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Stroop interference and negative priming (NP) suppression in normal aging

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ABSTRACT

Age-related differences in the reduction of Stroop interference were explored by comparing the performance of 18 younger (of mean age: 30.0 ± 3.9 years) and 18 older healthy adults (of mean age: 75 ± 7.2 years) in a color-word Stroop task. The aim of this study was to determine whether a decrease in the efficiency of inhibitory mechanisms associated with aging could account for age-related differences in the ability to suppress a pre-potent response. Participants performed a Stroop task to assess Stroop interference and NP suppression concurrently. Results showed a greater Stroop interference in older than in young adults. On the other hand, the NP effect was only reliable in the younger group, the older group not showing NP suppression. These findings suggest that the slowing hypothesis alone cannot explain this pattern of results and that the age-related differences must also involve an inhibitory breakdown during aging.

1. Introduction

The performances of younger and older adults have been compared in many tasks providing information about the kind of processing that is affected by normal aging. Although there is a great debate about the processes involved in many cognitive tasks, the bulk of evidence shows that older adults are impaired in cognitive processes that involve control or top-down mechanisms, but not in those that can be considered more automatic (e.g., Amieva et al., 2002; Conway and Fthenaki, 2003; Andrés et al., 2008; Collette et al., 2009).

One task widely used to study age-related changes in controlled processing is the Stroop (1935) task. In this task, participants are presented with colored words that refer to colors, and are asked to respond to the stimulus color. The meaning of the word is the task-irrelevant dimension of the stimulus, and the color in which the stimulus is presented is the task-relevant dimension. In the congruent condition, both dimensions coincide (e.g., the word RED is printed in red), whereas in the incongruent condition they do not (e.g., the word RED is printed in blue). Participants usually respond more slowly in the incongruent than in the congruent condition, and also in a control condition in which the stimuli are not words (e.g., a string of colored Xs, or a set of non-color words). The Stroop interference effect reflects the extra time needed to resolve the conflict generated by the irrelevant but pre-potent dimension of the stimulus, i.e. the word meaning, in the incongruent condition. This conflict is produced by activation of the irrelevant but pre-potent word-reading response which is greater than that of the relevant but weaker color-naming response (e.g., McLeod, 1991; Spieler et al., 1996). Although there are different interpretations about how the conflict is resolved (McLeod, 1991; Aron, 2007, for reviews), one widely accepted view is that suppression processes relying on frontal lobe executive control mechanisms are engaged in preventing the irrelevant dimension from taking control of the response (Kane et al., 2007).

Reviewing the literature on age-related changes in the Stroop task, we found that older adults do not always show impaired performance, as measured by a greater Stroop interference effect, compared to younger adults. Age-related differences seem to depend on the task format used and/or whether overall speed has been controlled for or not. For instance, when the traditional card version of the Stroop test is used (Stroop, 1935), older adults clearly show greater interference effects than younger adults (Dulaney and Rogers, 1994; Spieler et al., 1996; Davidson et al., 2003; Belleville et al., 2006; Andrés et al., 2008; Ludwig et al., 2009). However, when an item-by-item version is used, in which stimuli are randomly presented on the computer screen, findings vary. Some authors have found greater Stroop effects in older than younger participants (e.g., Hartley, 1993; West and Bell, 1997; West and Alain, 2000; Davidson et al., 2003; Rush et al., 2006), whereas others have found either small or non-significant age-related differences (Basak and Verhaeghen, 2003; Langley et al., 2005; Borella et al., 2009; Ludwig et al., 2009). These divergent results might depend on whether the authors controlled for overall speed. When transformed scores are used to control for speed, similar Stroop effects have been reported in younger and older

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adults (Verhaeghen and De Meersman, 1998; Little and Hartley, 2000; Langley et al., 2005; Ludwig et al., 2009).

Different processes might therefore be involved in different task formats, with some processes being more affected by aging than others. For instance, interference effects in the Stroop card version might be affected by contextual processing, proactive interference, stimulus distinctiveness, and eye movements (Ludwig et al., 2009, for a more detailed discussion). These factors are not, or only minimally, involved in the item-by-item version. Since age-related changes in Stroop interference are mainly observed with the card version, it is possible that the suppression of irrelevant information, which is the most widely accepted interpretation of Stroop interference in the item-by-item computerized version, is not compromised in normal aging.

In the present study we investigated aged-related inhibition processing, aiming to avoid the above-mentioned issues that might compromise an inhibition interpretation of the differences in Stroop interference between younger and older adults. First, we used an item-by-item computerized task to measure how the conflict arising from suppression of the task-irrelevant dimension of the Stroop stimuli is resolved (McLeod, 1991; Salo et al., 2001; Ludwig et al., 2009). The first objective of the present experiment was, therefore, to validate the appropriateness of our procedure to observe aged-related changes in Stroop interference. We also computed ratio scores to control for general slowing as an explanation of age-related differences in the size of Stroop interference.

However, the main contribution of the present study was that NP, a measure of distractor inhibition, and the standard Stroop effect were measured in the same experiment. In the standard NP procedure, participants are presented with pairs of prime and probe displays containing two stimuli, the to-be-responded target, and the to-be-ignored distractor. In the critical trials, participants had to respond to a target that had served as a distractor in the previous prime display (the ignored repetition condition). The common finding is that reaction times (RTs) to targets in the ignored repetition condition are slower than in the control condition, in which the distractor in the prime display is not repeated as the target in the probe display (Tipper, 1985, 2001; Fox, 1995; May et al., 1995; Mayr and Buchner, 2007, for reviews). The approach, nonetheless, is not new. For example, Andrés et al. (2008) recently measured Stroop and NP in a single experiment. Their results showed age-related differences in Stroop but not in NP. They interpreted these findings as evidence of age-related changes in controlled inhibition as indexed by the Stroop effect, but not in automatic inhibition indexed by NP. Other authors (Vakil et al., 1996) used a similar blocked procedure to the one used by Andrés et al. (2008) and found age-related differences in Stroop and NP effects. However, both studies used the card version of the Stroop task in a blocked design, and therefore their results could be due to factors other than inhibition processing, as mentioned above.

Although NP can be the result of episodic retrieval, distractor inhibition, or both (see Tipper, 2001, for a review), relevant procedure manipulations can favor the involvement of either inhibition- or memory-related processes (Malley and Strayer, 1995; Kane et al., 1997; Catena et al., 2002). Here, we used a similar task to the one used by Catena et al. (2002) which allowed us to measure Stroop and NP concurrently in the same paradigm. As discussed by Catena et al. (2002) (see also Section 4 for more details), the results can be accounted for better in terms of inhibition than episodic retrieval. Accordingly, we intermixed trials in which the to-be-ignored irrelevant colored word in trial n became the to-be-responded word color in trial $n + 1$ (the ignored repetition condition), with trials in which no such relationship between trials n and $n + 1$ occurred (the control condition). We hypothesized that if the previously observed age-related increase in Stroop interference is mainly due to impaired inhibitory processing, older adults should show a reduced NP effect compared with younger participants.

2. Subjects and methods

2.1. Participants

Two groups of adults participated in this study. The participants in the young group were 18 undergraduate psychology students (7 males and 11 females; aged 18–35, mean age: 30 ± 3.9 years), from UNED University (Madrid) who received course credit for their participation. The other group comprised 18 healthy older adult volunteers (7 males and 11 females, aged 65–81, mean age: 75 ± 7.2 years), living in the community in the Madrid area. All participants had normal or corrected-to-normal vision and normal color vision. One older subject was excluded due to the large number of outlier trials (more than 20%).

Before the experimental session started, all the participants performed a series of screening tests; the results are shown in Table 1. Some tests were used to rule out possible cognitive impairment or dementia, including the mini-mental state examination (MMSE) (Folstein et al., 1975), the global deterioration scale (GDS) (Reisberg et al., 1988), the blessed scale (BS) (Blessed et al., 1968) and the clock-drawing test (CDT) (Shulman, 2000). The Yesavage depression scale (Martínez de la Iglesia et al., 2002) was used to identify any subjects suffering from depression, as it is well-known that depressive states can affect cognitive performance. Finally, participants completed some subtests from the Barcelona battery (Peña-Casanova, 1991) and the vocabulary test of the WAIS battery (Whechsler, 1988) to compare the cognitive functions of the two groups. A t-test for independent samples revealed no significant differences between the two groups (all $p > 0.05$) except in the BS, because the elderly tended to remember the past more than the younger adults.

This study was approved by the UNED ethics committee and was therefore in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. All the participants gave their informed consent before participating in the study.

2.2. Stimuli and apparatus

Four basic color words were used as stimuli (red, green, blue and yellow). Each word was displayed in one of the four different colors (red, green, blue or yellow). The stimuli were presented on a Toshiba M 40-285 laptop with a 15.4″ color monitor and a Centrino processor, 120-GB hard drive, and 1024-MB RAM. E-Prime software 1.11 (Schneider et al., 2002) was used to display the stimuli, control the timing and record the participants' responses. Participants responded orally through the microphone interfaced

Table 1
Screening scores for the two groups of participants, mean ± S.D.

Parameters	Younger adults	Older adults
Education	17.5 ± 3.1	15.22 ± 3.91
MMSE	29.44 ± 0.70	29.44 ± 0.70
GDS	1 ± 0	1 ± 0
BS*	0 ± 0	0.3 ± 0.3
Yesavage	1.3 ± 1.29	1.6 ± 1.5
CDT	9 ± 0	9 ± 0
Naming Barcelona	14 ± 0	13.83 ± 0.5
Superimpose pictures Barcelona	6 ± 0	5.8 ± 0.32
Comprehension Barcelona	8 ± 0	8 ± 0
Vocabulary WAIS	63.22 ± 4.45	65.44 ± 3.5

* $p < 0.05$, t-test for independent samples.

with an external response box (Cibertec Software). The experimenter recorded the participants' responses manually by pressing the appropriate key in the computer keyboard.

2.3. Procedure

Participants sat comfortably at the computer at a distance of approximately 50 cm. They were tested individually in a dimly lit room. Each trial started with a black fixation cross displayed on a light gray background in the center of the screen. After 1000 ms, one of the four color words appeared in the center of the screen (Times New Roman, 25, corresponding to a visual angle of 1.14×3.43 degrees). Stimuli were pseudo-randomly presented so that neither the same color nor the same word was presented in two consecutive trials; they remained on the screen until the participant responded (Fig. 1).

Participants were instructed to name the color of the stimulus word while ignoring its semantic meaning. They had to respond as quickly as possible making as few errors as possible. The experiment consisted of a block of 32 practice trials and five blocks of 48 experimental trials each. The total number of trials was 240. After completing the experimental task, the participants were told that the target in some trials could have been the distractor in the previous trial. No participants reported having been aware of this critical manipulation.

2.4. Experimental design

The Stroop design consisted of a between-participants factor, Group (younger and older adults), and a within-participants factor, Congruency (congruent or incongruent). Responses for the Stroop analysis were coded as a function of the congruency between the color and the meaning of the stimulus. Congruent trials were those in which the color of the word coincided with the color in which it was presented. Incongruent trials were those in which the color word did not coincide with the color in which it was displayed. Trials were also coded according to the congruency of the previous trial ($N - 1$) in order to compute the NP effect for each trial.

The design for the NP-effect consisted of a between-participants factor, Group (younger and older adults), and a within-participants factor, Repetition (ignored repetition and control). Responses for NP analyses were coded as a function of the relationship between the color of the current target word and the color denoted by the word in the previous trial (distractor). Different types of trial were coded: ignored repetition trials were those in which the word in the preceding trial denoted the color of the word color of the current stimulus. Control trials were those in which both the target (color) and the distractor (word) in the current trial were different from the target and distractor in the previous trial. The ignored repetition condition was always an incongruent trial preceded by an incongruent trial.

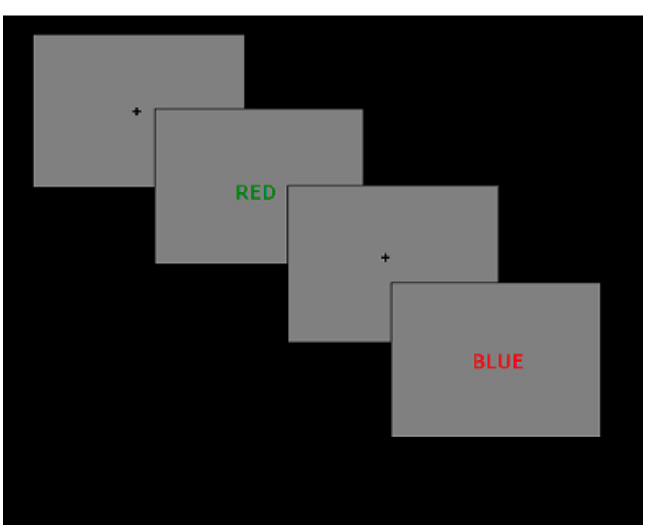

Fig. 1. Sequence of events for 2 consecutive trials. The first trial consists in an incongruent trial where word "red" and ink "green" do not match. The second trial is an ignored repetition trial in where the dimension ignored of the previous trial (the word "red") is the actual dimension of respond (color "red"). Stimuli are not scaled to size. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

3. Results

Separate mixed analyses of variance (ANOVAs) were conducted for the Stroop and NP effects. The first trial of each block was eliminated from all the analyses. Trials with either incorrect or procedural errors (0.6% and 0.9% for younger and older adults, respectively), together with trials with RTs either faster than 200 ms or slower than 2000 ms (0.76% and 4% for younger and older adults, respectively) were excluded from the RT analyses. Table 2 shows the mean RTs and the percentage of errors for each experimental condition.

3.1. Analysis of the Stroop effect

A 2×2 (group: young and older adults) (congruency: congruent and incongruent conditions) mixed ANOVA was performed on the mean RTs. We computed the Stroop interference as the difference between incongruent–congruent trials.

The results showed a highly significant Stroop effect [$F(1, 33) = 65.86$, mean square error (MSE) = 4373.11, $p < 0.001$]. The congruent condition produced faster RTs (808 ms) than the incongruent condition (936 ms). Group main effect was also highly significant [$F(1, 33) = 12.25$, MSE = 4388.95, $p < 0.01$]. The older group was significantly slower (952 ms) than the younger group (792 ms). More interestingly, the two-way interaction congruency $\times$ group was significant [$F(1, 33) = 5.43$, MSE = 4388.95, $p < 0.05$]. The analysis of the interaction showed that the Stroop effect was greater for the older (165 ms) than for the younger participants (92 ms). To address the possibility that age-related differences in the Stroop task were partly due to differences in generalized slowing, we computed individuals' Stroop effects as a percentage of their Incongruent RTs using the following formula: [(Incongruent RT-Congruent RT)/Incongruent RT $\times$ 100)]. The analysis showed the same pattern of results as with the untransformed data.

3.2. Analysis of the NP effect

A 2×2 (group: young and older adults) (repetition: ignored repetition and control) mixed ANOVA was performed on the mean RTs. We computed the NP effect as the difference between ignored

Table 2
Mean RTs (ms) and error percentages (in parentheses) for each experimental condition for the 2 groups in the STROOP–NP experiment.

Stroop	Congruent	Incongruent
Young adults	746 (0.06)	838 (0.15)
Older adults	870 (0.04)	1035 (0.20)
NP	$N - 1$ Incongruent Control	$N - 1$ Incongruent Ignored repetition
Young adults	823 (0.14)	857 (0.18)
Older adults	1028 (0.17)	1037 (0.19)

repetition and control conditions. The results showed a main effect of repetition [$F(1,33) = 9.99$, MSE = 822.59, $p < 0.01$], the ignored repetition condition producing longer RTs (947 ms) than the control condition (926 ms). The main effect of group was also significant [$F(1, 33) = 12.17$, MSE = 53447.9, $p < 0.01$], the older adults being slower (1033 ms) than the younger adults (840 ms). Interestingly, the group × repetition interaction was marginally significant [$F(1, 33) = 3.4$, MSE = 822.59, $p = 0.07$]. Further analyses of the interaction revealed that younger but not older adults showed NP effects (the difference between Ignored repetition and control conditions for older adults was 9 ms while for younger adults it was 34 ms). We again computed individuals' NP effects as a percentage of their ignored repetition RT, in a similar way to the Stroop analysis [(Ignored Repetition RT − Control RT)/Ignored Repetition RT × 100)]. The statistical results did not differ.

3.3. Analysis of errors

Separate repeated-measures ANOVAs were conducted for Stroop and NP effects with the percentage of errors as the dependent variable.

Stroop effect: A 2 (group) × 2 (congruency) mixed ANOVA was performed on the mean percentage of errors in all the experimental conditions. Only the main effect of Congruency was significant [$F(1,33) = 17.87$ MSE = 0.15, $p < 0.001$], showing that the percentage of errors was higher for Incongruent trials (0.17%) than for Congruent trials (0.05%). No other main effect or interaction was significant in this analysis. There was no difference in the percentage of errors between the two groups (Table 2).

NP effect. No main effect or interaction was significant in this analysis ($p > 0.05$) (Table 2).

4. Discussion

The present study was designed to explore whether the increased Stroop interference reported in many aging studies implies age-related deficits in controlled inhibitory processing. An age-related decline has been observed in tasks requiring the intentional inhibition of information, as occurs in the Stroop task (e.g., Hartman and Hasher, 1991). Conway and Fthenaki (2003) proposed that controlled inhibitory processes are modulated by executive control, which is sensitive to normal aging (Faust and Balota, 1997; Fuentes, 2004; Langley et al., 2005, for a recent review). To meet that aim, we first adopted a version of the Stroop task that avoided the involvement of processes other than inhibition, which can also be compromised in aging.

The traditional card version that has been widely used in educational and clinical settings seems to depend on other factors that are not related to inhibition. The stimuli are presented simultaneously on sheets of paper and participants have to name the stimulus colors as quickly as possible. Ludwig et al. (2009) recently suggested that this version is not really appropriate to address age-related inhibitory processing deficits and proposed an item-by-item design instead. However, the item-by-item version has produced conflicting results. Ludwig et al. (2009) did not find age-related changes in Stroop interference when they used the computerized version. In their study, they transformed the Stroop scores to take into account age-related differences in overall speed; this procedure has also been used in a number of other item-by-item studies that also failed to observe increased Stroop interference in older adults (Verhaeghen and De Meersman, 1998; Langley et al., 2005; Borella et al., 2009). Given that we found greater Stroop interference in our older adults than in the younger group with both raw and transformed data, the different results cannot be attributed to generalized slowing in older participants. They could therefore be due to differences in the control condition. Ludwig et al. (2009) used both reading words and naming the color of rectangular patches as control conditions, whereas in the present study we computed the Stroop interference effect as the difference between incongruent and congruent trials. Ludwig et al. (2009) also included congruent trials in their item-by-item condition, although they did not use them for computing the Stroop effect. It is possible that differences in the magnitude of interference between younger and older adults could have occurred if the congruent condition had been used as the control condition (Kieley and Hartley, 1997; Rush et al., 2006). These are typically referred to as the "total" Stroop effect (Spieler et al., 1996). This form of Stroop effect may be more likely to reveal inhibitory deficits due to the fact that a failure to inhibit attention to the word can lead to slow RTs on incongruent trials, but could actually speed up performance on congruent trials, leading to a more pronounced difference in performance between the incongruent and congruent conditions (Barch et al., 1999; Rush et al., 2006). Some authors have pointed out that non-color related stimuli might produce certain interference effects in color naming (McLeod, 1991), which might underestimate the interference effects. It is also well-known that different ways to compute Stroop interference may produce different results (Kieley and Hartley, 1997). These authors found aging effects in Stroop interference when they computed the interference score as the difference between correct incongruent and congruent trials. On the other hand, age-equivalence in the Stroop effect was found when interference was computed as the difference between incongruent and neutral trials, although older adults were significantly slower than younger adults in the incongruent trials. In any event, the present results show that our item-by-item design was appropriate to observe age-related changes in Stroop interference.

A second important aim of the present study was to understand better the role of inhibitory processes in age-related changes in Stroop interference. Various theoretical accounts of Stroop interference have been put forward (Aron, 2007, for a recent review). A well-documented explanation for conflict resolution, the process that seems to delay responding in incongruent trials, refers to executive mechanisms triggering attention-dependent inhibitory processes to prevent highly automatic activation of word meaning from taking control of responses (Kane et al., 2007). One way to investigate the likelihood of inhibition as a determining factor for the observed increased Stroop effect in aging is to compute an additional inhibition measure using the same stimuli, the same sample and the same paradigm. By arranging the sequence of Stroop trials, we were able to compute Stroop and NP effects concurrently in the same experiment (Catena et al., 2002). According to the age-related inhibition deficit hypothesis, older adults should not show significant NP, which might account for the greater Stroop effect in older than younger adults. Thus, failure to suppress distractor information (the word meaning) in the current trial made the task-irrelevant word a stronger competitor with color naming, increasing conflict and therefore Stroop interference. The fact that the younger group showed a positive correlation ($r = 0.33$) and the older group a negative correlation ($r = -0.14$) between Stroop and NP scores further supports the age-related inhibition failure account. However, before a stronger case can be made from this pattern of results, we have to be able to demonstrate that NP in the present study reflects distractor inhibition rather than episodic retrieval. Procedural details and neuroimaging findings could further support the inhibitory nature of NP.

In the present task we followed a similar procedure to that of Catena et al. (2002). In that study, the authors presented stimuli with all the letters colored in primes (trial n) and probes (trial $n + 1$), mixed with trials in which only one letter was colored either in primes, or in probes, or in both. Significantly, they observed both a Stroop effect and NP in the all-letter-colored condition, similar to our study, but also in the all-single letter-colored condition. According to the episodic retrieval account of NP (Neill and Valdes, 1992; Neill et al., 1994), the retrieval process is facilitated when primes and probes are similar. This account predicts more NP in the all–all letter-colored than in the all-single letter-colored condition. However, Catena et al. (2002) reported a similar magnitude of NP in the two conditions. They suggested that an inhibition account of NP accommodated their findings better. This is also supported by the fact that we used a small set of stimuli (four-color words) that were repeated frequently throughout the experiment. This might have led to high activation of the irrelevant words. According to the NP inhibition model of Malley and Strayer (1995) as well as Kramer and Strayer (2001), highly activated distractors are likely to interfere with responding and therefore have to be suppressed.

The involvement of attention-dependent inhibitory mechanisms in the NP effect is also supported by both neurophysiological evidence (Gibbons, 2006; Frings and Groh-Bordin, 2007; Hinojosa et al., 2009) and neuroimaging data (Vuilleurmier et al., 2005). NP has been associated with increased activity in the anterior cingulate cortex and the insula, brain areas associated with inhibitory processing (Leung et al., 2008). Frings and Groh-Bordin (2007) found the N2 component associated with cognitive control and response inhibition located in anterior brain regions (Folstein and Petten, 2008). Significantly, these anterior areas are also activated when a Stroop task is used. For instance, Adleman et al. (2002) found activation in the prefrontal cortex and the anterior cingulate gyrus, areas also activated in NP. In a recent study, Pardo et al. (2007) reported that the largest age-related declines occurred particularly in three medial regions: the anterior cingulate cortex, the subgenual cingulate cortex, and the dorsomedial thalamus. These findings suggest an age-related dysfunction in the executive attention network, in keeping with the present results.

5. Conclusions

Briefly, older adults seem to present a deficit in implementing attentional control when the task requires dealing with salient distracting information, such as the words in the Stroop task. The use of an item-by-item design allowed us to discard factors other than inhibition as the cause of an age-related increase in Stroop interference, and the arrangement of trials in the Stroop procedure proved useful to measure Stroop interference and NP effects concurrently within a single experiment. NP results helped us to understand better the age-related inhibition deficit that has been reported frequently to explain the large Stroop interference usually observed in the elderly.

Conflict of interest statement

None.

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References

Adleman, N.E., Menon, V., Blasey, C.M., Weite, C.D., Warsofsky, I.S., Glover, G.H., Reiss, A.L., 2002. A developmental fMRI study of the Stroop color-word task. NeuroImage 16, 67–75.
Amieva, H., Lafont, S., Auriacombe, S., Le Carret, N., Dartigues, J-F., Orgogozo, J-M., Colette, F., 2002. Inhibitory breakdown and dementia of the Alzheimer type: a general phenomenon? J. Clin. Exp. Neuropsychol. 24, 503–516.
Andrés, P., Guerrini, C., Phillips, L., Perfect, T., 2008. Differential effects on aging on executive and automatic inhibition. Dev. Neuropsychol. 33, 101–123.
Aron, A.R., 2007. The neural basis of inhibition in cognitive control. Neuroscientist 13, 214–228.
Barch, D.M., Carter, C.S., Hachten, P.C., Usher, M., Cohen, J.D., 1999. The benefits of distractibility: mechanisms underlying increased Stroop effects in schizophrenia. Schizophr. Bull. 25, 749–762.
Basak, C., Verhaeghen, P., 2003. Subitizing speed, subitizing range, counting speed, the Stroop effect, and aging: capacity differences and speed equivalence. Psychol. Aging 18, 240–249.
Belleville, S., Rouleau, N., Van der Linden, M., 2006. Use of the Hayling task to measure inhibition of prepotent responses in normal aging and Alzheimeŕs disease. Brain Cogn. 62, 113–119.
Blessed, G., Tomlinson, B.E., Roth, M., 1968. The association between quantitative measures of dementia and of senile change in the cerebral grey matter of elderly subjects. Br. J. Psychiatry 114, 797–811.
Borella, E., Delaloye, C., Lecerf, T., Renaud, O., de Ribaupierre, A., 2009. Do age differences between young and older adults in inhibitory tasks depend on the degree of activation of information? Eur. J. Cogn. Psychol. 21, 445–472.
Catena, A., Fuentes, J.L., Tudela, P., 2002. Priming and interference effects can be dissociated in the Stroop task: new evidence in favor of the automaticity of word recognition. Psychon. Bull. Rev. 9, 113–118.
Collette, F., Germain, S., Hogge, M., Van der Linden, M., 2009. Inhibitory control of memory in normal ageing: dissociation between impaired intentional and preserved unintentional processes. Memory 17, 104–122.
Conway, M..A., Fthenaki, A., 2003. Disruption of inhibitory control of memory following lesions to the frontal and temporal lobes. Cortex 39, 667–686.
Davidson, D.J., Zacks, R.T., Williams, C.C., 2003. Stroop interference, practice, and aging. Neuropsychol. Dev. Cogn. B., Aging Neuropsychol. Cogn. 10, 85–98.
Dulaney, C.L., Rogers, W.A., 1994. Mechanisms underlying reduction in Stroop interference with practice for young and old adults. J. Exp. Psychol. Learn. 20, 470–484.
Faust, M.E., Balota, D.A., 1997. Inhibition of return and covert orienting in healthy older adults and individuals with dementia of the Alzheimer's type. Neuropsychology 11, 13–29.
Folstein, F., Folstein, S.L., McHugh, P.R., 1975. Mini-mental state, a practical method for grading the cognitive state of patients for the clinician. J. Psychiatr. Res. 12, 189–198.
Folstein, J.R., Petten, V.C., 2008. Influence of cognitive control and mismatch on the N2 component of the ERP: a review. Psychophysiology 45, 152–170.
Fox, E., 1995. Negative priming from ignored distractors in visual selection: a review. Psychon. Bull. Rev. 2, 145–173.
Frings, C., Groh-Bordin, C., 2007. Electrophysiological correlates of visual identity negative priming. Brain Res. 1176, 82–91.
Fuentes, L.J., 2004. Inhibitory processing in the attentional networks. In: Posner, M.I. (Ed.), Cognitive Neuroscience of Attention. Guilford Press, New York, pp. 45–55.
Gibbons, H., 2006. An event-related potential investigation of varieties of negative priming. J. Psychophysiol. 20, 170–185.
Hartley, A.A., 1993. Evidence for the selective preservation of spatial selective attention in old age. Psychol. Aging 3, 371–379.
Hartman, M., Hasher, L., 1991. Aging and suppression: memory of previously relevant information. Psychol. Aging 6, 587–594.
Hinojosa, J.A., Pozo, M.A., Méndez-Bértolo, C., Luna, D., 2009. Event-related potential correlates of visual identity negative priming unbiased by trial-by-trial effect. Brain Cogn. 69, 531–537.
Kane, M.J., Conway, A.R.A., Hambrick, D.Z., Engle, R.W., 2007. Variation in working memory capacity as variation in executive attention and control. In: Miyake, A., Kane, M.J., Conway, A.R.A., Jarrold, C., Towse, J.N. (Eds.), Variation in Working Memory. Oxford University Press, New York, NY, USA, pp. 21–46.
Kane, M.J., May, C.P., Hasher, L., Rahhal, T., Stoltzfus, E.R., 1997. Dual mechanisms of negative priming. J. Exp. Psychol. Hum. Percept. Perform. 23, 632–650.
Kieley, J.M., Hartley, A.A., 1997. Age-related equivalence of identity suppression in the Stroop color-word task. Psychol. Aging 12, 22–29.
Kramer, A.F., Strayer, D.L., 2001. Influence of stimulus repetition on negative priming. Psychol. Aging 16, 580–587.
Langley, L.K., Vivas, A.B., Fuentes, L.J., Bagne, A.G., 2005. Differential age effects on attention-based inhibition: inhibitory tagging and inhibition of return. Psychol. Aging 20, 356–360.
Leung, K.K., Lee, T.M.C., Xiao, Z., Wang, Z., Zhang, J.X.X., Yip, P.S.F., Li, L.S.W., 2008. Neural activities for negative priming with affective stimuli: an fMRI study. Neurosci. Lett. 433, 194–198.
Little, D.M., Hartley, A.A., 2000. Further evidence that negative priming in the Stroop color-word task is equivalent in older and younger adults. Psychol. Aging 15, 9–17.

Ludwig, C., Borella, E., Tettamanti, M., De Ribaupierre A., 2009. Adult age differences in the color Stroop test: a comparison between an item-by-item and a blocked version. Arch. Gerontol. Geriatr. doi:10.1016/j.archger.2009.09040.
Malley, G.B., Strayer, D.L., 1995. Effect of stimulus repetition on positive and negative identity priming. Percept. Psychophys. 57, 567–667.
Martínez de la Iglesia, J., Onis Vilches, M.C., Duenas Herrerro, R., Colomer, C.A., Aguado Taberne, C., Luque Luque, R., 2002. The Spanish version of the Yesavage abbreviated questionnaire (GDS) to screen depressive dysfunctions in patients older than 65 years. Medifam 12, 620–630 (in Spanish).
May, C.P., Kane, M.J., Hasher, L., 1995. Determinants of negative priming. Psychol. Bull. 118, 35–54.
Mayr, S., Buchner, A., 2007. Negative priming as a memory phenomenon. J. Psychol. 215, 35–51.
McLeod, C.M., 1991. Half a century of research on the Stroop effect: an integrative review. Psychol. Bull. 109, 163–203.
Neill, W.T., Valdes, L.A., 1992. Persistence of negative priming: steady state or decay? J. Exp. Psychol. Learn. 18, 565–576.
Neill, W.T., Terry, K.M., Valdes, L.A., 1994. Negative priming without probe selection. Psychon. Bull. Rev. 1, 119–121.
Pardo, J.V., Lee, J.T., Sheikh, S.A., Surerus-Johnson, C., Shah, H., Munch, K.R., Carlis, J.V., Lewis, S.M., Kuskowski, M.A., Dysken, M.W., 2007. Where the brain grows old: decline in anterior cingulated and medial prefrontal function with normal aging. NeuroImage 35, 1231–1237.
Peña-Casanova, J., 1991. Programa Integrado de Exploración Neuropsicológica (Test Barcelona). Normalidad, semiología y patología neuropsicológica. Masson, Barcelona (in Spanish).
Reisberg, B., Ferris, S.H., De Leon, M.J., Crook, T., 1988. Global deterioration scale (GDS). Psychopharmacol. Bull. 24, 661–663.
Rush, B.K., Barch, D.M., Braver, T.S., 2006. Accounting for cognitive aging: context processing, inhibition or processing speed? Neuropsychol. Dev. Cogn. B., Aging Neuropsychol. Cogn. 13, 588–610.
Salo, R., Henik, A., Robertson, L.C., 2001. Interpreting Stroop interference: an analysis of differences between task versions. Neuropsychology 15, 462–471.
Schneider, W., Eschman, A., Zuccoloto, A., 2002. E-Prime Reference Guide. Psychology Software Tools Inc., Pittsburgh.
Shulman, K.I., 2000. Clock-drawing: is it the ideal cognitive screening test? Int. J. Geriatr. Psychiatry 15, 548–561.
Spieler, D.H., Balota, D.A., Faust, M.E., 1996. Stroop performance in healthy younger and older adults and in individuals with dementia of the Alhzheimeŕs type. J. Exp. Psychol. Hum. Percept. Perform. 22, 461–479.
Stroop, J.R., 1935. Studies of interference in serial verbal reactions. J. Exp. Psychol. 18, 643–662.
Tipper, S., 1985. The negative priming effect: inhibitory priming by ignored objects. Q. J. Exp. Psychol. 37, 571–590.
Tipper, S., 2001. Does negative priming reflect inhibitory mechanisms? A review and integration of conflicting views. Q. J. Exp. Psychol. 54, 321–343.
Vakil, E., Manovich, R., Ramati, T., Blachstein, H., 1996. The Stroop color-word task as a measure of selective attention: efficiency in the elderly. Dev. Neuropsychol. 12, 313–325.
Verhaeghen, P., De Meersman, L., 1998. Aging and the Stroop effect: a metanalysis. Psychol. Aging 13, 120–126.
Vuilleurmier, P., Schwartz, S., Duhoux, S., Dolan, R.J., Driver, J., 2005. Selective attention modulates neural substrates of repetition priming and implicit visual memory: suppressions and enhancements revealed by fMRI. J. Cogn. Neurosci. 17, 1245–1260.
West, R., Alain, C., 2000. Age-related declined in inhibitory control contributes to the increased Stroop effect observed in older adults. Psychophysiology 37, 179–189.
West, R., Bell, M.A., 1997. Stroop color-word interference and electroencephalogram activation: evidence for age-related decline of the anterior attention system. Neuropsychology 11, 421–427.
Whechsler, D., 1988. Test de Inteligencia para adultos-Revisado. WAIS-R. Buenos Aires, Paidós (in Portuguese).