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Priming Effects from Young-Old to Very Old Age on a Word-Stem Completion Task: Minimizing Explicit Contamination

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ABSTRACT

We investigated the size of repetition priming effects from young-old to very old age using a newly developed Word-Stem Completion (WSC) task. Retrospectively, we examined the role of explicit, intentional retrieval strategies in priming. We constructed our task by taking factors into account that were known to complicate the measurement of significant and valid priming effects. Within our sample of 170 cognitively healthy elderly persons of 55–94 years old, we found no effects on priming of age, gender, education, intelligence, cognitive status, memory complaints, or depressive symptoms. Participants that *subsequent* to task administration reported awareness of the study–test relationship obtained higher priming scores. However, analysis of stem-completion times showed that explicit contamination *during* the task was unlikely. The results suggest that WSC priming is age-invariant up to very old age. This task with increased validity might contribute to the differentiation with Alzheimer's disease by improving specificity of assessment.

Keywords: Implicit memory; Priming; Word-stem completion; Very old age; Explicit contamination.

INTRODUCTION

It remains unclear whether tasks measuring repetition priming can differentiate between patients with Alzheimer's disease (AD) and normal elderly controls. Inconsistent findings in the research literature may be explained by differences between studies in participant and task characteristics (e.g., Fleischman, 2007). Particularly in normal aging up to very old age, it is questionable whether priming remains stable or shows decline relative to young-old age.

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It is also questionable whether tasks used in previous studies were suitable to reliably and validly measure priming in the elderly population.

The main purpose of the present study is to investigate whether the size of priming effects remains relatively stable in normal aging from young-old to very old age. To prevent biased results as a consequence of the adoption of explicit or intentional retrieval strategies, we measured priming with a newly developed task that minimized this possibility. We constructed this task by integrating previous research findings about task characteristics that tend to elicit explicit contamination. This approach facilitates the non-confounded study of the relationship between age and implicit memory (i.e., automatic retrieval).

Clinical neuropsychological assessment may benefit from a thorough study of priming effects in very old age. An improved priming task may contribute to the differentiation between normal aging and the early stage of AD (also advocated by Fleischman, 2007). Considering the notoriously low reliability of priming measures (e.g., Buchner & Wippich, 2000; Meier & Perrig, 2000), it is not likely that a priming task on its own will ever differentiate adequately between two diagnostic groups. Nonetheless, it may significantly improve differential assessment, if used in combination with episodic memory tests. Episodic memory tasks are highly sensitive to preclinical AD (e.g., Spaan, Raaijmakers, & Jonker, 2003). However, the most sensitive tests tend to elicit relatively many false positive classifications as well, presumably because of effortful retrieval demands as in (delayed) recall measures (e.g., Bäckman, Jones, Berger, Laukka, & Small, 2005; Lowndes & Savage, 2007; Spaan et al., 2003; Tierney et al., 1996, 2001). Particularly, elderly persons of very old age (i.e., 75 years and older), low educational level (or low-average intelligence), and/or depression may be at risk for a false diagnosis (e.g., Bäckman, Small, Wahlin, & Larsson, 2000; Spaan et al., 2003). Assessment may, therefore, benefit from the additional administration of a test that shows normal performance in these persons, but on which early AD patients fail by showing reduced or absent priming effects. Thus, specificity of assessment may eventually improve (e.g., Fleischman, 2007).

Priming in Alzheimer's Disease (AD) and Normal Aging

Numerous studies found impaired priming in early AD patients relative to cognitively healthy controls (for reviews, see: Fleischman, 2007; Meiran & Jelicic, 1995; Spaan et al., 2003). The exact nature of these effects and its constraints are, however, less clear. As Fleischman noted, one current assumption is that AD patients perform deficiently on priming tasks sensitive to conceptual processing, whereas they show preserved priming on perceptual priming tasks. AD patients' performance is believed to be particularly impaired on tasks that require the generation or production of an item at retrieval, instead of identifying or classifying it. The Word-Stem Completion

(WSC) task has frequently shown impaired priming in AD patients (e.g., Fleischman et al., 1999, 2001; McGeorge, Taylor, Della Sala, & Shanks, 2002; Meiran & Jelicic, 1995; Spaan et al., 2003), presumably because of its generative task demands (e.g., Gabrieli et al., 1999). Whether the WSC task should be classified as a conceptual or a perceptual task has long been debated and may be related to how test stimuli are processed (e.g., Mitchell & Bruss, 2003). More specifically, perceptual components of the WSC task may be reduced when stimuli are articulated (e.g., Ryan, Ostergaard, Norton, & Johnson, 2001), which will be further discussed below.

These task characteristics explain patterns of impaired versus preserved priming in AD to a certain extent. However, additional inconsistent findings are reported in differentiating between AD patients and normal controls of very old age, relative to differentiation at a younger age (e.g., Spaan et al., 2003). Absence of significant differences between AD patients and normal controls may be due to compromised cognitive status or preclinical dementia in the controls, which is more likely to occur in very old persons (e.g., Sliwinski, Lipton, Buschke, & Stewart, 1996). Heterogeneous cognitive status in aged control groups may have made AD priming appear unimpaired (Fleischman, 2007).

Alternatively, significant differences with AD patients may not be found because priming effects decrease as the age of non-demented, cognitively healthy persons further increases. Various studies found reduced priming effects in elderly participants in their 70s or their 80s (e.g., Davis et al., 1990; Fleischman et al., 1999; Meiran & Jelicic, 1995). Priming reductions with advanced normal aging may be explained by the administration of tasks that somehow invoke intentional, explicit processing (e.g., Fleischman, 2007). In this case, implicit memory tasks, despite the absence of explicit reference to previously presented items, are contaminated by the use of explicit retrieval strategies (*explicit contamination*; e.g., Beauregard, Benhamou, Laurent, & Chertkow, 1999). As explicit memory shows impairments in (advanced) normal aging, explicit contamination puts older persons at a disadvantage compared to younger persons (e.g., Fleischman, 2007; Mitchell & Bruss, 2003). This may explain reduced differences in priming between AD patients and normal controls of very old age, again making AD priming appear unimpaired (Fleischman, 2007).

There are two different ways in which an implicit memory task can be contaminated by explicit memory (e.g., Fay, Isingrini, & Pouthas, 2005; Lee, 2008). The first is *intentional retrieval* or deliberately searching for a previously studied item (e.g., Richardson-Klavehn, Gardiner, & Java, 1994; Schacter, Bowers, & Booker, 1989). The second refers to the *subjective awareness* of participants reexperiencing recently studied items. The second aspect of explicit contamination does not necessarily involve the first aspect, as occurs in automatic or unintentional retrieval. Along with several researchers, we consider awareness problematic only when it causes participants to change their strategy and adopt intentional retrieval processes on upcoming items (e.g., Richardson-Klavehn et al., 1994; Roediger & McDermot, 1993). In addition, as we emphasized above, the susceptibility of an implicit memory task to changing strategies would artificially compromise performance of participants of very old age, reduced intelligence or depression, because they may not benefit from their awareness by means of intentional (i.e., effortful) retrieval strategies. Thus, this would complicate the study of the relationship between age and priming. Finally, from a practical point of view, this would diminish the diagnostic value of such a task in differentiating between normal aging and AD.

Methods for Minimizing Explicit Contamination

The WSC task is a popular and by elderly participants well tolerated implicit memory task. In this task, participants are presented with words at a seemingly independent study task. After some delay, participants are asked to complete two- or three-letter word-stems with the first word that comes to mind, without notification to the study task. Mitchell and Bruss (2003) emphasized that the WSC task is highly susceptible to explicit contamination. Fortunately, previous studies led to various suggestions to minimize the possibility of both the use of intentional retrieval strategies and subjective awareness of the study–test relationship.

First of all, in our opinion, the study task should seem *meaningful* on its own within the battery of tasks, to prevent participants getting suspicious about the reason for administering it. This may lead to explicit contamination or, alternatively, to diminished motivation to cooperate (and decreased encoding of the study items as a result). For example, the frequently used ratings for ‘pleasantness’ seem senseless for words of little affective value (e.g., a ‘tile’). On the contrary, a task that requires the participant to define words seems more meaningful when the battery also contains other ‘vocabulary’ tasks, such as naming and verbal fluency.

Furthermore, to make it less likely that items are recalled as a result of explicit awareness, it is important to *extend the interval* between the study and the test phase (e.g., Mitchell & Bruss, 2003). The interval should not be too short and it should preferably be filled with intervening tasks that, of course, should not interfere with the stimuli of the WSC task, but will help to disguise the study–test relationship (Mitchell & Bruss, 2003).

In addition, long processing times of test-phase stimuli have to be prevented by demanding completions under time constraints (i.e., the *speeded response procedure*: instructing the participant to name the first word that comes to mind; Beauregard et al., 1999; Horton, Wilson, & Evans, 2001; Lee, 2008; Mitchell & Bruss). This limits the time available for those participants who might try to think back to the study list. Correspondingly, several studies found that explicit instructions to try to retrieve studied words lengthened stem-completion times compared to instructions to complete stems with the first word coming to mind (e.g., Major & Horton, 2008; Mitchell & Bruss; Richardson-Klavehn & Gardiner, 1995). This confirms that voluntary, intentional retrieval strategies are effortful and time-consuming (e.g., Fay et al., 2005). *Limited exposure duration* of the target stimuli during the study phase may also help to minimize the chance of explicit contamination (Mitchell & Bruss; e.g., 2 s per stimulus).

In several studies, participants were asked about their explicit awareness, *subsequent* to task administration (see Mitchell & Bruss, footnote 3, for an overview). However, this gives little information about the participant's state of awareness *during* completion or use of intentional retrieval strategies (e.g., Fay et al., 2005; Lee, 2008). Participants may have completed word-stems without awareness (i.e., they indeed named the first word that came to mind) and only later became test aware or, at least, it did not change their retrieval strategy. Similarly, Mitchell and Bruss' participants that claimed study–test awareness in postexperimental interviews stated that knowledge of this relationship usually did not bias their responses, because thinking back to the study list slowed their response time. Thus, retrieval probably still was automatic, uncontaminated by conscious, explicit processing to produce previously studied items. In any case, measuring stem-completion times enables comparison of latencies between different task conditions that might reflect the use of intentional retrieval strategies. Therefore, a *postexperimental interview* in combination with measurement of *stem-completion times* will provide a good method to retrospectively investigate the possibly detrimental impact of explicit contamination during the completion task (e.g., Fay et al., 2005).

Methods for Preventing Floor Effects in Word-Stem Completion Priming

In addition, it is also important to construct a task that is not 'too difficult'. Spaan, Raaijmakers, and Jonker (2005) also administered a WSC task, but consistently found floor effects in all their clinical groups, ranging from cognitively healthy elderly to demented participants. In the same study, a word-identification priming task – together with an explicit memory measure (a paired-associate learning test) – adequately predicted the transition to dementia within two years. These findings, along with the abovementioned production/identification-theory of priming performance in AD (e.g., Gabrieli et al., 1999), suggest that if the floor effects of the former WSC task had been prevented, perhaps even stronger effects had been found than were found with the word-identification priming task.

In preventing these floor effects, first of all, it is important that the study task used for the WSC task ensures sufficiently *deep encoding* to exclude the possibility of poor priming performance as a result of poor attention. The above mentioned task that requires participants to define words seems appropriate. Afterwards, an indication of depth of encoding may be obtained by rating the quality of the definitions provided by the participant and by taking into account the mean time to complete the definitions.

Furthermore, Ryan et al. (2001) emphasized the importance of a study task that requires *pronouncing* the test stimuli. By reading the words aloud, the impact of articulation or phonological components is enhanced. Ryan et al. suggested that WSC search is driven by a cue-specific matching process between the phonological properties of the stem and the target word. Participants may adopt a strategy of pronouncing the stem internally and then search for items in their lexicon that begin with a similar sound (e.g., Rueckl & Mathew, 1999).

As the interval between the study and the test phase should not be too short to prevent explicit contamination, naturally, it should *neither be too long* to prevent floor effects. In the Spaan et al. (2005) study, the interval between study and test was filled with four neuropsychological tasks (two working memory and two verbal episodic memory tasks, comprising about 25 minutes), which may have been too long.

Finally, *baseline completion probability* should not be too low (e.g., Ryan et al., 2001). In the Spaan et al. (2005) study, WSC items were selected with a baseline completion probability of only 2 in 200 completions. This low probability may be necessary in a sample of young, highly educated persons, but it is inappropriate in a sample of elderly participants with a great variety of educational background or intelligence.

This Study

This study was aimed at investigating the size of repetition priming effects within the normal aging spectrum from young-old (55 years) to very old age (up to 94 years) using a newly developed WSC task. In constructing this task, we tried to take into account the factors that may complicate the measurement of significant and valid priming effects, as reviewed above.

Our first question was whether we could measure significant priming effects with our new WSC task in a broad sample of 170 elderly participants. In addition, we examined the influence of various demographic and other relevant participant-related variables (e.g., age, education, intelligence, depressive symptoms, etc.) on priming. More specifically, we investigated whether WSC priming was age-invariant up to very old age or whether priming effects declined from a certain age. In other words, does the size of priming effects remain stable up to very old age or does it show decline relative to young-old age?

Our second set of research questions focused on the role of explicit contamination in priming: did the priming effects we found validly reflect implicit memory performance (i.e., automatic, unintentional retrieval processes) or were the results compromised by the use of explicit intentional retrieval strategies? Explicit awareness of the study–test relationship may or may not occur, but our primary focus was on whether awareness led to a change of strategy in completing the stems (according to an analysis of stem-completion times). This is of interest to our study insofar as it obscured the relationship between age and priming. If that was the case, the usefulness of our newly developed WSC task in future differential assessment would also be reduced.

In short, we expected that when the factors reviewed above are taken into account, we would find significant and valid priming effects, irrespective of age and other participant-related characteristics.

METHOD

Participants

Participants were 181 community-dwelling volunteers between 55 and 94 years of age, recruited from different municipalities in the Netherlands through flyers and referrals from other participants. Participants were administered a semi-structured questionnaire to screen for a history of Cerebrovascular Accidents ($N = 3$), Traumatic Brain Injury ($N = 1$) or other neurological or psychiatric causes of cognitive dysfunctioning. In addition, persons with a history of substance abuse ($N = 2$) or using medication that might influence the central nervous system were excluded from the study. Participants that did not have Dutch as their native language were excluded as well ($N = 1$). To minimize the possibility of demented cases, participants with a score below 24 on the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975; $N = 4$) were subsequently excluded. None of the participants had impaired vision that interfered with test performance. None of the included participants had a missing value on the WSC task or WD. Prior to the test session, participants gave their informed consent. Afterwards, they received a little present to thank them for participating.

Table 1 presents the characteristics of the final sample of 170 participants, as well as for four different age groups. The latter also serves the purpose of illustrating the distribution of these characteristics with respect to age. There are no seriously confounding participant-related variables that complicate the study of the relationship between age and priming. The four age groups did not differ significantly (p values > .05) regarding level of education, estimated IQ, gender distribution, or alcohol consumption. In addition, although the youngest group showed significantly fewer depressive symptoms than the oldest group ($p = .01$), the ratio of participants reporting a considerable amount of depressive symptoms did not differ significantly between the age groups (i.e., only 5% of the entire sample scored above the CES-D cut-off value of 27 (Zich, Attkisson, & Greenfield, 1990) and 28% scored above the more stringent

TABLE 1. Sample characteristics: for the entire sample and per age group separately

	Age group (years)											
	Total (55-94) N = 170		55-64 N = 52		65-74 N = 44		75-84 N = 54		85+ N = 20			
Participant-related variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	Age r [c]	WSC r [d]
Age (years)	71.76	10.08	59.50	2.60	69.93	3.06	79.24	2.57	87.50	2.71	—	–.15
Level of education [a]	4.76	1.48	5.19	1.31	4.82	1.47	4.48	1.53	4.25	1.59	–.23**	.12
Gender (% female)	66		54		73		69		80		.17*	–.11
Global cognitive status (MMSE)	28.69	1.23	29.08	0.93	28.95	1.12	28.44	1.36	27.75	1.21	–.35**	.11
Estimated IQ (DART)	110.14	13.30	112.81	12.22	109.89	13.83	108.28	13.05	108.75	15.29	–.15	.16*
Depressive symptoms (CES-D)	12.53	6.73	10.23	6.28	12.92	6.17	13.28	6.42	15.63	8.33	.29**	–.05
Memory complaints [b]	2.64	1.32	2.69	1.34	2.66	1.20	2.76	1.33	2.15	1.46	–.08	–.02
Alcohol consumption (units/week)	7.33	8.34	9.04	8.46	7.75	8.64	6.46	7.73	4.30	8.39	–.21*	.15

Note: MMSE, Mini-Mental State Examination (Folstein et al., 1975; Maximum = 30); DART, Dutch Adult Reading Test (Schmand et al., 1992); CES-D, Center for Epidemiologic Studies Depression Scale (Radloff, 1977).

[a]Education is coded according to Verhage (1964): 1=elementary education not completed; 2=elementary education; 3=less than lower vocational training; 4=lower vocational training; 5=intermediate vocational training, 6=higher vocational training; 7=university.

[b]Measured by answers on three questions (Maximum=10).

[c]Age r reflects the Pearson correlation of each variable with age.

[d]WSC r reflects the Pearson correlation of each variable with the priming score of the Word-Stem Completion task.

*p < .05, two-tailed. **p < .01, two-tailed.

cut-off value of 16 (Beekman et al., 1997)). Nonetheless, the oldest group scored significantly lower on the MMSE than the two youngest groups ($p < .01$). These differences are, however, not of clinical concern because MMSE scores were high, also in the oldest group (i.e., 89% had a score of 27 or above); these are not indicative of possible dementia or cognitive impairment.

General Procedure

All participants were administered a comprehensive neuropsychological test battery of various measures of episodic and semantic memory, processing and executive functioning.[1] This test battery also included the WSC task and its study task Word Definitions (WD), on which we focus our attention within the current study. These tasks are described in detail below. The interval between WD and the WSC task was filled with an information processing test and an executive functioning test, both containing nonverbal stimuli (Symbol Search and Rule Shift Cards Test). This interval took about 10 minutes.

The test battery was administered in the home environment of the participant by means of a laptop computer. The computer was operated by a trained neuropsychology student, supervised by a clinical neuropsychologist (P.E.J.S.). The participant only had to look at the screen, on which the stimuli were presented and responded orally. The experimenter registered the responses into the computer (by pressing a key or by a mouse click) to avoid unnecessarily large variances in reaction times that may arise as a result of the participant's unfamiliarity with operating a computer. In addition, we deliberately did not require motor responses from the participant (i.e. (speeded) finger or hand movements) because these may be influenced by physical limitations that are unrelated to the cognitive processes that we intended to measure (e.g., due to diseases common in (very) old persons, such as diabetes or rheumatism, but were not reason for exclusion). One could argue that the registration of responses into the computer by the experimenter only provides an indirect measure of the participant's behavior. However, based on both our clinical experience with testing elderly persons and experimental research findings of increased variability of speeded motor responses in the elderly (e.g., Bunce

[1]In addition to the WSC task and its study task WD, the battery included: five episodic memory measures (free recall of a list of inherently unrelated words; two cued recall measures (of semantically related and semantically unrelated word pairs); two recognition tests ('yes'/'no' and forced choice of the words from the free recall and the cued recall tests, respectively)); seven semantic memory measures (three fluency tests (using superordinate categories, subcategories, and letter cues); four naming measures (accuracy and speed of naming pictures and naming of verbal descriptions of words)); two processing speed measures (computerized variants of the Symbol Search and Digit Symbol-Coding subtests of the Wechsler Adult Intelligence Scale–Third edition (WAIS-III; Wechsler, 1997)); three measures of executive functioning (computerized variants of Rule Shift Cards Test of the Behavioural Assessment of the Dysexecutive Syndrome (BADS; Wilson, Alderman, Burgess, Emslie, & Evans, 1996), Stroop (1935), and Raven (1956)).

et al., 2007; MacDonald, Hultsch, & Dixon, 2008), we expect error variance as a result of the experimenter's behavior (who is young and experienced in operating the computer) to be much smaller than the amount of error variance expected when the participant is operating the computer. The latter situation would also (unnecessarily) increase task complexity for the participant.

Word Definitions (WD; Study Task for the WSC Task)

This task required participants to define each word (out of 17), presented on the screen for 2 s, while the participant first had to read it aloud (to enhance the impact of articulation or phonological components; e.g., Ryan et al., 2001). Afterwards, all answers were credited 0, 1 or 2 points to rate the quality of the definitions (reflecting depth of encoding). Answers were credited 0 points when they were incorrect (according to Van Dale, 2005) or when the participant could not define a word. Answers were credited 1 point if the definition was superficially correct but lacked specificity because it might as well represent related but essentially different concepts. Definitions that were correct and sufficiently specific were credited 2 points. The participant was allowed no more than 30 s to define each word (to prevent large variations in processing time between participants).

Word-Stem Completion (WSC) Task

This task required participants to complete two- or three-letter word-stems with the first (Dutch) word that came to mind. This word should add a minimum of two letters to the stem. As soon as the participant named a word that completed a stem, the experimenter pressed a key to record the stem-completion time. The task consisted of two conditions: 17 experimental stems – which could be completed with words from WD – and 17 control stems (related to target words that were not previously presented). The participant was not alerted to the connection with WD. Target words were all concrete imaginable nouns. They were selected from a list of word-stem completion norms (Phaf & Wolters, 1991). Words were selected with a moderate baseline completion probability (*M* = 43.2 in 200 completions; *SD* = 13.1), to reduce the possibility of spontaneous completion but also to prevent floor effects (as occurred in Spaan et al., 2005). Experimental and control stems were matched for: (1) baseline completion probability for each target word; (2) the number of different words named for each stem; (3) target word length; (4) target word syllable length; and (5) target word absolute and logarithmic lexical frequency (Baayen, Piepenbrock, & Van Rijn, 1993). No stems were selected that had a clearly different sound than the corresponding target word when it was pronounced (e.g., 'bl<u>o</u>-' and 'bl<u>oe</u>m' (Dutch for 'flower'); e.g., Ryan et al., 2001). Experimental and control stems were matched for minor sound deviations. None of the words included in preceding tests could complete the stems. Target words were not semantically associated with previously presented words. The actual task was preceded by three practice trials. Main score: WSC priming score: number of experimental stems completed with a target word minus number of control stems completed with a target word (range: −17 to 17).

Subsequent to the WSC task, participants were questioned about their insight into the connection between WD and the WSC task. The first question was: 'Did you mention words during this test that you have encountered before (during the entire test administration)?', rated on a scale of 0 (*No*), to 1 (*Yes, sometimes*), to 2 (*Yes, often*). In case of the latter two response options, a second (non-multiple choice) question was asked: 'At which test did you encounter these words?'. The response was coded dependent on whether WD was identified as the study task. Because these questions were asked *subsequent* to administration of the WSC task, only then the degree of insight into the study–test relationship became apparent to the experimenter. During task administration there was no opportunity for the participant to show possible awareness of this relationship to the experimenter because the items were presented successively. Thus, it was not possible that the experimenter was biased in his (speed of) registration of the responses *during* the task depending on a certain degree of insight of the participant.

RESULTS

Psychometric Properties of the WSC Task

A paired *t*-test analysis, performed over the entire sample of 170 elderly participants, showed a significant priming effect: on average, more experimental stems ($M = 6.76$, $SD = 2.52$) were completed with a target word than control stems ($M = 4.29$, $SD = 1.94$), $t(169) = 11.81$, $p < .01$. Thus, it is possible to measure significant priming effects with our new WSC task[2] (see also Table 2).

An internal consistency reliability analysis, performed over the experimental stems of the WSC task (score 0 or 1) showed a moderate Cronbach's alpha value of .47. Considering the restriction of range effect, it is possible that Cronbach's alpha will be substantially higher when this task is administered to (dementia) patients or to younger adults as well. Nonetheless, reliability of implicit memory measures is known to be worse than reliability levels

[2]We critically reviewed the individual responses per item in order to investigate the impact of a more flexible but systematic evaluation of the completions of the experimental stems (i.e., with a word conceptually similar but not identical to the target word presented in the study task; e.g., stem 'slo-', target word 'sloot' (Dutch for 'ditch'), response 'slootwater' (Dutch for 'ditchwater')). It seems reasonable to conclude that in these cases, participants *did* (implicitly) recall the actual target word that was presented in WD. However, more liberal scoring methods did not show different results in any of the analyses that were reported.

TABLE 2. WSC priming score in relation to degree of insight

WSC task variable	Total group N = 170			'Degree of Insight'-group[b] No Insight N = 34			Modest Insight N = 74			Adequate Insight N = 62		
	M	*SD*	*95% C.I.* [a]	*M*	*SD*	*95% C.I.*	*M*	*SD*	*95% C.I.*	*M*	*SD*	*95% C.I.*
Priming score	2.47	2.73	2.06–2.88	1.56	2.57	0.66–2.46	2.14	2.62	1.53-2.74	3.37	2.72	2.68–4.06

Note: WSC, Word-Stem Completion.
[a]95% Confidence Interval for the mean.
[b]'No Insight' = not aware of connection between WSC task and study task Word Definitions (WD; response to question 'Did you mention words that you have encountered before?' = 'No'); 'Modest Insight' = aware of this connection (response = 'Yes, sometimes' or 'Yes, often'), but did not identify WD in response to subsequent question 'At which test did you encounter these words?'; 'Adequate Insight' = aware of this connection, and identified WD.

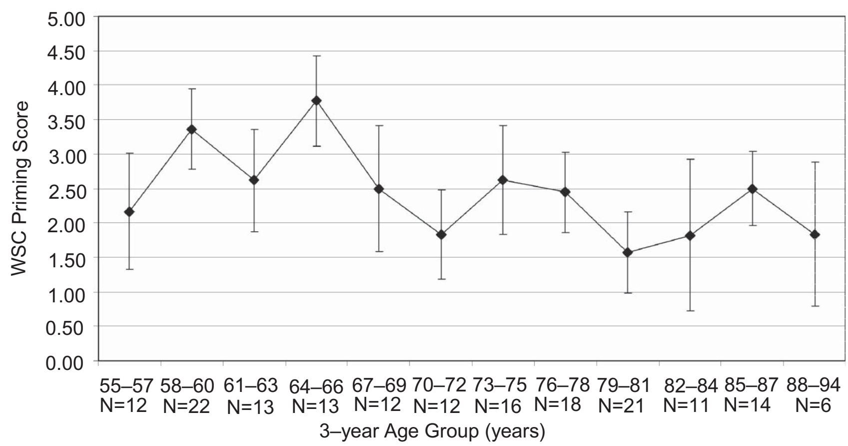
of explicit memory measures (e.g., Buchner & Wippich, 2000; Meier & Perrig, 2000). Item analysis showed one item (stem 'mot-'; target word 'motor') that slightly decreased item consistency; if it was deleted, Cronbach's increased to .48. Overall, reliability of the WSC task seems reasonably high.

The Influence of Age on Priming

Our main question was whether the size of priming effects remained stable up to very old age (e.g., Fleischman, 2007; Mitchell & Bruss, 2003) or whether it showed decline (from a certain age) relative to young-old age (e.g., Davis et al., 1990; Fleischman et al., 1999; Meiran & Jelicic, 1995). Table 1 shows that a higher WSC priming score only weakly correlated with a younger age ($r = -.15$, $p = .06$). In addition, to explore the size of priming effects in relation to age as accurately as possible, we calculated the mean WSC priming score for each three-year age group separately (i.e., smaller age ranges were not useful based on the number of participants per age group). Figure 1 illustrates that age, indeed, hardly influenced WSC priming. A linear regression function best described the relationship: WSC priming score = 5.34 – 0.04 × Age, $F(1, 168) = 3.74$, $p = .06$; 1.6% variance explained, $SE = 2.71$.

From these results, we may conclude that priming with our new WSC task was largely age-invariant. In very old age (up to 94 years old), the size of priming effects remained quite stable and did not show evident decline from a certain age onwards. In contrast, additional analyses performed over the other subtests of the neuropsychological test battery showed that age correlated strongly with most explicit (episodic and semantic) memory measures (r values up to .52), as well as with measures of processing speed (r values up to .59) and executive functioning (r values up to .40).

FIGURE 1. Mean Word-Stem Completion (WSC) priming score per three-year age group separately; error bars represent the standard errors of the means.



The Influence of Other Participant-Related Variables on Priming

In addition, we examined the influence of other demographic and clinically relevant participant-related variables (e.g., intelligence, education, depressive symptoms) on priming. These variables, in addition to very old age, are known to be related to explicit memory performance (e.g., Bäckman et al., 2000; Spaan et al., 2003). These variables may, however, be *un*related to priming, which would facilitate the detection of performance differences with AD.

Table 1 shows that a higher WSC priming score only correlated significantly but weakly with a higher estimated IQ (r = .16, p = .04). Thus, the influence of verbal intelligence on priming was only modest, and low-average intelligence (i.e., DART-IQ of 85 or below) did not interfere with obtaining a significant priming effect, $t(6) = 4.10$, $p < .01$; $M = 2.00$, $SD = 1.29$. In contrast, additional analyses performed over the other subtests of the neuropsychological test battery showed that verbal intelligence correlated strongly with most explicit (episodic and semantic) memory measures (r values up to .42), as well as with measures of processing speed (r values up to .37) and executive functioning (r values up to .48). Furthermore, participants with low-average intelligence performed significantly worse on most measures than participants with high-average intelligence. In addition, WSC priming was not influenced by education, gender, global cognitive status, or depressive symptoms. Regarding the last variable: even participants scoring above the CES-D cut-off value of 27 (Zich et al., 1990) obtained a significant priming effect, $t(7) = 4.04$, $p < .01$. In contrast, the CES-D score correlated significantly with worse performance on measures of processing speed (r values up to –.26) and executive functioning (r values up to .21).

In sum, in addition to age, none of the other participant-related characteristics of our sample showed a significant effect on WSC priming score. Particularly, participants with low-average intelligence or many depressive symptoms did not show impaired priming.

The influence of Depth of Encoding on Priming

Although we did not find obvious floor effects on priming, it is still important to examine the possibility that lower WSC priming scores were related to poor attention (or other reasons for poor encoding of the test stimuli) during the study phase. In other words, does our study task WD generally ensure sufficiently deep encoding? Therefore, we retrospectively examined whether priming scores were related to the qualitative rating of the responses during WD (WD-score) and by the average time taken by the participant for defining the words (WD-time; maximum 30 s allowed).

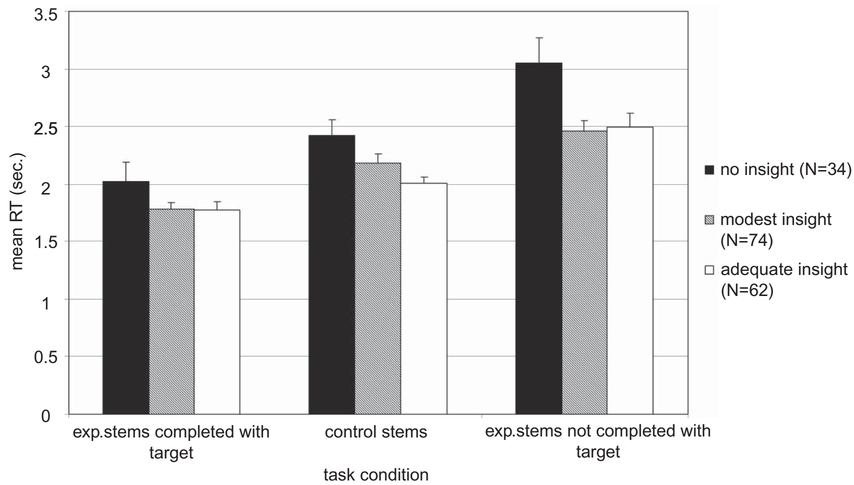
The WSC priming score did not correlate with WD-score ($r = .08$, $p = .30$) or with WD-time ($r = -.10$, $p = .18$). Analyses of the data of four 10-year age groups (as were presented in Table 1) showed consistent results. Thus, depth of encoding did not affect WSC priming performance. Alternatively, poor performance on WD, which might reflect reduced attention or impaired knowledge of the experimental stimuli, was not related to reduced or absent priming effects.

The Role of Explicit Contamination

Although we did not find an obvious age effect on priming (which might have been explained by explicit contamination), it is still important to investigate the possibility that the WSC priming effects we found were influenced by explicit contamination. Susceptibility of our task to explicit contamination would render it less valid, which would compromise its utility in future differential assessment. If our WSC task results were contaminated by the use of explicit, intentional, retrieval strategies, participants that noticed the study–test relationship may not have named the first word that came to their minds, but instead tried to think back to the study list to solve the stems. Therefore, we retrospectively investigated whether the priming effects we found validly reflected – most likely – automatic or unintentional retrieval that is uncontaminated by conscious, explicit processing.

For this purpose, we used the results of the postexperimental interview, which led to the subdivision of three ‘degree of insight’-groups (see Table 2). First, we investigated whether participants with better insight into the connection between the WSC task and study task WD also obtained higher priming scores. Indeed, participants with ‘adequate insight’ (i.e., who correctly identified WD as the study task) obtained higher priming scores than participants with ‘modest-’ ($p = .02$) or ‘no insight’ ($p < .01$), $F(2, 167) = 6.19$, $p < .01$;

FIGURE 2. Mean response time (RT) for experimental (exp.) stems completed with a target word, control stems, and experimental (exp.) stems *not* completed with a target word, per degree-of-insight-group separately.



the 'modest-' and 'no insight' groups did not differ (p = .89). Thus, this insight *might* explain their higher level of performance at the WSC task.

However, this conclusion cannot be drawn without first investigating the response times of these participants. On the basis of our review of the literature, we concluded that explicit (intentional or voluntary) retrieval of words from the study phase takes more time than automatic retrieval or implicit remembering (e.g., Fay et al., 2005; Major & Horton, 2008; Mitchell & Bruss, 2003; Richardson-Klavehn & Gardiner, 1995). Nonetheless, despite their evidently higher priming scores, the 'adequate insight' group did not need more time to complete the experimental stems with a target word than the other two groups, $F(2, 167) = 2.16$, $p = .12$; they were even slightly faster than the 'no insight' group ($p = .19$; see Figure 2, left part, for an illustration). In addition, completion times of experimental stems that were completed with a target word were generally faster than completion times of experimental stems that were *not* completed with a target word, $F(1, 334) = 79.57$, $p < .01$; this pattern did not differ between the three insight groups, $F(2, 334) = 1.19$, $p = .31$; see left versus right part of Figure 2.

It is, however, possible that the 'adequate insight' group benefitted from their awareness of the study–test relationship during completion of the stems and still was faster than the other groups. This might be due to characteristics of this group that are unrelated to the WSC task. However, in this case, we would expect the 'adequate insight' group to have *slower* completion times on the control stems than the other two groups (the 'no insight' group in particular). This expectation is based on the rationale that *if* the 'adequate insight' group indeed changed to intentional retrieval strategies to complete the stems, they will also have adopted this strategy in their attempt to complete the control stems. Because these attempts were in vain from the start, their completion times should obviously increase before they completed these stems with the first word that subsequently came to mind (see also Fay et al., 2005; Horton et al., 2001; Major & Horton, 2008). However, we found the opposite pattern instead: the 'adequate insight' group was, again, significantly faster than the 'no insight' group ($p < .01$) and also slightly faster than the 'modest insight' group ($p = .32$), $F(2, 167) = 4.70$, $p = .01$ (see middle part of Figure 2).[3]

In sum, we conclude that our results were – most likely – not contaminated by the use of intentional retrieval strategies during completion, but validly reflect implicit memory performance or, at least, represent automatic retrieval processes, even in participants that – after completion of the task – turned out to be aware of the study–test relationship. Thus, our new WSC task did not seem susceptible to a change to explicit memory strategies in an elderly sample. In addition, only a minority of participants (36%) showed correct awareness of the study–test relationship.

Although the 'no insight' group had the lowest priming scores, they still obtained significant priming effects, $t(33) = 3.53$, $p < .01$. A stepwise discriminant analysis showed that these 34 participants were best differentiated from the other participants that had at least some degree of insight by a lower estimated IQ and worse performance on an episodic memory measure of free recall, and a semantic memory measure of picture naming (residual variance 0.64; 78.8% correctly classified participants).

DISCUSSION

In the present study, we investigated the size of repetition priming effects within the normal aging spectrum from young-old (55 years) to very old age (up to 94 years) using a newly developed Word-Stem Completion (WSC) task. We constructed this task while taking factors into account that were known

[3]We found the same patterns when we combined the 'no insight' and the 'modest insight' groups into one 'inadequate insight' group ($N = 108$), to contrast with the 'adequate insight' group ($N = 62$); lower priming score: $t(168) = -3.36$, $p < .01$; similar RT's for experimental stems completed with a target word: $t(168) = 0.81$, $p = .42$; no score x insight-group interaction for the experimental stems: $F(1, 336) = 0.18$, $p = .67$; slower instead of faster RT's for control stems: $t(168) = 2.74$, $p < .01$. In addition, consistent with the absent age effect on priming, we found no significant interaction effect between age (the subdivision into four 10-year age groups) and insight ('inadequate' versus 'adequate') on priming score, $F(3, 162) = 1.33$, $p = .27$. Furthermore, we found no interaction effect between educational class (a subdivision into three classes) and insight on the priming score, $F(2, 164) = 0.20$, $p = .82$.

to complicate the measurement of priming effects (e.g., Fay et al., 2005; Mitchell & Bruss, 2003; Ryan et al., 2001; Spaan et al., 2005). Accordingly, the possibilities of floor effects and explicit contamination were minimized. We evaluated the influence on priming of age and other relevant participant-related characteristics. Retrospectively, we examined whether priming effects validly reflected implicit memory performance (or at least, automatic retrieval processes) and were not obscured by the use of explicit, intentional retrieval strategies.

The Influence of Age and Other Participant-Related Characteristics on Priming

Our WSC task was able to measure significant priming effects in a broad sample of cognitively healthy elderly persons. Thus, the floor effects evident in Spaan et al. (2005) were successfully prevented in the new WSC task.

We found no effects on priming of age, gender, education, intelligence, cognitive status, subjective memory complaints, or depressive symptoms. WSC priming explained only a minor proportion of age-related variance and there was no evidence of a decline from a certain age. Furthermore, participants with low-average intelligence or many depressive symptoms did not show impaired priming relative to participants with high-average intelligence or fewer depressive symptoms. In contrast, we found decline of explicit memory, processing speed and executive functioning in relation to increased age, lower level of intelligence and a higher degree of depressive symptoms. This is in agreement with previous findings (e.g., Bäckman et al., 2000; Spaan et al., 2003).

Thus, our data suggest that WSC priming is age-invariant up to very old age (consistent with, e.g., Fleischman, 2007; Mitchell & Bruss, 2003) and argue against findings that priming effects may be reduced in elderly participants in their 70s or their 80s (e.g., Davis et al., 1990; Fleischman et al., 1999; Meiran & Jelicic, 1995). Hence, our task is able to measure significant priming effects in a varied but non-demented elderly population irrelevant of specific characteristics of the participants. This will facilitate the detection of significant differences with AD patients, who may show reduced or absent priming effects (e.g., Fleischman et al., 1999, 2001; McGeorge et al., 2002; Meiran & Jelicic, 1995; Spaan et al., 2003). This decline may only be visible *if* the applied task enables the measurement of significant priming effects in non-demented elderly persons (e.g., Fleischman, 2007).

The Validity of the Word-Stem Completion Priming Effects

The above described results would still be of reduced value for differential assessment, if priming effects did not validly reflect implicit memory performance or, at least, automatic retrieval processes. Participants that subsequent to task administration reported to be aware of the connection between the WSC task and its study task, indeed, obtained higher priming scores. However, experimental stems completed with a target showed generally faster response times than both control stems and experimental stems not completed with a target. This pattern did not differ between adequately aware, modestly aware and unaware participants. In addition, completion times for control stems in adequately aware participants were significantly faster (i.e., definitely not slower) than in unaware participants (and slightly faster than in modestly aware participants; results similar to Fay et al., 2005).

These results argue against the possibility that adequately aware participants obtained higher priming scores due to intentional retrieval strategies during the completion process. Thus, because of their generally faster completion times – also in the control stems where explicit memory strategies are useless – it is unlikely that they tried to think back to the study list to solve the stems. Priming effects in the subsequently aware participants could, therefore, *not* be explained by the effect of explicit contamination *during* the task. Despite their awareness, they still named the first word that came to mind (i.e., automatic retrieval), as they ought to do to maintain task validity.

Strengths and Limitations of the Present Study

The impact of reduced global cognitive status in relation to priming seems irrelevant in our study, because our sample only included participants with a high level of global cognitive functioning (according to the MMSE). The impact of preclinical dementia on the results will, therefore, be negligible. This might explain, in part, why we do not find age effects on priming in very old persons (e.g., Fleischman, 2007), in contrast with several other studies (e.g., Davis et al., 1990; Fleischman et al., 1999; Meiran & Jelicic, 1995).

Mitchell and Bruss (2003) hypothesized that inadequate statistical power might explain why some studies fail to detect age differences that are subtle but real. This does, however, not explain the lack of age effects in our study considering our relatively large sample size (N = 170). Statistical power to detect only a medium effect size of 0.30 regarding the correlation between age and WSC priming score in our sample was high (0.98; $\alpha = 0.05$). Thus, the fact that the actual correlation ($r = -.15$) did not reach significance is not the consequence of a lack of power. We only would have needed a sample size of 84 to obtain an effect size of 0.30 with a power of 0.80 *if* the age effect really would have existed.

Furthermore, though there was no obvious effect on priming regarding age, education, intelligence, gender and depressive symptoms, priming *did* differ according to level of insight into the study–test relationship. Thus, the degree of variance in relation to the mean is not that large that it prevents the detection of significant differences per se. Moreover, the reliability of our WSC task was reasonably high (.48) considering the restriction of range effect in our non-patient study and in the light of the notoriously low reliability of implicit memory measures relative to explicit memory measures (e.g., Buchner & Wippich, 2000; Meier & Perrig, 2000). In addition, age effects *were* found, as expected, on numerous other cognitive tasks of our test battery (*r* values up to −.59).

The stem-completion times were registered into the computer by the experimenter, instead of by the participant, to avoid unnecessarily large variability. It is, however, not possible that our investigation of whether explicit contamination took place was influenced by experimenter bias because the degree of awareness of the study–test relationship only became apparent to the experimenter *after* administration of the WSC task. Furthermore, we emphasize that our study did not specifically aim at investigating which specific methods were most efficient to minimize explicit contamination. We merely constructed a task by integrating previous research findings about task characteristics that tend to elicit explicit contamination (reviewed above), in order to properly study WSC priming up to very old age. Foremost, our study contributes to the discussion on preserved versus decreased priming effects with increasing age. Our data suggest that WSC priming is largely age-invariant up to very old age, probably as a result of our efforts to minimize explicit contamination (also stressed by Mitchell and Bruss, 2003), investigated in a heterogeneous but non-demented elderly sample.

Future research needs to focus on whether these priming effects remain stable over time, in a longitudinal research design, in contrast to explicit memory decline (e.g., Fleischman, Wilson, Gabrieli, Bienias, & Bennett, 2004). In addition, we expect future research to show impaired performance in early AD patients, relative to age-matched controls, because of our task's emphasis on item-generation (instead of identification; e.g., Gabrieli et al., 1999) and its increased impact of phonological (rather than perceptual) components (Ryan et al., 2001). At last, this task with increased validity might, thus, contribute to the differentiation between normal aging and AD by improving specificity of assessment.

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