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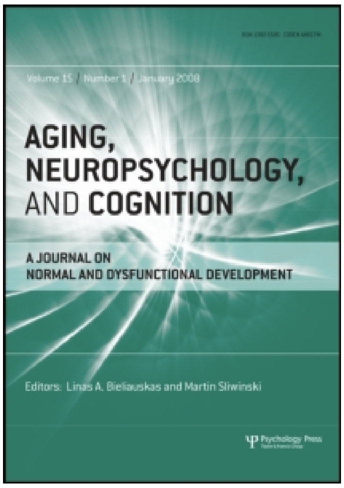

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Semantic Hyperpriming in Normal Aging: A Consequence of Instructions?

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Semantic Hyperpriming in Normal Aging: A Consequence of Instructions?

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ABSTRACT

Semantic hyperpriming has consistently been found in normal aging. However, because the standard instructions to test semantic priming are generally ambiguous (focusing on both accuracy and speed), it is difficult to account for hyperpriming in older adults. By using the direct and mediated priming paradigms, this study investigates whether older adults' response mode at testing may explain hyperpriming. First, we show that, under identical conditions, inducing a response mode that favors speed leads to greater priming effects in older adults. The pattern of results is similar to what is observed under standard instructions. Second, prompting a response mode that favors accuracy leads to greater priming effects in younger adults. We discuss various explanations for these findings and conclude, in accordance with the Ratcliff, Thapar, Gomez, and McKoon (2004a) diffusion model, that hyperpriming in normal aging is contingent on older adults' response mode at testing.

Keywords: Semantic priming; Hyperpriming; Normal aging.

Many studies have investigated the integrity of semantic memory in older adults. Semantic Priming (SP) is one of the paradigms that have most often been used to investigate semantic memory. In this paradigm, a target word (e.g., *lion*) is processed faster and more accurately – for example in a lexical decision task – when it is preceded by a semantically related prime word (e.g., *tiger*) than when it is preceded by a non-related prime word (e.g., *house*) (for reviews, see Laver & Burke, 1993; Myerson, Ferraro, Hale, & Lima, 1992). Many of these studies showed similar priming effects in younger and older adults, and concluded that the semantic network is preserved in normal aging (Bowles & Poon, 1985; Burke, White, & Diaz, 1987; Chiarello, Church, & Hoyer, 1985; Linnville, 1995; Quaireau, 1995; White & Abrams, 2004). Nevertheless, the size of the SP effect was often

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found to be numerically larger for older adults (Giffard, Desgranges, Kerrouche, Piolino, & Eustache, 2003; Laver, 2000; Myerson, Hale, Chen, & Lawrence, 1997). Although this age-related hyperpriming is consistent among studies, the size of this hyperpriming effect is small and becomes statistically significant only in meta-analyses (Laver & Burke, 1993; Myerson et al., 1992).

Three main explanations have been proposed for this age-related hyperpriming effect: a larger semantic network (Laver, 2000; Laver & Burke, 1993), a general cognitive slowing (Myerson et al., 1997), and more conservative decision criteria for older adults (Ratcliff, Thapar, Gomez, & McKoon, 2004a).

According to the larger semantic network explanation (Laver & Burke, 1993), the hyperpriming effect can be explained by older adults' greater experience of life. These authors claim that the SP effect is enhanced proportionally to the number of indirect connections between the different nodes within the semantic network, and that these indirect connections depend on exposure to language. Indeed, given that older adults have a longer experience of language, they could have more indirect connections and, therefore, more activation might spread to the target node.

In the view of Myerson and colleagues (Myerson, Hale, Wagstaff, Poon, & Smith 1990; Myerson et al., 1992, 1997), hyperpriming could be due to the general cognitive slowing observed in aging. These authors showed that, when the latencies of older adults' RTs are plotted as a function of young adults' RTs, the resulting linear function has a 1.5 slope (Lima, Hale, & Myerson, 1991), which means that older adults as a group are 1.5 times slower than younger adults (for both related and unrelated word pairs). Because of these longer latencies, their semantic priming effect could be 1.5 times larger (Myerson et al., 1992, 1997; see also Giffard et al., 2003; Laver & Burke, 1993).

Another straightforward approach to hyperpriming was proposed by Ratcliff et al. (2004a), who suggest that the adoption of more conservative criteria by older adults could explain age-related hyperpriming. Indeed, according to their diffusion model, making a lexical decision depends on several kinds of processing: (1) the rate of accumulation of information (the 'drift rate'), which reflects the quality of the match between the test string and lexical memory (in other words, word knowledge is represented in the drift rate of the model); (2) the criteria that determine the amount of information needed before making a decision; and (3) non-decision components, such as encoding and response execution. According to this model, while the SP effect is due to a difference in the 'drift rate' between a primed and an unprimed word, hyperpriming in aging is related only to differences in the decision criteria. The decision criteria allow one to account for the bias that exists in the speed-accuracy relationship (the speed-accuracy trade-off, i.e., the fact that accuracy tends to decrease when speed is increased). The decision criteria are represented in the model through a boundary separation, which determines the quantity of evidence required to give a '*word*' response. A higher boundary is associated

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with better accuracy, but more time is needed to reach the boundary. Thus, the larger SP effect is related to the difference in RTs. This assumption is supported by studies that note that decision criteria become more conservative in aging (Ratcliff, Thapar, & McKoon, 2001, 2004b; Thapar, Ratcliff, & McKoon, 2003).

So far, there has been no clear evidence allowing one to choose between these different explanations. One reason is related to the fact that RTs are longer for older than for younger adults. At first sight, this difference in RTs should favor the general cognitive slowing explanation. However, Laver (2000) showed that older adults maintained their hyperpriming effect even when, by using temporal deadlines, they responded as fast as younger adults. Moreover, according to the Ratcliff et al. (2004a) study, the difference in decision criteria also leads to longer RTs. So, if it is possible to control the differences in decision criteria between age groups (as did Ratcliff et al., 2004b), both age groups should present similar RTs. In other words, both these studies suggest that younger and older adults could respond with similar latencies, at least under favorable conditions.

In the same vein, one possible way to induce younger and older adults to respond with similar latencies is to manipulate the instructions given to the participants (Ratcliff et al., 2004b). Indeed, in previous studies, because participants were asked to respond both as fast and as accurately as possible, the instructions might be considered as ambiguous, and thus might be understood differently across age groups. Consequently, the first aim of the present study was to better understand the impact of unambiguous instructions given to the participants. To do this, the instructions given to the participants focused either on speed or on accuracy (but never on both at the same time). Although such a manipulation had already been used in the context of recognition (Ratcliff et al., 2004b), to the best of our knowledge, it had never been used in SP studies.

This manipulation of instructions could provide new evidence supporting one or more explanations of the hyperpriming effect. If unambiguous instructions have no impact on the difference in RTs (i.e., the 1.5 slope; Myerson et al., 1990, 1992, 1997) or on the SP difference between age groups, this study will provide new evidence in favor of the general cognitive slowing explanation. More generally, this explanation might not be rejected as long as the relation between RTs and the SP effect is a linear function *and* as long as older adults are slower than younger ones, regardless of instructions.[1]

[1]Indeed, one cannot exclude the possibility that the 1.5 slope described by the general cognitive slowing hypothesis might change for other reasons that are not controlled when manipulating instructions. For example, when asked to respond as quickly as possible, older adults might improve their RTs more than younger adults because younger adults' RTs are already nearer the threshold below which it is difficult to respond any faster. In this case, the difference between younger and older adults' RTs could become a 1.3 slope instead of a 1.5 slope, but the older adults' SP effect should also be 1.3 times greater than the younger adults' SP effect.

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On the other hand, if the relation between RTs and the SP effect was no longer a linear function, the larger semantic network would appear to be a more convincing explanation. More specifically, by using a temporal deadline, Laver (2000) showed that younger and older adults were able to respond within similar latencies (for recent replication with another priming task – the pronunciation task – see Laver, 2009), although the SP effect remained larger for older adults. These results led Laver (2000) to conclude that, even when younger and older adults' RTs were the same, hyperpriming was still observed and did not depend on RTs. In this context, the accuracy instructions might lead to similar RTs between age groups, while maintaining the hyperpriming effect in the older adults. Such results would provide new evidence in favor of a richer semantic network in older adults (Laver, 2000).

Finally, if the manipulation of instructions has an impact on the decision criteria and the SP effect is modulated according to instruction and not age, the data would support Ratcliff et al.'s (2004a) view. Indeed, according to Ratcliff et al. (2004a, p. 287), 'the more conservative criteria are all that is needed to produce the right scaling behavior to give the larger priming effects for older subjects'. However, these authors did not know whether it is possible for older participants to set their criteria as low as younger participants. In this context, the removal of any ambiguity in the instructions should provide information about the possibility of modulating the decision criteria in younger and older participants, as was the case in Ratcliff et al.'s (2004b) study. In other words, in this case, the SP effects should be modulated by the speed-accuracy trade-off. Moreover, they should depend on decision criteria, as measured by signal detection theory analysis (Snodgrass & Corwin, 1988).

As meta-analyses have shown the hyperpriming effect to be consistent (Laver & Burke, 1993; Myerson et al., 1992), the aim of this study was not to replicate hyperpriming. Rather, our aim was to further explore the influence of decision criteria on SP effects in both young and older adults. More specifically, the purpose was to assess the impact of unambiguous instructions, that is, instructions that favor either speed or accuracy but not both at the same time. To address this issue, we used a double lexical decision (LD) task (i.e., a lexical decision task in which participants have to make their decision on both prime and target letter strings), which is the most widely used task for exploring SP effects (for reviews, see Laver & Burke, 1993; Myerson et al., 1992; see also Pomarol-Clotet, Oh, Laws, & McKenna, 2008). We also manipulated the strength of the associations between the prime and the target by using direct and indirect (i.e., mediated priming; Chwilla & Kolk, 2002) SP paradigms. In the indirect SP paradigm, the prime word (*lion*) is semantically related to the target (*stripes*) only through one mediating word (*tiger*). This means that only indirect semantic associations exist between the prime and the target. This paradigm appears particularly relevant given that, according to some authors (e.g., Laver & Burke, 1993),

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age-related hyperpriming results from the greater number of indirect associations in the older adults' semantic network. Thus, one might think that, even if older adults have a larger semantic network, the direct associations involved in direct SP might be too salient to allow them to take advantage of that larger semantic network. For example, one cannot exclude the possibility that the studies that did not show differences between age groups were studies in which the association strength between the prime and the target was greater (Bowles & Poon, 1985; Burke et al., 1987; Chiarello et al., 1985; Linnville, 1995; Quaireau, 1995; White & Abrams, 2004). Thus investigating the mediated SP effect might avoid this possible problem.

METHOD

Participants

Thirty-two older adults (aged 60–75) and 32 younger adults (aged 18–30) took part in the study. The older adults were volunteers recruited in the University of the Third Age (Liège). The younger ones were undergraduate students at the University of Liège. Participants with any history of neurological or psychiatric illness were excluded from the study, and all of them were native speakers of French. The older adults had an average of 14.1 years of education, and the younger adults 15.6, $t(62) = 3.6$, $p < .001$. Although the older adults had on average 1.5 years less education than the younger adults, the Mill Hill vocabulary scale (Deltour, 1993) showed that their vocabulary knowledge (34.97) was marginally greater than that of the younger adults (33.12), $t(62) = 1.75$, $p = .08$.

Materials

The stimuli consisted of 360 prime-target pairs presented in black uppercase letters (in 18-point Courier New) on a white background at the center of a PC monitor. Of the 720 letter strings, 540 were real French words and 180 were pseudo-words. The pseudo-words met the phonographic constraints of French: they were derived from real French words by substituting one letter, and this substitute letter had roughly the same association frequency with its neighboring letters as the original letter (for the substitution table, see Véronis, 1986).

During each of the four conditions of the experiment, the participants were presented with a set of 90 prime-target pairs. Each condition contained 15 target (related) pairs, 15 counterbalanced (control) pairs, 15 unrelated filler pairs and 45 pairs with a pseudo-word. The pseudo-word occurred either 22 or 23 times in the prime position and 23 or 22 times in the target position. The proportion of related pairs was .166. The unrelated filler pairs, target pairs and counterbalanced pairs were all matched for frequency and length.

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Two versions of the task were constructed. In each version, the counterbalanced pairs were constructed by rearranging the target related pairs from the other version, so that they were unrelated; these counterbalanced pairs were included to give us control pairs that did not differ from the related pairs on any features other than their semantic association.

To create our related pairs, we generated 200 triplets (prime – mediator – target) *a priori*. In order to evaluate the semantic distance between the prime and the target of each triplet, 100 undergraduate students were asked to perform a free association task: 50 students were asked to list the first five words that came to mind for the prime, and 50 other students had to perform the free association task on the mediated *a priori* word in order to prevent the prime words from influencing the mediator words. The selection criteria for the mediated related pairs were inspired by Anaki and Henik (2003): for a triplet, the mediator should be provided with a mean frequency superior to .2, or should be the word that was the most often given in response to the prime; the target had to meet the same criteria in response to the mediator word and should not be produced in response to the prime word. Of our 200 *a priori* pairs, 78 met the criteria for the mediated related pairs. From these 78 items, 60 pairs were used in the present study and distributed between the two versions of the mediated priming task. The direct related pairs were chosen among triplets that did not reach criteria for mediated pairs. The selection criteria were that the association between the prime and the mediator (or the mediator and the target, i.e., direct associations) in the *a priori* triplets had to be provided with a mean frequency superior to .2, and the target should be the word that was most often given in response to the prime (or to the mediator). Among the pairs that met these criteria, 60 items were used for the direct priming task.

Procedure

Participants were seated at a distance of 50 cm from the computer screen. Four conditions were administered which differed according to the type of target pair (direct vs. mediated pairs) and the instructions given (speed vs. accuracy). In the direct condition, the associations between the prime and the target were direct; in the mediated pairs, the associations were indirect. Under the speed instructions, the participants were asked to respond as fast as possible, with no reference to accuracy; under the accuracy instructions, the participants were simply asked to respond as accurately as possible.

The order of both the instructions and the stimuli (i.e., stimuli presented under each instruction) was counterbalanced across participants.

Each trial began with the presentation of a fixation cross displayed at the center of the monitor. Five hundred milliseconds after the onset of the fixation cross, the prime word and the target word were presented simultaneously for 400 ms (SOA = 0). The prime and target words were presented to the left and right, respectively, of the fixation cross. After the 400-ms presentation, a blank screen appeared and the participants had to decide, as fast as possible under the speed instruction, or as accurately as possible under the accuracy instruction, whether the two letter strings were French words or not. The participants had to respond by pressing the 'C' key of an AZERTY keyboard with their right index finger if two French words had been presented and by pressing the 'N' key with their left index finger if at least one of the two letter strings was not a French word. The trials were presented randomly with the restriction that a target trial could not start the session. The proportion of correct expected 'yes' and 'no' decisions was .50. In case of error, no feedback was given. A practice list of five items preceded the experimental session.

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RESULTS

Four older participants were removed from the analyses because their priming size was more than 3 standard deviations (*SD*) from the mean.

The first analyses aimed to determine whether the manipulation of the instructions had an impact on younger and older participants' RTs and accuracy.

RT Analyses

An analysis of variance (ANOVA) was performed on RTs (see Table 1) for all correct responses with Age group (2 levels: younger vs. older) as between-participants variable and Instructions (2 levels: speed vs. accuracy) and Type of priming (2 levels: direct vs. mediated) as within-participant variables. This analysis revealed a significant Age group × Instructions interaction, $F(1, 58) = 19.1$, $MSE = 39377$, $\eta^2_p = .25$, $p < .001$, and a significant Type of priming × Instructions interaction, $F(1, 58) = 23.6$, $MSE = 16998$; $\eta^2_p = .29$, $p < .001$.

The Age group × Instruction interaction might suggest that instructions did not influence older and younger adults' responses in the same way. This interpretation is confirmed by planned comparisons, which revealed that

TABLE 1. Mean Reaction Times (in ms) for Correct Responses According to Instructions and Type of Priming

Type of priming	Direct		Mediated	
Instructions	Accuracy	Speed	Accuracy	Speed
Age group				
Young	801 (41)	503 (26)	1005 (54)	536 (33)
Older	662 (44)	581 (28)	857 (58)	620 (35)

Note: SEM values are presented in parentheses.

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older adults responded slower than younger adults under speed instructions, $F(1, 58) = 3.91$, $MSE = 49763$, $p = .05$, but faster than younger adults under accuracy instructions, $F(1, 58) = 5.21$, $MSE = 118047$, $p = .03$.

The Type of priming × Instructions interaction showed that the impact of the instructions was greater for the mediated priming than for the direct priming condition. However, the instruction effect was significant for both direct, $F(1,58) = 59.85$, $p < .001$, and mediated, $F(1,58) = 97.02$, $p < .001$, conditions.

We also noted a significant Instruction effect, $F(1, 58) = 111.8$, $MSE = 39377$, $\eta^2_p = .66$, $p < .001$, showing that participants responded globally faster under the speed instructions than the accuracy instructions, and a significant Type of priming effect, $F(1, 58) = 42.8$, $MSE = 19236$, $\eta^2_p = .42$, $p < .001$, showing that responses were slower for the mediated priming than for the direct priming condition.

Finally, the Age group × Type of priming interaction, the Age group × Type of priming × Instructions interaction and the main effect of Age group on RTs were not significant (all *p*s > .1). Given the significant Age group × Instructions interaction, this absence of Age group effect on mean RTs could be merely the result of averaging across instructional conditions.

To sum up, this analysis revealed first that all participants followed the instructions since they responded faster under accuracy than speed instructions. Second, the overall RTs were similar between age groups; however our results suggest that the impact of the instructions was greater for younger than for older adults.

Accuracy Analyses

Similar analyses were performed on proportions of correct responses (see Table 2). As with the RTs, the Age group × Instructions interaction was significant, $F(1, 58) = 16.9$, $MSE = 0.003$, $\eta^2_p = .22$, $p < .001$. Again, these results suggest that participants followed the instructions, but also that the instructions did not influence younger and older adults in the same way: their impact was larger for younger adults since older adults responded less accurately than younger adults under accuracy instructions, but more accurately than younger adults under speed instructions. Nevertheless, planned

TABLE 2. Mean Accuracy According to Instructions and Type of Priming

Type of priming	Direct		Mediated	
Instructions	Accuracy	Speed	Accuracy	Speed
Age group				
Young	.82 (.01)	.75 (.01)	.81 (.01)	.73 (.01)
Older	.81 (.01)	.78 (.02)	.77 (.02)	.76 (.02)

Note: SEM values are presented in parentheses.

comparisons did not reach significance when we compared the main effect of Age for both instruction conditions: $F(1, 58) = 1.83$, $p = .18$ and $F(1, 58) = 2.04$, $p = .16$, for accuracy and speed instructions, respectively.

We also noted a significant main effect of Instructions, $F(1, 58) = 42.05$, $MSE = 0.003$, $\eta^2_p = .42$, $p < .001$, showing that responses were less accurate for the speed than for the accuracy condition, and a significant Type of priming effect, $F(1, 58) = 15.3$, $MSE = 0.003$, $\eta^2_p = .21$, $p < .001$, showing that responses were less accurate for the mediated than for the direct priming condition.

Again, the analyses did not reveal any main effect of Age group, $F(1, 58) = 0.015$, $MSE = 0.02$, $\eta^2_p < .001$, $p = .90$. The *F* ratio for the main Age effect may seem quite surprising; however, the average proportions of correct responses for older and younger adults are respectively .782 and .779, while the *SD*s are 0.083 and 0.070, respectively. In fact, the variance in the present study is small in comparison with other studies (e.g., Laver, 2009). One possible explanation of this observation is that almost 80% of the stimuli were very easy to process, while 20% of the stimuli were very difficult to process. This could have led to a very small within variability.

Finally, no other interactions were significant (all *p*s > .1).

To sum up, this analysis revealed first that participants generally followed the instructions since they responded more accurately under accuracy than speed instructions. Second, the overall accuracy level was similar in both age groups; nevertheless, our results again suggest that the impact of the instructions was greater for younger than for older adults, as was the case for RTs.

Decision Criteria Measures

Our focused instructions seem to influence the participants' response mode, as reflected by the RT and accuracy analyses. In order to further explore the impact of instructions, we performed a signal detection theory analysis to estimate bias criteria (C; see Table 3; Brophy, 1986). Decision criteria measures are based on the hits (responding 'word' to a word item) and false alarms (responding 'word' to a nonword item). Interestingly, we observed that these decision criteria measures were not influenced by Age

TABLE 3. C Scores According to Instructions and Type of Priming

Type of priming	Direct		Mediated	
Instructions	Accuracy	Speed	Accuracy	Speed
Age group				
Young	–.19 (.02)	–.21 (.02)	–.18 (.02)	–.20 (.03)
Older	–.19 (.02)	–.20 (.02)	–.16 (.03)	–.18 (.03)

Note: SEM values are presented in parentheses.

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group, $F(1, 58) = 0.54$, $MSE = 0.026$, $\eta^2_p < .01$, $p = .46$, but were affected by Instructions, $F(1, 58) = 5.13$, $MSE = 0.004$, $\eta^2_p = .08$, $p = .03$. The speed instruction leads to a slightly more liberal bias than the accuracy instruction. The Age group × Instructions interaction and other effects were non-significant (all *p*s > .1).

Priming Analyses

For the priming analyses, we only performed analyses on RTs for correct responses since accuracy levels were at ceiling. Indeed, accuracy levels were about .95 for related pairs and .925 for counterbalanced pairs all over the conditions. This means that participants made on average just under one error (i.e., a proportion of .933) for the related pairs and just over one error for the counterbalanced pairs.

Concerning RT analyses, *t*-tests for related and counterbalanced words indicated that the RTs for related words were smaller than for counterbalanced words (i.e., significant priming effect) for each Age group, Instruction type and Type of priming (all *p*s < .05). To further analyze the influence of Type of priming, Age group and Instruction on this significant priming, priming scores were computed as the RTs for counterbalanced words minus the RTs for related words (see Table 4). An ANOVA showed that the Age group × Instruction interaction was not significant, $F(1, 58) = .11$, $MSE = 12698$, $\eta^2_p = .002$, $p = .74$. In addition, the main effect of Age group had little impact on the priming scores, $F(1, 58) = 0.01$, $MSE = 21146.6$, $\eta^2_p < .001$, $p = .91$, unlike the main effect of Instructions, $F(1, 58) = 5.13$, $MSE = 12698$, $\eta^2_p = .08$, $p = .03$.

Finally, we noted larger priming scores under the mediated than under the direct priming condition, $F(1, 58) = 8.7$, $MSE = 13550$, $\eta^2_p = .13$, $p = .004$, suggesting that the size of the priming effect is not proportionally related to the strength of the association between the prime and the target. However, since RTs were slower for the mediated than for the direct conditions, two other explanations could be proposed. First, it is possible that more time was allowed for spreading activation in the mediated condition, and that this greater accumulated spreading activation led to larger priming effects. Second, it is also possible that, because of these longer latencies, the

TABLE 4. Size of the Priming Effect According to Instructions and Type of Priming

Type of priming	Direct		Mediated	
Instructions	Accuracy	Speed	Accuracy	Speed
Age group				
Young	49 (17)	31 (11)	107 (31)	50 (21)
Older	47 (18)	24 (12)	103 (33)	70 (23)

Note: SEM values are presented in parentheses.

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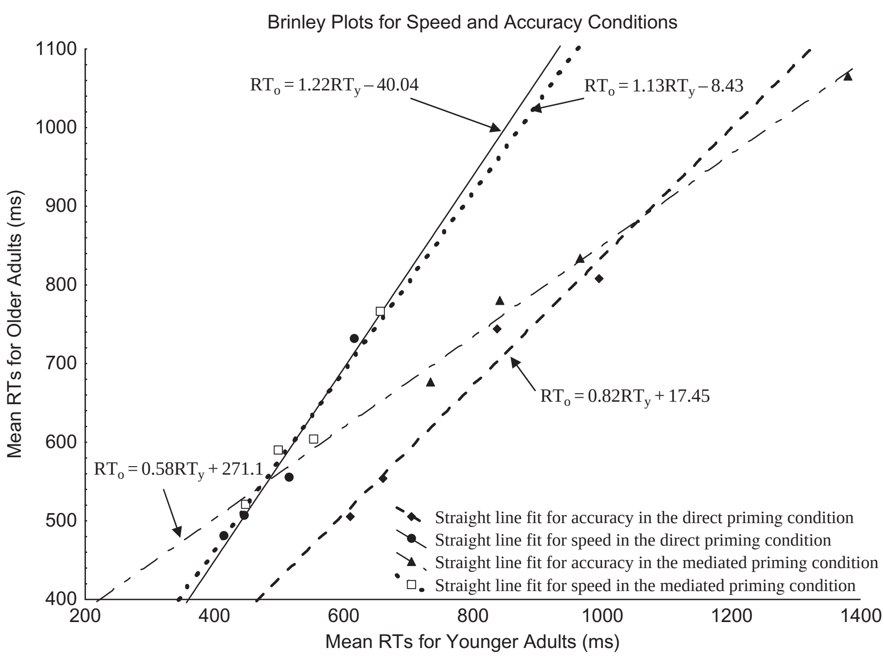
semantic priming effect for the mediated pairs could be mathematically larger (as suggested by the general cognitive slowing). No other interactions were significant (all *p*s > .1).

Brinley Plots

A standard procedure for examining response times in aging research is to plot older adults' RTs against younger adults' RTs to produce a Brinley plot (Brinley, 1965). This procedure might support the general cognitive slowing hypothesis since the 1.5 slope observed is usually obtained with this procedure. Figure 1 shows fitted straight lines under both speed and accuracy instructions plotted separately for the direct and mediated priming conditions. In each case, the average RTs for correct responses for older adults are plotted against the average RTs for younger adults for each experimental condition. The points for each function are the points for the four possible kinds of letter string pairs: related pairs, counterbalanced pairs, filler pairs and pseudo-word pairs.

For the direct priming condition, the slope was 0.82 (intercept + 17.45 ms) under accuracy instructions and 1.22 (intercept –40.04 ms) under speed

FIGURE 1. Brinley plots for mean correct RTs in both the direct and mediated priming conditions, and for both the speed and accuracy instructions. The points represent the mean RTs for related, counterbalanced, filler, and pseudo-word pairs for older and younger adults. Straight lines are fitted for direct and mediated priming conditions under speed and accuracy instructions.



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instructions. For the mediated priming condition, the slope was 0.58 (intercept + 271.1 ms) under accuracy instructions and 1.13 (intercept + 8.43 ms) under speed instructions. These analyses replicate Ratcliff et al.'s (2004a) results, which showed a slope that varied according to instructions, with a value higher than 1 for the speed condition and a value near 1 for the accuracy condition. Moreover, given that the greater slope observed in the present study is a 1.22 slope, while the slope is around 1.5 when instructions are ambiguous, our results suggest that the instructions are not understood in the same way in the two Age groups: younger adults seem to favor speed while older adults seem to favor accuracy.

Interestingly, it should also be observed that, under the speed instructions, the slope is 1.22 for direct priming. Slopes >1 should lead to a larger priming effect. However, the priming effect ratio (i.e., older adults' priming effect divided by younger adults' priming effect) is .77 since the priming effect is greater for younger adults (31 ms) than for older adults (24 ms). These results run counter to the cognitive slowing proposal whereby the older adults' priming effect should be proportional to the slope obtained by the Brinley plot.

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DISCUSSION

Studies on semantic priming have consistently shown a larger priming effect in normal aging (for meta-analyses, see Laver & Burke, 1993; Myerson et al., 1992). Three main explanations have been proposed to account for this age-related hyperpriming: the general cognitive slowing explanation (Myerson et al., 1990, 1992, 1997), the larger semantic network explanation (Laver, 2000; Laver & Burke, 1993), and the more conservative attitude of older adults (Ratcliff et al., 2004a). The aim of the present study was to further investigate these explanations by manipulating the instructions given to the participants. Indeed, the instructions given in the context of SP studies are generally ambiguous, as they focus on both accuracy and speed. One cannot rule out the possibility that younger and older adults understood these ambiguous instructions differently, which could lead to differences in the size of priming effects. Since, according to Laver (2000), the hyperpriming effect observed in normal aging is related to the greater number of indirect associations between the prime and the target words, we also manipulated the type of priming (direct vs. mediated). The number of indirect associations should increase with the number of nodes between the prime and the target. In this context, one might hypothesize that, in the mediated priming condition, the hyperpriming effect in older adults would be more pronounced if this effect was in fact due to a larger semantic network.

The first important result was that age had very little impact on either RTs or accuracy levels, whereas the manipulation of instructions had a considerable

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impact. Specifically, we showed that, under speed instructions, both groups responded significantly faster than under accuracy instructions, while, under accuracy instructions, both groups responded more accurately than under speed instructions. Nevertheless, this claim should be taken with caution since the impact of the instructions is smaller for older adults for both the RT and accuracy measures. Indeed, it is possible that older adults are not able to apply the instructions as well as younger adults, and that the absence of any age effect on RTs or accuracy is merely the result of averaging across instructional conditions.

Concerning the SP effect, our results show that the size of priming depends more on a processing mode driven by instructions (a larger priming effect under accuracy than under speed instructions) than on age.

These results provide interesting new evidence with which to evaluate the hyperpriming explanations. The manipulation of instructions appeared particularly relevant for the discrimination of the three possible explanations, because each explanation leads to different predictions: according to the general cognitive slowing hypothesis (Myerson et al., 1990, 1992, 1997), older adults should show longer RTs regardless of the instructions, and the SP effect should be proportional to the difference between younger and older adults' RTs. The prediction of the larger semantic network hypothesis (Laver, 2000; Laver & Burke, 1993) is that the SP effect should be larger in older adults, independently of the difference in RTs, and thus regardless of the instructions. Finally, the diffusion model (Ratcliff et al., 2004a) suggests that SP effects should vary according to the decision criteria, which have been shown to vary depending on the instructions given to the participants (Ratcliff et al., 2004b).

Although the aim of this study was not to replicate the hyperpriming effect but to investigate explanations of that effect, we still assessed whether hyperpriming occurred in elderly participants. The analysis of Table 4 shows that a numerically (but not statistically) larger priming effect for older adults did occur only in the mediated condition under speed instructions. So, among the four experimental conditions (i.e., two types of priming and two kinds of instructions), only the relationship between the younger and older adults' SP effect for the direct priming condition under speed instructions is surprising (i.e., an absence of hyperpriming). Indeed, a smaller priming effect under accuracy instructions could easily be accounted for by both the general cognitive slowing and diffusion models. According to the general cognitive slowing hypothesis, the size of the priming effect should be proportional to the RTs. Thus, when RTs are longer for older adults, their priming effect should be larger than in younger ones, while, when RTs are shorter for older adults, their priming effect should be smaller than in younger ones. According to the diffusion model, the size of the priming effect should be proportional to the conservative attitude of the participants.

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Thus, when both age groups presented similar bias criteria, we could expect to see a similar priming effect. Since the size of the priming effect was rather similar (i.e., 49 vs. 47 ms for the direct priming condition and 107 vs. 103 ms for the mediated priming condition), these results are compatible with these both explanations. Concerning the size of the SP effect for the mediated condition under speed instructions, older adults presented a larger SP effect than younger adults, which is what is usually observed. Thus, only the SP effect size for the direct priming condition under speed instructions was unexpected. However, this result does not deviate completely from previous studies (e.g., Balota, Black, & Cheney, 1992; Burke et al., 1987; Burke & Yee, 1984).

Among hyperpriming explanations, general cognitive slowing predicts that older adults should always be slower than younger adults and that the size of the priming effect should be proportional to the slope obtained with the Brinley plots. The results of our study showed that this is not necessarily the case. Indeed, in both the direct and mediated SP tasks, we showed that, under speed instructions, older adults (with global mean RTs of 582 and 648 ms, respectively) responded slower than younger participants (mean RTs of 503 and 535 ms, respectively). Under accuracy instructions, though, older adults (668 and 886 ms, respectively) responded faster than younger adults (801 and 1005 ms, respectively). Concerning the proportional relationship between the slope obtained with the Brinley plots and the size of the priming effect, our results militate against a mathematical relation since the slope is 1.22 under speed instructions for direct priming conditions, while the priming ratio is .77. Finally, we also showed that, under accuracy instructions, the slope is smaller than 1, which should mean that older adults' cognitive processing was faster than younger adults'. None of these results support the general cognitive slowing explanation.

The larger semantic network explanation predicts that older adults should consistently present larger SP effects in both instruction conditions. Indeed, Laver (2000) found larger priming effects in older adults even when latencies were controlled by temporal deadlines, which means that controlling RTs should have little impact on the hyperpriming effect usually observed. Thus, although the manipulation of instructions has a differential impact on the RTs of older and younger adults, it should not have any impact on the size of the SP effect. These predictions should be particularly true in the mediated conditions. According to Laver and Burke (1993), hyperpriming is due to the greater number of indirect associations in the older adults' semantic network. Thus, according to this explanation, because mediated priming is based on indirect associations, the mediated condition should favor hyperpriming. In this study, the different types of word pairs were processed similarly by the two age groups. Moreover, older adults did not consistently present larger priming effects (see Table 4): they presented

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numerically larger priming effects under the speed instructions than younger adults; however, under the accuracy instructions, the priming effects were numerically greater (although not significantly so) in younger adults than in older adults. These results suggest that the larger semantic network is not sufficient to account for hyperpriming in normal aging; conversely, they suggest that the size of the priming effect depends more on the instructions.

According to Ratcliff et al. (2004a), older adults' hyperpriming is directly related to their more conservative attitude. In this view, if it were possible to control the decision criteria between age groups, the size of the priming effect should be similar in both. Ratcliff et al. (2004b) showed that the instructions given to the participants could have an impact on the decision criteria. For this reason, we manipulated our instructions in order to control the decision criteria and assess the impact of this manipulation on the size of the priming effect. However, we did not find evidence of differences in decision criteria between age groups. Thus, these results suggest that, similarly to RTs and accuracy, decision criteria are closely related to the instructions given to participants and that the differences usually observed between age groups might be due to the difference in their understanding of ambiguous instructions.

Although age per se did not have any impact on the decision bias, the manipulation of instructions had a direct impact on participants' decision criteria. Indeed, as in previous studies (Ratcliff et al., 2004b), the more conservative criteria were associated with the accuracy instructions. Interestingly, the size of the priming effect did not vary according to age but it did vary according to instructions, as was the case for the bias analyses. Moreover, the more conservative scores and the larger SP effect were both observed under accuracy instructions. Thus, the fact that the size of the priming effect varied with instructions, just as the response bias did, seems to confirm the diffusion model's explanation.

Nevertheless, the extent of the Instruction effect differed between age groups: the impact of instructions was smaller in older than in younger adults. More specifically, under speed instructions, older adults were slower and more accurate than younger adults, while under accuracy instructions, they responded faster and less accurately than younger adults. The pattern of results observed under the speed instructions was similar to what is observed in lexical decision studies (i.e., older adults are slower and more accurate than younger adults; e.g., Madden, Welsh-Bohmer, & Tupler, 1999; Ratcliff et al., 2004a). Thus, our results suggest that, when given ambiguous instructions (i.e., when participants are asked to respond as fast *and* as accurately as possible), participants might focus more on speed than on accuracy. Another possibility is that younger adults focus more on speed while older adults focus more on accuracy. These results also suggest that older adults are less inclined than younger ones to sacrifice one aspect of the instructions (i.e., to sacrifice speed under accuracy instructions, or to sacrifice accuracy under speed instructions), even when asked to do so.

In conclusion, our study shows that, under speed instructions, the pattern of results is similar to what is observed under ambiguous instructions. It is therefore possible that participants who receive ambiguous instructions might favor speed rather than accuracy. This hypothesis would explain why, under ambiguous instructions, younger adults are faster and less accurate than older adults, while under accuracy instructions, the pattern of results is reversed. Our results also suggest that older adults may be less inclined to set aside one aspect of the instructions, even when asked to do so (i.e., they are numerically slower and more accurate under speed instructions and faster and less accurate under accuracy instructions, than younger adults). These results may contribute to explaining the hyperpriming effect generally observed in aging. Indeed, of the three main explanations, our results did not confirm the predictions of either the general cognitive slowing or the larger semantic network hypothesis. On the other hand, our results do seem to confirm the diffusion model: they show that the size of the priming effect varies with the speed-accuracy trade-off. In this context, the differences resulting from the application of ambiguous instructions support the idea that older adults naturally have a more conservative attitude because they focus more on accuracy, while younger adults may focus more on speed; however, this difference may be reversed when the instructions focus only on accuracy.

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