.024$) and non-corresponding conditions ($p = 0.049$) of the control group.

Discussion

The researchers that reported an enlarged Simon effect for older participants attributed this pattern to cognitive declines found in older adults (D'Ascenzo et al., 2021; Kawai et al., 2012; Kubo-Kawai & Kawai, 2010; Van der Lubbe & Verleger, 2002; Vu & Proctor, 2008). They emphasize that the decline on inhibitory control increases the processing of irrelevant attributes (spatial location), which enhances the temporal difference between the corresponding and non-corresponding trials.

Our study was elaborated based on the assumptions that the Simon effect is larger for older participants (Kawai et al., 2012; Kubo-Kawai & Kawai, 2010; Van der Lubbe & Verleger, 2002) and also considering evidences indicating cognitive declines in older adults (Nissim et al., 2017; Scrivano & Kieffaber, 2021; Wang et al., 2011). Actually, the magnitude of the Simon effect for older volunteers found herein (42 ms) showed a similar pattern to those reported by others. For instance, Van der Lubbe and Verleger (2002) obtained a Simon effect of 48 ms for older adults against 20 ms for younger adults; and Pick and Proctor (1999) reported an effect of 85 ms against 45 ms in an auditory task, but 33 ms against 7 ms in a visual Simon task, for older and younger adults, respectively. Therefore, in the present study we replicate the basic pattern of an enhanced Simon effect for older adults as already described.

It has been considered that aged-related declines could hinder the transfer of the incompatible learning to the Simon effect. Hence, the null hypothesis predicted that the expected larger Simon effect would be more difficult to modulate by the training of the incompatibility task (Kawai et al., 2012; Kubo-Kawai & Kawai, 2010; Van der Lubbe & Verleger, 2002) and that aged related cognitive decline could affect the transfer of learning. Indeed, scientific reports about aging commonly focus on functional declines (Lupien & Wan 2004; Nyberg & Pudas, 2019). Higher physical and psychological capabilities are rarely observed in this population and are restricted to few older people (McLaughlin et al. 2012). The usual aging is a natural and no-pathological condition but has been associated to declines of perception, memory, cognitive and motor capabilities (Kattenstroth et al., 2010; Krampe, 2002; Park et al., 2001; Persson et al., 2006).

The premise that the transfer effects could be impaired was not confirmed in this study. The transfer effects of incompatibility training seems preserved in older participants, since the two-way interaction revealed a 42 ms Simon effect for the control group (without previous practice), while the Simon effect was absent for the spatial incompatible practice group (in fact, it was reversed, but not significantly). The spatial Incompatibility training reversed the expected pattern of errors rates, since the experimental group had fewer errors in non-corresponding than in corresponding condition. Thus, our results should be viewed as evidence that the incompatibility task practice induced modulations in the spatial inhibitory capabilities required in the Simon task.

The present study contributes to a better understanding of the phenomenon, providing the first evidence that cognitive mechanisms required for transfer the incompatibility learning to the Simon task seems to be preserved, although aging affects the automatic response inhibition. Although measures of brain functions have not used here, the results pointed implications to future researches investigate which systems are modulating the Simon effect in older adults. Wang and Weekes (2014) emphasized that the prefrontal cortex plays an important role representing the abstract response rules to respond contralaterally during the transfer of incompatibility learning. They showed that the incompatibility practice group had reduced activity in the anterior midcingulate cortex and an increased functional coupling between this area and the right frontopolar cortex in relation to the group that had previous spatial compatibility task practice; the temporoparietal junction was also more bilaterally responsive to the stimuli that matched with the previously practiced task configuration. They also found an important correlation between the activity of the right frontopolar cortex-ventral premotor cortex pathway and the magnitude of the Simon effect due to the prior practice. This finding led them to propose that this circuit might represent the neuronal substrate for the abstract representation of response rules acquired by the spatial incompatibility task training. The present study does not prove but suggests that these systems are preserved and can modulate the inhibitory control in older adults, since the incompatibility training prevented the enlarged Simon effect. However, other perspectives are possible. Although the declarative short-term memories involve mainly PFC connections (Fuster, 2009), which are more sensitive to neuronal and cognitive decline during aging (Cabeza et al., 2016), for procedural memories, the short-term associations have shown relative preservation for older adults (Ward et al., 2013). Considering also the role of the cerebellum and subcortical networks for neuroplastic modulation of the motor activity (Aisenberg et al., 2018; Opie & Semmler, 2020), it must be considered also how the cerebellar activity and fronto-subthalamic inhibitory circuitry are modified by the spatial incompatibility training in elderly.

Albeit the contributions of the present research, it is important to interpret the results carefully and considering some limitations. For instance, further studies are necessary to examine the transfer effects observed here using larger samples of clinical and healthy populations of different age ranges and also from other countries. Until now, Tagliabue et al. (2000) investigated children and young adults and divided the participants in groups with compatible and incompatible previous practices. Our results complements partially Tagliabue and colleagues' (2000) data since we studied older adults but without compatible previous practice. The present study adopted an experimental design more similar to Iani et al. (2009), which investigated modulations in the Simon effect when only the Simon task was conducted or when it was performed after an incompatibility task. They found that the Simon effect was affected by correspondence sequence and also by previous incompatibility practice. Thus, remained to be investigated how previous compatible training would affect the Simon effect in older participants. For the present study, the use of a previous compatible training could inflate the Simon effect, then the investigation was restricted to understand how this behavioral marker (the enlarged Simon effect in elderly), commonly verified in a single session of the Simon task, would be modulated by the incompatible previous practice.

Some studies used a baseline condition and showed specific effects of the incompatibility training on Simon task performance (Verghese et al., 2018; Wang & Weekes, 2014). Commonly, incompatibility practice decreases RT and increases accuracy, with prominent modulations in the no-corresponding condition (Verghese et al., 2018; Wang & Weekes, 2014). The experimental design adopted here cannot respond how these specific modulations occur in older participants and maybe future works with a baseline condition can offer a better understanding about the specificities regarding the transfer effects of incompatible training in older population.

Evidences showing that cognitive training improve behavioral performance in normal aging and mild cognitive impairment have strengthened the first hypothesis and indicated its possible use to prevent or reduce cognitive decline (Vermeij et al., 2016). Buchanan et al. (2019) conducted a systematic review about cognitive training and reported small to large effects for cognitive improvements in different domains, such as general cognitive functioning, attention and memory, visual recognition, perceptual speed and for some executive functions. Hill et al. (2016) also conducted a systematic review and meta-analysis study specifically to investigate the effects of computerized cognitive training in elderly and found small to moderate impact on global cognition, attention, working memory, learning, and memory. The results obtained by Butler et al. (2018) suggested that improvements elicited by cognitive trainings may be restricted to healthy older adults. Therefore, these findings indicate that computerized cognitive training can be also effective to improve spatial inhibitory control capabilities in older people.

More recently, a systematic review and meta-analysis found 25 studies about the cognitive-motor training effects on executive functions of older people (Wollesen et al., 2020). Authors concluded that cognitive-motor and technology-based interventions can have a positive impact on global and specific cognitive functions, as attention and inhibitory control. However, none of the referred revisions and meta-analysis found works assessing the transfer of incompatible learning to the Simon task in older adults.

Our findings do not prove that incompatibility training influenced other general inhibitory capabilities. The absence of studies using other inhibitory tasks makes this question still opened, since there are some evidences that the training effects can be both context-dependent (Yamaguchi & Proctor, 2009) and specific to tasks that share inhibitory demands, or stimulus-response mappings (Spierer et al., 2013). Another issue refers to the majority presence of women in the present study. Although most of the studies with the Simon task had included participants of both sexes (Cespón et al., 2020), Stoet (2017) found stronger post-error slowing and higher Simon effects in women than men. Considering that sexes differences have not yet been studied within this paradigm, it is important that further studies investigate possible sexes interferences in the transfer of incompatible learning to a subsequent Simon Task in aged people.

Despite some limitations, is relevant to consider that the transfer effect of incompatibility practices to a subsequent Simon task was not previously investigated in older adults. Nagy et al. (2020) even explored some possibilities to reduce age-related changes in the Simon effect using a Posner-type gaze-cued task version. They tested different levels of correct response facilitation for all combinations of Simon and Gaze conditions (congruent gaze-correspondent Simon, incongruent gaze-correspondent Simon, congruent gaze-no correspondent Simon, and incongruent gaze-no correspondent Simon). Although was expected that irrelevant gaze direction could facilitate the manual, the anticipated facilitation was not observed, suggesting that general slowing and decreased inhibitory functions in the elderly are not affected by social cue and that gaze perception worked more as a further load on their cognitive processing. The present study showed unequivocally that the occurrence of the enlarged Simon effect for older people can be prevented by previous incompatibility training.

Conclusion

As concluding remarks, it is important to note that Cognitive training programs involve structured activities and exercises planned to stimulate general and specific cognitive functions. Usually these activities are indicated to older people aiming to prevent cognitive decline and to slow dementia progress. However, the effectiveness of cognitive training in elderly is still being debated considering the large number of opened questions. In this field, studies about the inhibitory control training in older adults are rare. The present study explored this gap and provided some evidences that spatial inhibitory control capabilities required in the Simon task can be trained and modified in older people; and that protocols based on transfer effects between two tasks have potential use for studies about inhibitory control training. Additional studies are necessary for a better understanding about functional effects of the incompatibility training in older adults. Applications and adaptations of the spatial compatibility training for recovering or improving some aging-related deficits are still only speculations.

Contributors

T. E. M. DIAS and F. F. L. CAVALCANTI contributed to programming; data collection and data analysis. W. MACHADO-PINHEIRO contributed with a critical revision of the article; A. S. COSTA contributed to conception of the work and with a critical revision of the article. E. F. Q. CONDE was responsible for conception of the work and funding acquisition; data analysis and interpretation; also contributed to writing the article; and made the final approval of the version to be published.

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