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Loss of Attentional Inhibition in Older Adults—Does It Really Exist? An Experimental Dissociation of Inhibitory and Memory Retrieval Processes

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It is commonly assumed that attentional inhibitory functioning decreases with age, even though empirical evidence is mixed. These inconsistencies possibly stem from methodological artifacts: distractor inhibition is typically assessed with the negative priming paradigm, which confounds inhibition and episodic retrieval. In the present study, we investigated age differences in a sequential distractor repetition paradigm (Giesen, Frings, & Rothermund, 2012) that provides independent estimates of distractor inhibition and episodic retrieval processes. Older (60+ yrs) and younger (below 30 years) adults identified target letters that were flanked by distractors (JKJ). Inhibitory processes were preserved in older adults, who showed reliable distractor repetition benefits resulting from persistent distractor inhibition; however, a significant loss of inhibition was apparent for the older subgroup of participants (65+ yrs) compared with a subgroup of young-old participants (60 to 64 years). No age differences were found for episodic retrieval processes of stimulus–response bindings that were indexed by an interaction of distractor repetition and response relation. Findings highlight the importance of dissociating between distractor inhibition and retrieval processes that are differently implicated in age-related cognitive change.

Keywords: loss of inhibition, distractor inhibition, episodic retrieval, age differences, stimulus–response binding

A prominent view in the cognitive aging literature holds that the ability to inhibit task-irrelevant material decreases with age: According to the inhibition deficit theory (IDT) by Hasher and colleagues (e.g., Hasher & Zacks, 1988; Lustig, Hasher, & Zacks, 2007), becoming older is characterized by a gradual loss of inhibitory efficacy. Because more information is chronically activated related to this inhibition deficit, older adults' working memory becomes increasingly "cluttered" with task-irrelevant information. This, in turn, has adverse effects on the functioning of a broad range of cognitive processes (e.g., attention, working memory, language comprehension and production, problem solving; see Lustig et al., 2007) that are essential for properly performing everyday actions and behaviors. The investigation of age-related differences with regard to inhibitory functioning is therefore of pivotal interest for an aging society.

For the last decades, there has been an ongoing debate regarding whether inhibition reflects a single, unitary construct or rather has to be regarded as a "family" of independent processes (for a discussion, see, e.g., Burke & Osborne, 2007; Harnishfeger, 1995; Lustig, Hasher, & Tonev, 2001). Indeed, recent findings argue in favor of the latter view, showing that multiple independent inhibitory functions can be identified both theoretically (e.g., Harnishfeger, 1995; Nigg, 2000) and empirically (e.g., Friedman & Miyake, 2004; Kok, 1999). Whether and to which extent these distinct inhibitory functions are differentially affected by age-related changes is thus a subject of further scientific scrutiny. For instance, in a recent reformulation of the IDT, Lustig and colleagues (2007) take these theoretical developments into account: They propose three independent inhibitory processes (prevention of *access* to working memory, *deletion* of no longer relevant material, and *restraint* of prepotent responses), which all appear to be impaired in older compared with younger adults (see Lustig et al., 2007, for details).

The purpose of the present study was to focus on one inhibitory function in particular, namely, selective attentional inhibition of task-irrelevant distractor stimuli, and to investigate the extent to which it is affected by age-related changes in cognitive processing. Indeed, the question of whether one can assume a "loss of attentional inhibition" in old age is presently unresolved, mostly because empirical evidence for age differences in attentional inhibition is mixed: Some studies indeed reported reduced or absent distractor inhibition in older compared with younger adults (e.g., Hasher, Stoltzfus, Zacks, & Rypma, 1991; Kane, May, Hasher, Rahhal, & Stoltzfus, 1997; May, Kane, & Hasher, 1995; Verhaeghen & De Meersman, 1998). However, other studies as well as meta-analyses failed to replicate these results, suggesting that attentional inhibition processes may remain intact even in old age (for an overview, see Burke & Osborne, 2007; see also Buchner &

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Mayr, 2004; Gamboz, Russo, & Fox, 2002; Grant & Dagenbach, 2000; Kieley & Hartley, 1997; Kramer, Humphrey, Larish, Logan, & Strayer, 1994; Verhaeghen & Cerella, 2002).

A possible reason for these inconsistent empirical findings regarding an attentional inhibition deficit in older age is that the experimental paradigms with which attentional inhibition was assessed in the previously mentioned studies are not process-pure indicators of inhibition. These claims predominantly concern the negative priming (NP) paradigm. In particular, it was shown that the NP paradigm confounds inhibition and episodic retrieval processes (e.g., Neill, Valdes, Terry, & Gorfein, 1992): Instead of reflecting persisting inhibition of the prime distractor, NP effects might also indicate an automatic retrieval of episodic bindings between stimuli and/or responses (Rothermund, Wentura, & De Houwer, 2005; see also Giesen & Rothermund, 2014; Henson, Eckstein, Waszak, Frings, & Horner, 2014; Horner & Henson, 2009, 2011; Kane et al., 1997; Mayr & Buchner, 2006; Mayr, Buchner, & Dentale, 2009). Due to this ambiguity in the causal determination and theoretical interpretation of NP effects, existing inhibitory deficits in one age group might be masked or compensated by other processes. Thus, it is possible that older adults do suffer from attentional inhibitory deficits, but still produce reliable NP effects based on episodic binding and retrieval processes, which might be preserved in old age (Mayr & Buchner, 2014): For instance, Kane and colleagues (1997) demonstrated that older adults did show NP under conditions that strengthened episodic retrieval processes (e.g., when a high percentage of target repetition trials was included); however, older adults showed no NP in experimental conditions in which episodic retrieval was discouraged and only inhibition was operating (no target repetition trials). Alternatively, existing age group differences in NP effects that were obtained in some studies could, in principle, also be due to age differences in the efficiency of episodic binding and/or retrieval processes rather than resulting from a loss of attentional inhibition.

We should note that NP is not the only paradigm that allows assessing age differences in attentional inhibition (for an overview, see Kramer et al., 1994): For instance, age differences in attentional inhibition were investigated with the inhibition of return paradigm (Pratt & Chasteen, 2007) or in visual search and priming of pop-out (PoP; Wnuczko, Pratt, Hasher, & Walker). Results of these studies revealed age-invariant effects in these tasks. However, NP is still one of the most frequently used paradigms to investigate age differences in distractor inhibition, which is problematic.

In order to unambiguously evaluate age differences in distractor inhibition, it is thus necessary to empirically distinguish more clearly between the different underlying processes that may produce experimental effects. The aim of the present study is to investigate age differences separately for distractor inhibition and episodic response retrieval processes by employing an experimental paradigm that was recently introduced by Giesen, Frings, and Rothermund (2012), which allows for a separate and independent assessment of the two processes. The rationale and findings of the study by Giesen and colleagues were as follows: Participants saw letter triplets in a sequence of prime and probe trials, and had to identify the central target letter that was flanked by two distractors which had to be ignored (e.g., JKJ). The experimental task thus represented a situation that required selective attention to targets and selective inhibition of distractor stimuli to prevent distractors from interfering with the selection or execution of the target response. Distractor inhibition (DI) and episodic retrieval of distractor-response bindings can be measured within the same paradigm via independent types of sequential effects. DI is reflected in simple distractor repetition benefits (i.e., by comparing performance in distractor repetition trials with baseline sequences; Frings & Wühr, 2007; Neumann & DeSchepper, 1991; Yashar & Lamy, 2010): In a distractor repetition trial, the repeated distractor still suffers from becoming inhibited during the prime trial, and thus should not interfere with target selection or execution of the target response during the probe. Responding in the probe should thus be facilitated compared with the baseline trials in which a novel distractor is presented in the probe.

The paradigm by Giesen et al. (2012) also allows for a separate assessment of episodic stimulus–response (S-R) binding and retrieval processes. Episodic S-R binding refers to the idea that the prime distractor becomes transiently associated with the response that was executed during the prime trial. Repeating the prime distractor in the probe then leads to a retrieval of this episode and to a reactivation of the prime response. Retrieval of episodic S-R bindings is reflected in (a) a facilitative effect of distractor repetitions for sequences with response repetitions, but also (b) in a delaying effect of distractor repetitions on responding if a different response has to be given in the probe. Statistically, distractor repetition benefits indicating distractor inhibition correspond to a main effect of distractor repetitions, whereas an automatic retrieval of distractor-response bindings is indicated by an interaction of distractor relation and response relation (Rothermund et al., 2005; see also Frings, Moeller, & Rothermund, 2013; Frings & Rothermund, 2011; Frings, Rothermund, & Wentura, 2007; Giesen & Rothermund, 2011, 2014; Moeller & Frings, 2011, 2014; Moeller, Rothermund, & Frings, 2012). Due to the fact that the two effects are statistically independent, distractor repetition benefits can be considered as a pure indicator of inhibition, because they are not confounded with differential effects of episodic response retrieval and/or binding processes.

We should note that with regard to distractor repetition benefits, other theoretical explanations apart from distractor inhibition are possible. According to Neill and colleagues (1992), ignoring the distractor during the prime trial might result in associating it with some kind of "nonresponse" information like a "do not respond" or "ignore it" tag. Distractor repetition in the probe would then trigger episodic retrieval of these prime tags, which might facilitate responding in probe trials with distractor repetition due to reduced response competition or interference from distractors. The assumption of episodic retrieval of "do not respond" tags, however, is conceptually incompatible with the simultaneous occurrence of distractor-*response* binding and retrieval effects that we found in previous studies and also expect to find in our current study: Attaching "do not respond" tags to distractors would imply that distractors are *not* bound to any response but instead are marked as not being responded to. Furthermore, an account of distractor repetition benefits in terms of a retrieval of "do not respond" tags cannot explain why these effects differed between incompatible and neutral distractors in our previous study (Giesen et al., 2012, see next paragraph). In our view, these points render episodic retrieval of prime tags as an unlikely explanation for distractor repetition benefits, which are most parsimoniously explained by distractor inhibition. We will come back to this issue in the Discussion section and discuss the possibility of alternative explanations for distractor repetition benefits in more detail.

In order to demonstrate that distractor inhibition and episodic retrieval processes can in fact be independently assessed with their paradigm, Giesen et al. (2012) conducted two dissociation experiments. Distractors were either neutral (viz., noninterfering) or response-incompatible (viz., interfering) with the required target response. Assuming that inhibition is proportional to the amount of interference produced by distractors, this manipulation should result in weak or strong distractor inhibition, respectively (Grison & Strayer, 2001; Houghton, Tipper, Weaver, & Shore, 1996). In line with these expectations, Giesen et al. found that inhibition effects were reliably and consistently stronger for response-incompatible than for neutral distractors, indicating that distractor inhibition processes were responsive to the interference produced by the distractors. At the same time, episodic retrieval of distractor-response bindings did not differ between incompatible and neutral distractors: Although response-incompatible prime distractors were subjected to stronger inhibition, this did not prevent them from becoming associated with the executed prime response and from retrieving this binding on a later occasion. This indicates that distractor inhibition and episodic, distractor-based response-retrieval processes are two functionally independent processes that can be experimentally dissociated within the very same paradigm.

Overview of the Present Study

We used the sequential distractor repetition paradigm employed by Giesen et al. (2012) to investigate and to compare distractor inhibition and episodic retrieval processes in younger (≤30 years) and older (≥60 years) participants. To allow for a more fine-grained analysis of age-dependent differences in either process, we adopted two analytical approaches. Age was treated as a categorical factor in the first analytical approach. Based on findings of previous studies suggesting that inhibitory deficits may be restricted to older participants of advanced age (e.g., Bell, Buchner, & Mund, 2008; Mayr & Buchner, 2014; Persad, Abeles, Zacks, & Denburg, 2002), we further subdivided the sample of older participants into what we call "young-old" (<65 years) and "old-old" (≥65 years) participants. In a second set of analyses, age was treated as a continuous variable. We conducted multiple hierarchical regression analyses and tested for linear and quadratic effects of the age variable on distractor inhibition and episodic retrieval effects.

All participants took part in a sequential distractor-to-distractor repetition paradigm that was an adapted version of the study by Giesen and colleagues (2012, Experiment 1). For a series of prime and probe displays, participants saw letter triplets (JKJ). For each display, they had to identify the central target letter and were told to ignore the two flanking distractors. In order to maximize the necessity to inhibit distractor stimuli, only response-incompatible (i.e., response-interfering) distractors were used. Distractor relation and response relation were manipulated independently, meaning that distractors and/or responses could either repeat or change from prime to probe.

In order to assess age-related differences in inhibition and episodic retrieval, we measured effects of distractor inhibition and episodic retrieval of distractor-response bindings separately for each participant. If inhibitory abilities decrease with age, we should obtain an interaction of age group and distractor repetition, with stronger distractor repetition effects (i.e., stronger distractor inhibition) in younger compared with older participants and/or in young-old compared with old-old participants. Analogously, we expected a negative quadratic age trend across the entire sample of our study when age is treated as a continuous predictor. That is, distractor inhibition effects should be independent of age for younger adults, but should reflect a negative relationship with age within the group of older participants. Furthermore, and in line with findings from others (e.g., Kane et al., 1997; Mayr & Buchner, 2014), if episodic retrieval processes are preserved in old age, the three-way interaction of age group, distractor relation, and response relation should be absent, indicating that effects of episodic retrieval of distractor-response bindings do not differ between younger and older participants. Similarly, we predicted neither a quadratic nor a linear age trend with regard to episodic retrieval effects when age is regarded as a continuous predictor. Such a pattern of findings would provide an explanation of the inconsistent evidence in previous studies that confounded retrieval and distractor inhibition processes.

Method

Participants

The sample consisted of 40 younger adults (18 to 27 years; 29 female), 20 "young-old" adults (60 to 64 years; 15 female) and 23 "old-old" adults (65 to 78 years; 16 female). None of these participants reported a history of psychiatric and/or neurological diseases. Furthermore, participants were asked to provide information whether they used any (and if so, which) medication, which was checked in a second step by a pharmacist for drugs that indicate severe impairments (e.g., multiple sclerosis or Parkinson's disease), which also resulted in exclusion from the study. Older adults were recruited via newspaper advertisements, flyers distributed in the city of Jena, Germany, and from our lab's participant database. Participants of the young-old and old-old samples took part in two sessions, each lasting 45 to 60 min, and received between €7.50 and €10 (approximately US$10 to $15) for each session (depending on duration and as a compensation for transportation costs). Younger adults were students of the University Jena and were recruited on campus. They took part in one single session, which lasted between 35 to 40 min. Due to the shorter duration of the experimental session and absence of transportation costs, they received €2 (approximately US$3) and a chocolate bar or partial course credit for their participation.

Sample characteristics are displayed in Table 1. All younger participants reported normal or corrected-to-normal vision; visual acuity of older participants was measured with the Freiburg Visual Acuity Test (FrACT; Bach, 1996, 2012). Reflecting standard cohort differences, younger participants, on average, had more years of formal education than older participants. Regarding intelligence scores, samples reflected typical age-related differences with respect to both verbal intelligence (Multiple Choice Vocabulary Test [MWT-B]; Lehrl, 1990), $F(2, 80) = 19.77$; $p < .001$, $\eta_p^2 = .33$, and fluid intelligence (Digit-Symbol Subtest [ZST]; Von Aster, Neubauer, & Horn, 2009), $F(2, 80) = 58.10$; $p < .001$, $\eta_p^2 = .59$. Post hoc *t* tests with Bonferroni adjustment showed that compared

Table 1
Sample Statistics and Supplementary Test Results for Younger and Older Participants

Variable	Younger adults (18–27 yrs)	Young-old adults (60–64 yrs)	Old-old adults (65–78 yrs)
Sample size (*N*)	40	20	23
Sex female (*N* [%])	29 (72.5)	15 (75)	16 (69.5)
Age (*M* [*SD*])	21.6 (2.3)	61.7 (1.3)	69.8 (4.1)
Education (yrs of schooling; *N* [%])			
University-bound degree (12/13 yrs)	40 (100)	12 (60)	13 (56.5)
Middle school (10 yrs)	0	6 (30)	7 (30.4)
Lower secondary education (8 yrs)	0	2 (10)	3 (13.1)
	M (*SD*)	*M* (*SD*)	*M* (*SD*)
Supplementary tests			
Vocabulary/verbal IQ	108_a (11)	123_b (12)	126_b (13)
Processing speed/fluid intelligence (# correctly solved items)	88_a (12)	61_b (11)	61_b (11)
Visual acuity (measured in decVA)	—	0.86_a (0.23)	0.83_a (0.24)

Note. Means in the same row with different subscripts differ at $p < .001$ (Bonferroni adjusted).

with young adults, both samples of old adults had significantly higher scores on the Verbal IQ test, $t(58) = 4.63$, $p < .001$, $d = 1.26$, and $t(61) = 5.59$, $p < .001$, $d = 1.46$, for young-olds and old-olds, respectively, but had significantly lower scores on the fluid intelligence measure, $t(58) = 8.56$, $p < .001$, $d = 2.34$, and $t(61) = 9.23$, $p < .001$, $d = 2.42$, for young-olds and old-olds, respectively (see Table 1).

Materials

The four letters J, K, L, and M were used as stimuli in the letter identification task. Letters were arranged in triplets consisting of a target in the middle and two identical flanker distractors on each side (e.g., KLK). Distractors were always response-incompatible with target stimuli in a given prime or probe display. Stimulus triplets were presented centrally in black Arial font on a blank white screen; the font size was 18 pt for young adults and 22 pt for older adults, respectively.[1] Each letter was assigned to one of four keys of a response box that was connected to the computer via the parallel port. Throughout the experiment, participants were instructed to place their middle and index fingers of their left hand on the "J" and "K" keys and their index and middle finger of their right hand on the "L" and "M" keys. Participants' task was to identify the target stimulus by pressing the corresponding key of the response box for both prime and probe displays. Two additional keys were labeled with "Los" ("Go") and could be pressed with either the left or right thumb to start a prime-probe sequence. Throughout the experiment, older adults were provided with a schematic picture of the response box that was situated under the computer screen in order to help them memorize the assignment of the stimuli to response keys. The experiment was programmed with E-Prime 2.0; response time (reaction time [RT]) latencies and accuracy of responses were recorded.

Design

The experimental design comprised a 2 × 2 × 3 mixed factors design, with the within-subject factors Distractor Relation and Response Relation that were manipulated orthogonally, and the between-subjects factor Age Group. First, Distractor Relation was manipulated by either repeating the prime distractor in the probe (distractor repetition; 25% of all prime-probe sequences) or by presenting two different distractors in prime and probe (baseline; 75% of all prime-probe sequences). Second, Response Relation was manipulated by either repeating (25% of all prime-probe sequences) or changing (75% of all prime-probe sequences) responses between prime and probe (by repeating the target or not; see Table 2 for sample stimuli and the resulting number of trials per condition). Third, the Age Group factor consisted of the three samples of young, young-old, and old-old adults.

Additional Measures

In order to control for cognitive functioning across the different age group samples, all participants performed short measures of verbal abilities (MWT-B; Lehrl, 1990) and processing speed (ZST of the Wechsler Adult Intelligence Scale-III; German version: Von Aster, Neubauer, & Horn, 2009). The MWT-B is a short paper-and-pencil test that measures participants' vocabulary, which served as a proxy for verbal intelligence in the present study. Processing speed, as a proxy for fluid intelligence, was assessed by the ZST, a brief paper-and-pencil test in which participants have to assign symbols to given numbers while being pressed for time. Older adults also performed a computer-based measure of visual acuity (Freiburg Visual Acuity Test [FrACT], Version 3.7; Bach, 1996, 2012) to be able to control for proper vision in these subsamples.

Session Procedure

The general procedure varied slightly between the age-group samples. For younger adults, the session started with the computer exper-

[1] The experiment was conducted in two different lab rooms that varied with regard to the viewing distance to the computer screen. Different font sizes were chosen to result in a comparable visual angle of the stimulus display.

Table 2
Sample Stimuli of Prime-Probe Sequences in the Experiment

Response relation	Distractor relation	Sample sequences: Prime	Probe	# of trials[a]
Response repetition (RR)	Distractor repetition (DR)	JKJ	JKJ	16
	Baseline (B)	MKM	JKJ	48
Response change (RC)	Distractor repetition (DR)	JLJ	JKJ	48
	Baseline (B)	MLM	JKJ	144
Total				256

[a] Number of prime-probe sequences per condition for each participant.

iment, followed by the MWT-B and ZST. In turn, older adults took the FrACT, MWT-B, and ZST in a first session, together with some additional measures and other questionnaires that were unrelated to the present study, whereas the computer experiment was conducted in a second session. Older participants were only invited to take part in the second session if they showed no signs of deficiencies in understanding instructions or other indicators of disorientation or deviant behavior during the first session.

Experimental Procedure

Participants were tested individually. The experimental procedure was organized as follows. After some general oral explanations, instructions were given in written form on the screen. Participants were instructed to keep their fingers on the four response keys throughout the experiment and were asked to respond as fast as possible while trying to make only few mistakes. For both prime and probe displays, participants' task was to identify the target letter of the presented letter triplet by pressing the corresponding response key.

In order to become familiarized with the assignment of letters to response keys, older adults first performed a mapping exercise (24 trials) in which only single target letters were presented that had to be identified via key press. The mapping exercise was repeated if accuracy was below 60% correct responses; however, none of the older participants had to repeat the mapping exercise. After this, another practice block of 50 prime-probe sequences of the experimental task followed. Young adults had no mapping exercise but started with exercising the experimental task immediately. All practice blocks included feedback for erroneous or too-slow responses. After an incorrect response, the message "Falsche Taste!" ("Wrong key!") appeared; if responses were slower than 1,500 ms, the message "Zu langsam!" ("Too slow!") appeared. All negative feedback messages were presented centrally in red font, together with a frowning schema face, for 1,000 ms. If prime and probe responses were both timely and accurate, the message "Beide richtig!" ("Both correct!") was presented in green font, together with a smiley face, for 1,000 ms after the probe. The practice block was repeated if accuracy was below 60% correct responses (due to low accuracy, three young-old and four old-old participants, but none of the younger participants, had to repeat the practice block once before proceeding to the main experiment).

Upon successful completion of the practice block, each participant performed 256 prime-probe sequences of the experimental task that were constructed with respect to the factorial design and with the following constraints: (a) in each prime or probe display, targets and distractors were always different (i.e., nonidentical); (b) prime targets were never repeated as probe distractors; and (c) prime distractors were never repeated as probe targets (cf. Giesen et al., 2012, Experiment 1).

Table 3
Means of Logarithmized and Untransformed Probe RTs (in ms) and Probe Errors (%) for the Three Age Groups

	Age group	Response relation	Distractor relation: DR	B	DI effects ($[(B_{RR} + B_{RC}) - (DR_{RR} + DR_{RC})]/2$)	D-R retrieval effects ($[B - DR]_{RR} - [B - DR]_{RC}$)
ln(Probe RT)	Younger adults (18–27 yrs)	RR	6.06	6.16	.055 (.006)	.09 (.01)
		RC	6.45	6.46		
	Young-old adults (60–64 yrs)	RR	6.46	6.56	.055 (.009)	.09 (.02)
		RC	6.85	6.86		
	Old-old adults (65–78 yrs)	RR	6.47	6.53	.025 (.01)	.06 (.02)
		RC	6.83	6.82		
Probe RT (ms)	Younger adults (18–27 yrs)	RR	439	486	24 (3.1)	46 (6.6)
		RC	662	663		
	Young-old adults (60–64 yrs)	RR	661	737	44 (8.3)	64 (14.9)
		RC	984	995		
	Old-old adults (65–78 yrs)	RR	681	712	10 (8.8)	42 (14.2)
		RC	967	955		
Probe errors (%)	Younger adults (18–27 yrs)	RR	0.7	0.8	–0.5 (0.4)	1.2 (0.69)
		RC	6.5	5.4		
	Young-old adults (60–64 yrs)	RR	0.6	0.2	–0.4 (1.5)	0.0 (0.6)
		RC	2.0	1.6		
	Old-old adults (65–78 yrs)	RR	1.2	1.1	0.2 (1.5)	–1.1 (1.1)
		RC	2.9	3.3		

Note. Standard errors of the means are in parentheses. RT = reaction time; DR = distractor repetition; B = baseline (different distractor in prime and probe); DI effects = distractor inhibition effects, computed as the difference between B minus DR, averaged across response relation; D-R retrieval effects = retrieval of distractor-response bindings, computed as the difference in distractor repetition effects between the RR and RC conditions; RR = response repetition; RC = response change.

Each prime-probe trial consisted of the following sequence of events. First, a fixation cross was presented centrally. As soon as the participant pressed one of the "Go" keys, a blank display appeared briefly (750 ms), followed by the prime display in which a stimulus triplet was presented and remained on screen until a response was registered. Subsequently, another blank display (250 ms) appeared, followed by the probe display in which a second stimulus triplet was presented until a response was registered. The sequence ended with an intertrial interval (900 ms) with a blank black screen. Each participant performed 256 prime-probe trials, which were presented in eight blocks with optional breaks in between. At the end of the experiment, participants were asked whether they had used any strategies during the task. Finally, participants were thanked, debriefed, and paid accordingly.

Results

Data Reduction

Only probe RTs were analyzed. Prime-probe sequences with erroneous responses in the prime and/or probe (young adults, 8.5%; young-old adults, 3.2%; old-old adults, 5.1%) and probe RT outlier values (young adults, 1.0%; young-old adults, 0.6%; old-old adults, 0.9%; probe RTs below 300 ms or more than three interquartile ranges above the third quartile of the individual distribution of probe RTs were regarded as "outlier" values, according to Tukey, 1977) were discarded from analyses. Because older adults made only few errors in the identification task and none of the effects of interest was significant, error data are presented in Table 3 but are not further discussed.[2]

Logarithmic Transformation of Probe RT

In order to compare probe RT of the different age groups within a joint analysis, we conducted logarithmic transformations of probe RTs to control for effects of age group differences that are due to general slowing.[3] We then computed means of the transformed probe RTs for every condition of the factorial design, and separately for each participant. For ease of interpretation, however, we also report untransformed means in the tables and in the text (average RTs for the different cells of the factorial design for the three age groups are shown in Table 3).

We took two different analytical approaches to analyze the data. First, because participants of our study were sampled selectively from the upper ($\geq$60 years) and lower ($<$30 years) parts of the age spectrum, omitting a large group of middle-aged adults (30 to 60 years), we conducted a multivariate analysis of variance (MANOVA), in which age was regarded as a categorical factor. To bolster and support the findings from these analyses, we conducted a second set of analyses in which age was regarded as a continuous predictor in several hierarchical regression analyses.

Analytical Approach I: Age as Categorical Factor

Logarithmized probe mean RTs were entered into a 2 (distractor relation: repetition vs. baseline) $\times$ 2 (response relation: repetition vs. change) $\times$ 3 (age group: young vs. young-old vs. old-old adults) mixed models MANOVA. Global MANOVA results are reported in Table 4. To allow for a more fine-grained analysis of age-group specific differences between samples, we further decomposed the age group factor into two a priori orthogonal contrasts, namely, "younger adults versus old (i.e., young-old *and* old-old) adults" (first contrast) and "young-old versus old-old" adults (second contrast).

[2] A 2 (response relation) $\times$ 2 (distractor relation) $\times$ 3 (age group) MANOVA on probe error rates yielded a significant main effect of response relation, $F(1, 80) = 81.22$, $p < .001$, $\eta_p^2 = .50$, indicating that participants made fewer errors on trials with response repetition (0.7%) compared with response changes (3.6%; see Table 3). There was also a significant main effect of age group, $F(2, 80) = 10.86$, $p < .001$, $\eta_p^2 = .21$, which was due to the first contrast, $t(80) = 4.37$, $p < .001$, $d = 0.96$, indicating that older adults made generally fewer errors than did younger adults. The second contrast revealed a tendency for old-old adults to make more errors than young-old adults, $t(80) = 1.83$, $p = .07$, $d = 0.56$, which, however, failed conventional levels of significance. Only the Response Relation $\times$ Age Group interaction was significant, $F(2, 80) = 16.88$, $p < .001$, $\eta_p^2 = .30$, which is not of theoretical interest because it is not related to either inhibition or episodic retrieval effects, and is therefore not further discussed. None of the other effects were significant (all Fs $<$ 1.6, all ps $>$ .22). Furthermore, in order to control for a potential speed–accuracy trade-off, we repeated the main analyses for inverse efficiency scores (IES; Townsend & Ashby, 1983) to check whether the pattern that was obtained in probe performance based on logarithmized RTs would replicate. IES scores were computed for every condition of the factorial design and separately for each participant by dividing mean probe RT by the proportion of correct responses (i.e., IES = RT/PC). Analyses based on IES scores closely replicated the overall pattern that was prevalent in the main analyses provided in the text (see Footnote 3). These results support the conclusion that differences in speed–accuracy trade-offs between younger and older participants do not affect the overall pattern of results. We nevertheless refrained from using IES scores as the central dependent variable of interest because the use of IES transformations is not uncritical, especially if mean RT and error rates are negatively correlated, as was the case in the present study with $r(83) = -.43$, $p < .001$ (for details, see Bruyer & Brysbaert, 2011; Townsend & Ashby, 1983).

[3] We performed the same MANOVA and hierarchical regression analyses on untransformed mean probe RT and inverse efficiency scores (IES results are reported in parentheses), which yielded virtually identical results. For the MANOVA in which age was regarded as a categorical factor, the Distractor Relation $\times$ Age Group interaction was also significant, $F(2, 80) = 6.09$, $p = .003$, $\eta_p^2 = .39$ ($F[2, 80]_{IES} = 3.42$, $p = .04$, $\eta_p^2 = .08$), and was due to the "young-old versus old-old" comparison (second contrast), $t(80) = 3.48$, $p = .008$, $d = 1.06$ ($t[80]_{IES} = 2.55$, $p = .01$, $d = 0.77$), whereas the global "younger versus older" comparison (first contrast) was not significant, $|t|<1$, $d = 0.07$ ($|t|_{IES}<1$, $d = 0.15$). In turn, the three-way interaction between distractor relation, response relation, and age group was absent as well, $F<1$, $\eta_p^2 = .02$ ($F_{IES}<1$, $\eta_p^2 = .02$). As for the hierarchical regression analyses with age as a continuous predictor, results revealed a significant negative effect of the quadratic age trend on distractor inhibition effects, $\beta = -.31$, $t(78) = 2.83$, $p = .006$, $f^2 = .10$ ($\beta_{IES} = -.22$, $t[78] = 1.95$, $p = .03$ [one-tailed], $f^2 = .05$) when the full sample was considered. Follow-up analyses showed that participants' age had no influence on distractor inhibition effects for younger adults, $\beta = -.03$, $|t|<1$, $f^2 = .00$ ($\beta_{IES} = -.10$, $|t|<1$, $f^2 = .00$). However, for older adults, participants' age significantly and negatively affected distractor inhibition effects, $\beta = -.37$, $t(39) = 2.57$, $p = .01$, $f^2 = .15$ ($\beta_{IES} = -.28$, $t[39] = 1.88$, $p = .034$ [one-tailed], $f^2 = .08$). In contrast, the overall regression analysis on episodic retrieval effects yielded neither a linear, nor a quadratic age trend, $\beta = -.23$, $t(79) = 1.06$, $p = .29$, $f^2 = .01$ ($\beta_{IES} = -.15$, $|t|<1$, $p = .49$, $f^2 = .00$), and $\beta = -.15$, $t(78) = 1.34$, $p = .18$, $f^2 = .02$ ($\beta_{IES} = -.16$, $t[78] = 1.44$, $p = .15$, $f^2 = .03$), respectively. According to the follow-up analyses, participants' age had no effect on D-R retrieval effects for younger, $\beta = .15$, $|t|<1$, $f^2 = .02$ ($\beta_{IES} = .19$, $t[36] = 1.22$, $p = .23$, $f^2 = .04$), or older adults, $\beta = -.15$, $|t|<1$ $f^2 = .02$ ($\beta_{IES} = -.13$, $|t|<1$ $f^2 = .02$).

Table 4
Summary Table for MANOVA Results on Mean Logarithmized Probe RT

Variables	*df*	*F*	η_p^2	*p*
Between subjects				
Age group (A)	2	85.44***	.68	.000
Error	80	(0.074)		
Within subjects				
Distractor relation (D)	1	100.10***	.56	.000
Response relation (R)	1	741.93***	.90	.000
D × A	2	4.56*	.10	.013
D × R	1	100.71***	.56	.000
R × A	2	0.33	.00	.72
D × R × A	2	1.44	.04	.24
Error (D)	80	(0.002)		
Error (R)	80	(0.012)		
Error (D × R)	80	(0.001)		

Note. Values enclosed in parentheses represent mean square errors. *df* = degrees of freedom; RT = reaction time.
* $p < .05$. ** $p < .01$. *** $p < .001$.

As can be seen in Table 4, the MANOVA yielded significant main effects of distractor relation and response relation, indicating that probe responses were faster in sequences with distractor repetitions (732 ms) compared with baseline sequences (758 ms), and in sequences with response repetitions (619 ms) compared with sequences with response change (871 ms). There was also a significant main effect of age group, which was due to the first contrast that was significant, $t(80) = 13.07$, $p < .001$, $d = 2.87$, indicating that younger adults were generally faster than older adults. However, the second contrast was not significant, $|t| < 1$, $d = 0.08$, indicating that response latencies of young-old and old-old adults did not differ significantly.

DI effects. In line with our reasoning, the interaction of distractor relation and age group was significant, indicating that the strength of distractor inhibition differed between age groups (see Figure 1a). Planned contrasts revealed that distractor repetition benefits did not differ for the global age group comparison of "younger versus older adults" (first contrast), $t(80) = 1.06$, $p = .29$, $d = 0.23$. Importantly, however, distractor repetition effects for old-old adults were significantly smaller than for young-old adults (second contrast), $t(80) = 2.77$, $p = .007$, $d = 0.85$, which indicates a loss of inhibitory functioning in advanced age. Although significantly reduced in size, distractor inhibition effects were significantly different from zero for both young-old and old-old adults ($DI_{young\text{-}old}$: $t[19] = 6.64$, $p < .001$, $d_z = 1.48$; $DI_{old\text{-}old}$: $t[22] = 2.65$, $p = .02$, $d_z = 0.55$; see Table 3 for computation of distractor inhibition effects).

Episodic retrieval of distractor-response bindings. In addition, the Distractor Relation × Response Relation interaction was significant as well, replicating typical distractor-response binding and retrieval effects (Rothermund et al., 2005). Repetition of the prime distractor in the probe produced a significant RT benefit if the same response was required in prime and probe, $t(82) = 10.63$, $p < .001$, $d_z = 1.17$. In contrast, distractor repetition had no effect on prime-probe sequences involving a response change, $|t| < 1$, $d_z = 0.08$. Importantly, the three-way interaction between distractor relation, response relation, and age group was not significant, indicating that retrieval effects of distractor-response bindings were of equal magnitude for young, young-old, and old-old adults (see Figure 1b). Planned contrasts showed that the three-way interaction was neither significant for the first nor for the second contrast ("young vs. old" comparison: $|t| < 1$, $d = 0.19$; young-old vs. old-old comparison: $t[80] = 1.39$, $p = .17$, $d = 0.31$). These findings support the view that processes of episodic binding and memory retrieval are preserved and functionally intact even in older age (Kane et al., 1997; Mayr & Buchner, 2014). All other effects failed conventional levels of significance (see Table 4).

Analytical Approach II: Age as Continuous Variable

DI effects and episodic retrieval effects of distractor-response bindings were computed from logarithmized mean probe RTs for each participant (see Table 3). These effect measures were then used as dependent variables in separate hierarchical regression analyses. In a first step, each of these effects was then regressed on measures of vocabulary and processing speed in order to control

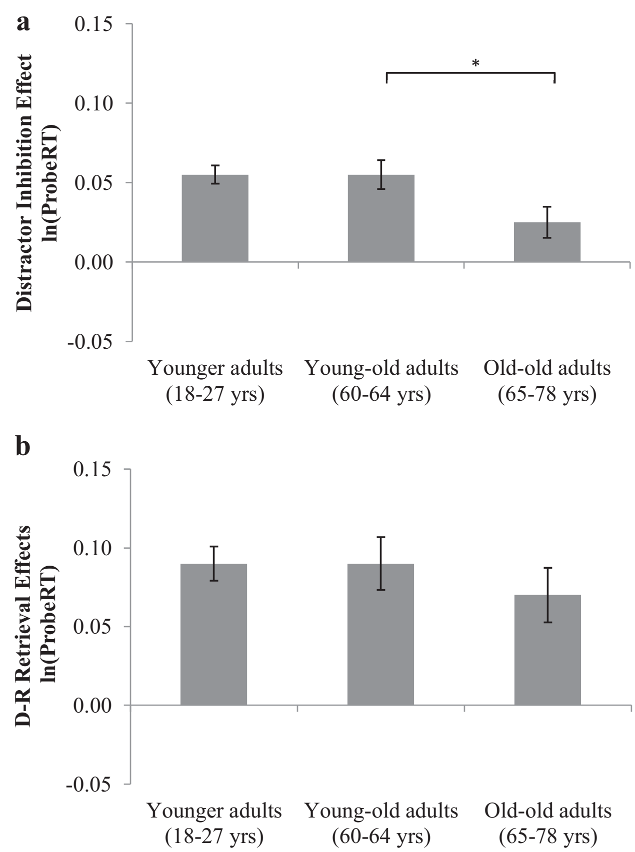

Figure 1. (a) Distractor inhibition effects (probe baseline trials [B] minus probe distractor repetition trials [DR], averaged across response relation; see Table 3) as a function of age group; positive values reflect probe performance benefits due to repetition of a persistently inhibited prime distractor. (b) Retrieval of distractor-response bindings $[(B–DR)_{RR} – (B–DR)_{RC}]$ as a function of age group; positive values indicate interaction effects that conform with expected effects due to distractor-based retrieval of previous responses (i.e., positive D-R retrieval effects for response repetition sequences and negative D-R retrieval effects for response change sequences). Error bars depict standard errors of the means.

for interindividual differences in overall cognitive functioning. In a second step, participant age was added as a continuous predictor. For overall analyses across age groups, the product term Age × Age was included as predictor in a third step in order to test for nonlinear (quadratic) age trends (see Tables 5 and 6, respectively).

DI effects. When participants from both age groups were considered (overall analysis), results revealed a significant negative effect of the quadratic age trend on distractor inhibition effects, $\beta = -.23$, $t(78) = 2.11$, $p = .04$, $f^2 = .05$ (see Table 5). To follow up on this effect, we performed additional hierarchical regression analyses separately for the younger and older subsamples and regressed distractor inhibition effects on control variables (Step 1) and age (Step 2) as predictors. In line with our reasoning, participants' age had no influence on distractor inhibition effects for younger adults, $\beta = .03$, $|t| < 1$, $f^2 = .00$. However, participants' age exerted a significant negative effect on distractor inhibition effects for older adults, $\beta = -.34$, $t(39) = 2.34$, $p = .03$, $f^2 = .15$, indicating a significant reduction in distractor inhibition abilities with advancing age within the older subsample.

Episodic retrieval of distractor-response bindings. In contrast, the overall regression analysis on episodic retrieval effects yielded neither a linear, nor a quadratic age trend on distractor-based retrieval effects, $\beta = -.39$, $t(79) = 1.97$, $p = .07$, $f^2 = .04$, and $\beta = -.15$, $t(78) = 1.39$, $p = .17$, $f^2 = .02$, respectively (see Table 6). Follow-up analysis, in which distractor-response retrieval effects were regressed on control variables (Step 1) and participants' age (Step 2) separately for younger and older subsamples corroborated these findings. Participants' age had no influence on distractor-based retrieval effects, neither for younger, $\beta = .18$, $t(36) = 1.15$, $p = .26$, $f^2 = .04$, nor for older, $\beta = -.17$, $t(39) = 1.06$, $p = .29$, $f^2 = .03$, adults. In line with the MANOVA results, these findings suggest that episodic retrieval effects remain functionally intact even in advanced age.

Discussion

We employed a distractor-to-distractor repetition paradigm that was adapted from Giesen and colleagues (2012, Experiment 1) in order to dissociate effects of distractor inhibition and episodic retrieval. This allowed us to examine differences between age groups separately for both processes.

Regarding inhibitory processes, we found evidence for significant age group differences indicating a loss of attentional inhibition in older age. Furthermore, this pattern prevailed in two different analytical approaches. When age was treated as a categorical factor, a comparison of the three age groups of our study revealed that this decrease in the strength of attentional inhibitory functioning was apparent only for the oldest subsample of our study (age 65+), whereas processes of attentional inhibition were of equal strength for the younger and young-old (age 60 to 64) groups. This conclusion was further corroborated by regression analyses in which age was regarded as a continuous predictor variable: In a first analysis, using the entire sample of our study, we found a significant nonlinear effect of age on distractor inhibition, indicating a combination of stability and decline during old age. Following up on this effect, we found that within the older sample, the ability to inhibit interfering distractors reflected a significant negative relationship with participants' age and decreased for participants of advanced age. Within the younger sample, however, distractor inhibition was unrelated to participants' age. These

Table 5
Summary of Hierarchical Multiple Regression of Distractor Inhibition Effects on Control Variables (Step 1), Age (Linear Trend; Step 2), and Age × Age (Quadratic Trend; Step 3) for the Full Sample (n = 83), and Follow-Up Analyses for the Younger and Older Subsamples (Analysis of Linear Age Effects Only)

		Criterion distractor inhibition effect[b]		
Sample	Predictor[a]	Step 1 β	Step 2 β	Step 3 β
Full sample	Z_Processing speed	.12	−.10	−.05
($N = 83$)	Z_Vocabulary	.03	.15	.13
	Z_Age (linear trend)		−.33	−.29
	Z_Age × Z_Age (quadratic trend)			−.23*
	R	.11	.21	.31
	Total R^2	.01	.04	.09
	ΔR^2	.01	.03	.05*
Younger adults	Z_Processing speed	−.34*	−.34	—
($n = 40$)	Z_Vocabulary	−.08	−.09	—
	Z_Age (linear trend)		.03	—
	R	.37	.38	—
	Total R^2	.14	.14	—
	ΔR^2	.14	.00	—
Older adults	Z_Processing speed	.29	.23	—
($n = 43$)	Z_Vocabulary	.17	.23	—
	Z_Age (linear trend)		−.34*	—
	R	.37	.50	—
	Total R^2	.14	.25*	—
	ΔR^2	.14	.11*	—

[a] Predictors were standardized to avoid multicollinearity (Aiken & West, 1991). [b] Based on logarithmized mean probe reaction times (see Table 3 for computation of distractor inhibition effects).
* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 6
Summary of Hierarchical Multiple Regression of D-R Retrieval Effects on Control Variables (Step 1), Age (Linear Trend; Step 2), and Age × Age (Quadratic Trend; Step 3) for the Full Sample (n = 83), and for the Younger and Older Subsamples (Analysis of Linear Age Effects Only)

		Criterion D-R retrieval effect[b]		
Sample	Predictor[a]	Step 1 β	Step 2 β	Step 3 β
Full sample (N = 83)	Z_Processing speed	.05	−.21	−.18
	Z_Vocabulary	.05	.20	.19
	Z_Age (linear trend)		−.39	−.37
	Z_Age × Z_Age (quadratic trend)			−.15
	R	.06	.21	.26
	Total R^2	.01	.05	.07
	ΔR^2	.01	.04	.02
Younger adults (n = 40)	Z_Processing speed	−.42*	−.37*	—
	Z_Vocabulary	.19	.14	—
	Z_Age (linear trend)		.18	—
	R	.41	.45	—
	Total R^2	.17*	.20*	—
	ΔR^2	.17*	.03	—
Older adults (n = 43)	Z_Processing speed	.15	.12	—
	Z_Vocabulary	.12	.14	—
	Z_Age (linear trend)		−.17	—
	R	.21	.27	—
	Total R^2	.04	.07	—
	ΔR^2	.04	.03	—

[a] Predictors were standardized to avoid multicollinearity (Aiken & West, 1991). [b] D-R = distractor-response; Based on logarithmized mean probe reaction times (see Table 3 for computation of D-R retrieval effects).
* $p < .05$. ** $p < .01$. *** $p < .001$.

findings corroborate the assumption that selective inhibitory abilities decrease during old age (Hasher & Zacks, 1988; Lustig et al., 2007). The results of the categorical analysis indicate that this decline in inhibitory functioning is due to the old-old sample (≥65 years) of participants in our study (cf. Bell et al., 2008; Persad et al., 2002). Fixing a specific age boundary is always somewhat arbitrary, however, and might depend on sample characteristics rather than on any clear-cut underlying change process. The regression analyses that we conducted thus indicated a linear decline of distractor inhibition within the older sample, with the probability of deficits in inhibition increasing with advancing age.

A second important finding of our study is that the present analyses yielded no evidence for age-related differences with respect to episodic S-R binding and retrieval processes. In line with findings by Kane and colleagues (1997) as well as Mayr and Buchner (2014), we can therefore conclude that automatic retrieval of episodic S-R bindings is preserved in old age.

In sum, our findings shed some light on the heterogeneous findings that were reported in the literature with regard to age differences in distractor inhibition. In particular, our study provides an answer why some studies failed to find age differences in attentional inhibitory processes. The present results support the conclusion that inhibitory deficits in older participants may have been masked by a retrieval of distractor-response bindings that surfaced as "distractor inhibition" in paradigms that confound distractor inhibition and episodic retrieval processes, particularly in the NP paradigm (Mayr & Buchner, 2014; Neill et al., 1992; Rothermund et al., 2005). Alternatively, differences in the strength of inhibition may also have gone unnoticed in previous studies that did not distinguish between young-old and old-old subsamples. Against this background, we (a) advocate the use of alternative paradigms that can be considered process-pure measures of distractor inhibition or that allow for a dissociation of different underlying processes, and we (b) emphasize the need to further distinguish between different age groups within the group of older participants.

Limitations

It should be noted that the measure we used to assess episodic binding and retrieval captures only a specific form of episodic binding and retrieval (viz., bindings between irrelevant stimuli and responses). Although this specific form of binding and retrieval constitutes a well-established and unambiguous indicator of automatic binding and retrieval processes, it still is not a measure of binding and retrieval in general. Other important forms of binding and retrieval processes are possible (e.g., stimulus-stimulus bindings, or bindings between relevant stimuli and response) that were not assessed with the present paradigm. We thus cannot rule out that age differences in binding and/or retrieval do exist that were not captured with the present task.

Specifically, another distinction between different types of binding processes is also important in order to evaluate the present findings correctly. The binding phenomena that were investigated in the present study (and also in Mayr & Buchner, 2014) only refer to automatic, feature-based associations: They are implicit and formed only incidentally as a by-product of responding to a combination of relevant and irrelevant stimuli (e.g., Hommel, 1998). In contrast, other studies investigated strategic processes of binding and association formation during a standard memory training (e.g., learning and recalling a list of paired associates; Campbell, Hasher, & Thomas, 2010; Campbell, Trelle, & Hasher, 2013; Naveh-Benjamin, 2000). Given that automatic and strategic binding and retrieval processes reflect qualitatively distinct phenomena, it should come as no surprise that results also differ with regard to age group differences in these processes. Whereas the findings of our study suggest that automatic binding and retrieval processes are not affected by age, other studies reported either enhanced (so-called hyper-binding; Campbell et al., 2010, 2013) or reduced (Naveh-Benjamin, 2000) binding in older participants for measures of strategic binding and memory retrieval. Given these heterogeneous results, it seems a worthwhile endeavor of future research to more systematically investigate and compare age differences for automatic and strategic forms of binding and memory.

Another caveat concerns the interpretation of distractor repetition benefits: In accordance with a large literature on distractor repetition effects (Frings & Wühr, 2007; Lamy, Antebi, Aviani, & Carmel, 2008; Neumann & DeSchepper, 1991; Yashar & Lamy, 2010), we interpret this effect as an unbiased estimator of distractor inhibition; however, other interpretations are possible. An alternative explanation is that distractor repetition benefits could also stem from a distractor-based retrieval of "do not respond" tags that may be stored together with the distractors as part of the prime trial episode (see Neill et al., 1992). Although logically possible, we view such a retrieval of "do not respond" tags as an unlikely explanation for distractor repetition benefits in the present case, for several reasons. First and most importantly, our experiment provided unambiguous evidence that distractors do become positively associated with responses, and that repetition of a distractor leads to a retrieval and activation of these response tendencies, which is incompatible with the assumption that distractors are marked with "do not respond" tags. This result replicates findings of a large number of previous studies that also reported evidence for distractor-response binding and retrieval (Frings & Rothermund, 2011; Frings et al., 2007, 2013; Giesen & Rothermund, 2011, 2014; Mayr & Buchner, 2006; Mayr et al., 2009; Moeller & Frings, 2011, 2014; Moeller et al., 2012; Rothermund et al., 2005). Relatedly, if distractor repetition benefits are assumed to reflect episodic retrieval processes, one would expect similar age group differences for this and other types of episodic retrieval effects. It would then be hard to explain why distractor repetition benefits were found to be age sensitive in our study, whereas episodic retrieval processes for distractor-response bindings were not. Furthermore, the assumption that distractor repetition benefits reflected a retrieval of "do not respond" tags cannot easily explain why these effects differ between response-relevant and response-irrelevant distractors (Giesen et al., 2012). This finding clearly indicates that the interference potential of the distractors triggered some kind of shielding reaction, which resulted in stronger inhibition of the distractors and correspondingly stronger distractor repetition benefits. In sum, then, although we concede that distractor repetition benefits could, in principle, also result from an episodic retrieval of "do not respond" tags, such an alternative explanation is hard to reconcile with important results that were obtained on our study and in the literature.

Theoretical Implications

Given the fact that processes of distractor inhibition, but not of binding and retrieval, were sensitive to age, the present results can be seen as a further validation of the paradigm's ability to dissociate these processes. Our findings thus substantiate the conclusion that processes of retrieving episodic bindings and attentional inhibition reflect independent mechanisms of action regulation. In this regard, the present findings are particularly insightful with respect to the issue of *what* is inhibited, because they argue against the view that the distractor becomes inhibited in its entirety so that its further processing is prevented altogether (e.g., by completely deactivating the mental representation of the distractor; Houghton & Tipper, 1994). If that were the case, we should not have obtained any evidence for distractor-response binding and retrieval effects at all. In our view, the present results therefore suggest that inhibition only prevented the distractor's access to the response selection stage (e.g., Tipper & Cranston, 1985; see also Fuentes, Vivas, & Humphreys, 1999; Tipper, Weaver, & Houghton, 1994). In other words, inhibition shields the selection of the target response by preventing a translation of the distractor into "its" associated response (indeed, this notion corresponds with the restraint function of inhibition; cf. Lustig et al., 2007). However, this did not prevent the emergence of a binding between the distractor and the *executed response* to the prime target. This attests that distractor inhibition and distractor-response binding and retrieval depict two functionally independent processes in the service of automatic action regulation (cf. Giesen et al., 2012).

In a similar vein, the present study yields initial support that the present paradigm is of merit to obtain a better understanding of (altered) cognitive processing in different age groups. The distractor-to-distractor repetition paradigm can therefore be regarded as a superior alternative in comparison with the NP paradigm, because it allows to measure attentional inhibitory processes in an unbiased way. Employing such a distractor repetition paradigm is therefore a promising avenue for future studies on topics related to cognitive aging. It would also be interesting to compare the present paradigm's sensitivity to detect age-related changes in distractor inhibition with that of other experimental tasks. For instance, Wnuczko et al. (2012) found no age-related changes in inhibitory processes when using a priming of PoP paradigm (for a similar conclusion regarding age differences in inhibition of return, see Pratt & Chasteen, 2007). Tentatively, this difference in findings might indicate that inhibition at the response selection stage is more susceptible to aging than at earlier stages of visual selection. However, future research is needed to address this issue in more detail.

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