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Brief Report

Selective directed forgetting in children

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ABSTRACT

When, after study of an item list, adults are cued to forget some of the list items and encode new information instead, such cuing often induces selective forgetting of the to-be-forgotten material without impairing recall of the other items. This study examined developmental trends in such selective directed forgetting by having second graders, sixth graders, and young adults study three successive lists of items and, after study of List 2, cuing them either to remember both List 1 and List 2 or to forget List 2 but remember List 1. Consistent with prior work, second graders exhibited no forgetting at all in response to the forget cue, whereas young adults selectively forgot List 2. Sixth graders showed still another pattern with forgetting of both List 1 and List 2, suggesting that the ability to selectively forget is still absent at this age level. Directed forgetting has often been attributed to the action of inhibitory control processes. On the basis of this view, the current finding that children during middle childhood do not yet show selective forgetting indicates that the control processes underlying selective directed forgetting mature into adolescence and early adulthood.

Introduction

A critical prerequisite for the everyday functioning of our memory is an efficient updating of the memory system. Such updating renders irrelevant out-of-date information, such as one's former home address, less accessible but enhances the accessibility of more relevant information, such as one's current address. Lab-based studies have repeatedly shown that young adults can forget irrelevant

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information when cued to do so, an ability often attributed to inhibitory processes (e.g., Geiselman, Bjork, & Fishman, 1983). Developmental work has shown that reliable memory updating typically arises at the end of the elementary school years, which is consistent with the view that, at earlier age levels, inhibitory processes are not yet sufficiently developed (e.g., Harnishfeger & Pope, 1996). More recent work now indicates that young adults not only can deal with updating tasks, in which participants are cued to forget all precue information, but also can deal with selective tasks, in which both relevant information and irrelevant information have been encoded and participants are cued to selectively forget the irrelevant precue information (e.g., Delaney, Nghiem, & Waldum, 2009). The current study sought to (a) determine whether such selective memory updating follows a similar developmental trend as does nonselective memory updating and (b) examine, on the basis of the findings, what type of process underlies selective memory updating.

A classic method of examining (nonselective) memory updating is the so-called list method directed forgetting (LMDF) task. In this task, participants successively study two item lists and, between lists, receive a cue either to remember the first list for a later memory test or to forget the list, pretending that it was presented for practice only. At test, participants are asked to recall both lists of items regardless of cue. Typically, relative to remember-cued participants, forget-cued participants show impaired recall of List 1 and improved recall of List 2, referred to as forgetting of the precue information and enhancement of the postcue information (e.g., Bjork, 1989). To date, a number of studies have examined LMDF in school-aged children, and the findings from this research generally indicate that younger, but not older, elementary school children show difficulties with the task (e.g., Aslan, Staudigl, Samenieh, & Bäuml, 2010; Harnishfeger & Pope, 1996; Zellner & Bäuml, 2004). For instance, Harnishfeger and Pope (1996) found that whereas fifth graders showed intact (adult-like) LMDF effects, the effects were completely absent in first graders and still reduced in third graders. Similarly, Zellner and Bäuml (2004) demonstrated reliable LMDF effects in fourth graders but not in second graders.

Arguably, the classic LMDF task does not represent a particularly demanding updating task because, in the forget condition, all of the List 1 information is designated as unimportant and, therefore, participants are asked to forget all precue items. In contrast, more recent research examined how participants deal with more challenging updating tasks, in which both relevant precue information and irrelevant precue information are provided and participants are asked to forget the irrelevant information but keep in mind the relevant precue information. For instance, Kliegl, Pastötter, and Bäuml (2013) had young adults study three successive lists of items. After presentation of List 2, participants were cued either to forget List 2 but keep in mind List 1 (RFR condition) or to keep both lists in mind (RRR condition). Thereafter, a third list consisting of relevant items only was presented. Across three experiments, the results consistently showed evidence for selectivity in LMDF; relative to the RRR condition, forgetting of List 2, but not of List 1, arose in the RFR condition, indicating that young adults are capable of selectively forgetting irrelevant precue information (for related results, see Aguirre, Gómez-Ariza, Andrés, Mazzoni, & Bajo, 2017; Aguirre, Gómez-Ariza, Bajo, Andrés, & Mazzoni, 2014; Delaney et al., 2009; but see Sahakyan, 2004).[1] To date, however, no study has yet examined developmental trends in selective LMDF.

The effects of both nonselective and selective cues to forget precue information have often been explained by retrieval inhibition. In the context of the classic (nonselective) LMDF task, this account assumes that forget-cued participants engage in active inhibitory processes that reduce access to List 1 items and, due to the resulting decrease in these items' interference potential, improve recall of List 2 (Geiselman et al., 1983). Regarding selective LMDF, the additional proposal is that inhibitory processes can flexibly target and suppress irrelevant precue information without affecting the relevant precue information (Aguirre et al., 2017; Kliegl et al., 2013). Indeed, recent work relating performance in the LMDF task to executive control mechanisms and the involvement of prefrontal cortical regions (Conway & Fthenaki, 2003; Hanslmayr et al., 2012) suggests that retrieval inhibition reflects the action

[1] Like many studies on nonselective LMDF, studies on selective LMDF typically did not find recall enhancement of the postcue items. This result may have been expected because, as in nonselective LMDF, in selective LMDF precue items are often tested prior to the postcue items. As shown in Pastötter, Kliegl, and Bäuml (2012), when the precue items are tested first and the postcue items are tested last, the postcue enhancement effect is often reduced or even absent.

of a fairly flexible control process and may be part of the cognitive and neural systems that support our ability to override prepotent responses (Anderson, 2005).

In the literature, the forgetting of the precue information in nonselective LMDF not only has been attributed to inhibitory processes but also has been explained by context change. According to this view, the forget cue induces a change in participants' mental context and, thus, impairs recall of the precue items due to a mismatch between the context at encoding and the context at test (Sahakyan & Kelley, 2002). Because this mismatch should affect all precue items, regardless of whether the items are to be forgotten or consist of a mixture of relevant and irrelevant information, no selectivity should arise, which of course contrasts with the finding of selectivity in young adults (e.g., Delaney et al., 2009; Kliegl et al., 2013).

To date, it remains unclear whether children can already show selectivity in LMDF. To conclude from the fact that older elementary school children show successful updating in nonselective LMDF that they show successful updating also in selective LMDF might be premature. Although the inhibitory capabilities of children at this age level may be sufficient to show updating in the easier nonselective task, the same capabilities might not be sufficient to show updating in a more demanding selective task. Indeed, children's inhibitory control processes are often assumed to improve with increasing age, and the finding that both executive control processes and prefrontal brain regions seem to mature into adolescence and even early adulthood (e.g., Blakemore & Choudhury, 2006; Diamond, 2002) is consistent with this view. The maturation level of inhibitory processes in older elementary school children or during middle childhood, thus, may guarantee successful memory updating in nonselective updating tasks but require still further maturation to accomplish updating in selective tasks.

This study addressed the issue and examined developmental trends in selective LMDF. In particular, we investigated whether sixth graders, who typically show LMDF in the classic nonselective task (e.g., Harnishfeger & Pope, 1996), also show selective LMDF. Following prior work on selective LMDF in adults (e.g., Kliegl et al., 2013), second graders, sixth graders, and young adults studied three lists of items and, after study of List 2, were cued either to remember both List 1 and List 2 (RRR condition) or to forget List 2 but remember List 1 (RFR condition). On the basis of the retrieval inhibition account and the view that the inhibitory processes required to show selective LMDF might not have fully matured before adolescence or even adulthood, we expected that (a) young adults would show selectivity in LMDF (i.e., show forgetting of List 2 but not of List 1) and that (b) although sixth graders might show forgetting of precue information (e.g., Harnishfeger & Pope, 1996; Zellner & Bäuml, 2004), their updating might not yet be selective (i.e., the forgetting may generalize from the irrelevant to the relevant precue information). Regarding second graders, we anticipated that, based on prior findings on LMDF in younger elementary school children (e.g., Harnishfeger & Pope, 1996; Zellner & Bäuml, 2004), no forgetting at all might arise of either List 2 or List 1. In contrast, on the basis of the context change account, one would expect to find no such developmental pattern but instead nonselective LMDF of Lists 1 and 2 across all three age groups. Indeed, prior work suggests that already young elementary school children can show context-dependent forgetting (e.g., Aslan & Bäuml, 2008) and, thus, the selective cue to forget might create a mismatch between the context at encoding and the context at test for all three age groups, inducing nonselective LMDF of both precue lists.

Method

Participants

In total, 40 second graders (M_{age} = 7.48 years, SD = 0.51; 52.5% female), 40 sixth graders (M_{age} = 11.68 years, SD = 0.53; 32.5% female), and 40 young adults (M_{age} = 23.98 years, SD = 2.08; 57.5% female) took part in the experiment. Indeed, an analysis of test power that was conducted with the G∗Power program (Version 3; Faul, Erdfelder, Lang, & Buchner, 2007) revealed that to detect at least a small- to medium-sized selective LMDF effect (f = .20; Cohen, 1988) for the critical interaction with a probability of 1 − beta = .95 and alpha = .05, 40 participants are required for each of the three age groups. The children were recruited from two elementary schools and a secondary

school near Regensburg, Germany, and participated on a voluntary basis. The adults were students of Regensburg University and received course credit or a monetary reward of 5 euros for participation. All participants were tested individually. Our study complied with the Declaration of Helsinki as adopted by the 18th World Medical Association (WMA) General Assembly and amended by the 64th WMA General Assembly.

Materials

Following prior developmental work on nonselective LMDF effects (e.g., Aslan et al., 2010; Harnishfeger & Pope, 1996; Zellner & Bäuml, 2004), we used concrete unrelated nouns (e.g., balloon, whistle, mountain, ant, orange) as study items. To facilitate encoding for the children, the items were presented together with line-drawing pictures (e.g., a picture of a balloon, a picture of a whistle), which were selected from the Snodgrass and Vanderwart (1980) norms. Overall, the study materials consisted of two stimulus sets (A and B), each containing three subsets. Subsets 1 and 2 of each set consisted of 5 nouns and their pictures, and Subset 3 of each set consisted of 10 nouns and their pictures. Items were chosen that elicited very high name agreement (90–100%), high image agreement (3–5), appropriate familiarity (1.5–5), and mean complexity (2–4) according to the norms. All items were translated into German. For half of the participants, Set A was assigned to the RRR condition and Set B was assigned to the RFR condition; for the other half, the assignment of stimulus sets to conditions was reversed. For half of the participants, Subset 1 of each set served as List 1 and Subset 2 served as List 2; for the other half, the assignment of subsets to study lists was reversed. Subset 3 always served as List 3.

Design

The experiment had a 2×3 design with the within-participants factor of cuing (RRR or RFR) and the between-participants factor of age group (second graders, sixth graders, or adults). Conditions differed in which cue was provided after List 2. In the RRR condition, List 2 was followed by a cue to remember both List 2 and List 1; in the RFR condition, List 2 was followed by a cue to forget List 2 but remember List 1.

Procedure

Participants were told that they would be presented with lists of line-drawing pictures and their labels to study for a later recall test. The three lists' items were presented individually on index cards with a presentation rate of 3 s per item. Each index card showed the image of an object together with its label. The experimenter said the label out loud before proceeding to the next index card. Each study list had its own color (yellow, blue, red, green, orange, or brown) in order to enhance discriminability of the single lists (see Bray & Ferguson, 1976). Item order within lists was random for all participants. List 1 encoding was always followed by a cue to remember this list for an upcoming memory test. Critically, List 2 encoding was followed by a cue to remember List 2 and also keep on remembering List 1 (RRR), or participants were told that List 2 had been presented erroneously, and thus should be forgotten, but that they should keep on remembering List 1 (RFR). Then, for all participants, List 3 was presented with a cue to remember the list. Following the study phase, second and sixth graders counted backward from a two-digit number in single steps and adults counted backward from a three-digit number in steps of threes for 60 s as a recency control. At test, participants were asked to recall the three lists' items irrespective of original cuing. Lists were referred to by their color (e.g., "Now recall the blue list"). Because the focus of this study was on precue item recall, participants were asked to recall precue lists first. To avoid potential list output order effects, we counterbalanced across participants the order in which lists needed to be recalled. Half of the participants recalled List 1 first and List 2 second; for the other half, list output order was reversed. For each participant, list output order was identical across the two cuing conditions. All participants recalled List 3 last. The experimenter noted the words recalled by the participants. Recall time for List 1 and List 2 items was 30 s each; recall time for List 3 items was 60 s. After a break of 2 min, the second cuing condition started. Half

of the participants completed the RRR condition first and the RFR condition second; for the other half, the order of cuing conditions was reversed. For half of the participants, stimulus Set A was used in the RRR condition and stimulus Set B was used in the RFR condition; for the other half, the assignment of sets to the two conditions was reversed.

Results

Fig. 1 shows mean recall rates for the two cuing conditions separately for the single age groups.[2] Recall data were scored using a conservative scoring method, according to which a study item was counted as correctly recalled only when it was produced with the correct list (e.g., a List 1 item was recalled during the test of List 1). A 2 × 3 × 3 analysis of variance (ANOVA) with the factors of cuing (RRR or RFR), list (List 1, List 2, or List 3), and age group (second graders, sixth graders, or adults) revealed a significant three-way interaction, $F(4, 234) = 3.57$, $MSE = 405.23$, $p = .008$, $\eta^2 = .06$, suggesting that the effects of cuing on later recall of the three lists varied with age. Separate 2 × 3 ANOVAs for the three age groups with the factors of cuing and list revealed the relationship of the interaction.

Effects in separate age groups

Second graders

ANOVA revealed a main effect of list, $F(2, 78) = 6.45$, $MSE = 375.84$, $p = .003$, $\eta^2 = .14$, reflecting that, overall, List 1 recall rates (25.9%) were higher than List 2 (15.4%) and List 3 (17.8%) recall rates. There was no main effect of cuing, $F(1, 39) < 1$, and no interaction between the two factors, $F(2, 78) < 1$, suggesting that the RFR cue did not induce any LMDF with respect to either the precue or postcue material.

Sixth graders

ANOVA revealed main effects of cuing, $F(1, 39) = 7.76$, $MSE = 612.43$, $p = .008$, $\eta^2 = .17$, and list, $F(2, 78) = 8.32$, $MSE = 403.27$, $p = .001$, $\eta^2 = .18$, reflecting higher overall recall rates in the RRR condition (33.3%) than in the RFR condition (24.4%) and higher overall recall rates for List 1 (36.3%) than for List 2 (24.5%) and List 3 (26.7%). There was also a significant interaction between the two factors, $F(2, 78) = 8.25$, $MSE = 341.56$, $p = .001$, $\eta^2 = .18$. Planned comparisons showed that cuing the children to selectively forget List 2 induced forgetting of both List 1 (44.0% vs. 28.5%), $t(39) = 2.96$, $p = .005$, $d = 0.61$, and List 2 (32.5% vs. 16.5%), $t(39) = 3.25$, $p = .002$, $d = 0.72$, but did not have any effect on List 3 recall (23.3% vs. 28.1%), $t(39) = 1.32$, $p = .193$, $d = 0.31$, indicating that the sixth graders showed nonselective forgetting of both precue lists and no enhancement of the postcue list.

Adults

ANOVA showed a main effect of list, $F(2, 78) = 8.46$, $MSE = 493.07$, $p < .001$, $\eta^2 = .18$, reflecting higher overall recall rates for List 1 (65.8%) than for List 2 (51.4%) and List 3 (57.4%), but showed no main effect of cuing, $F(1, 39) < 1$. There was also a significant interaction between the two factors, $F(2, 78) = 6.26$, $MSE = 558.22$, $p = .003$, $\eta^2 = .14$. Planned comparisons showed that cuing the adults to selectively forget List 2 did not cause any forgetting of List 1 (62.0% vs. 69.5%), $t(39) = 1.39$, $p = .173$, $d = 0.29$, but did induce forgetting of List 2 (58.8% vs. 44.0%), $t(39) = 2.33$, $p = .025$, $d = 0.46$, which indicates that the adults showed selective LMDF. In addition, the forget cue induced postcue enhancement of List 3 (53.0% vs. 61.8%), $t(39) = 2.29$, $p = .028$, $d = 0.38$.

[2] In this study, we used the within-participants design of selective LMDF, with each participant taking part in both the RRR and RFR conditions. The order of cue conditions did not influence results (all $ps > .05$), which is consistent with prior work (Kliegl et al., 2013). In addition, the order in which Lists 1 and 2 were recalled at test left results unaffected (all $ps > .05$).

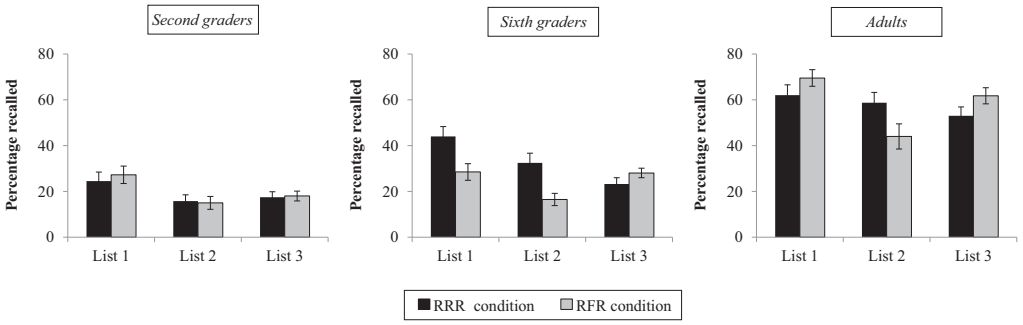

Fig. 1. Percentage of correctly recalled items as a function of cuing (RRR or RFR) separately for the three age groups (second graders, sixth graders, and adults). Error bars represent standard errors.

Table 1
Mean intrusion rates (and standard errors) as a percentage of original list length.

	List 1		List 2		List 3	
	RRR	RFR	RRR	RFR	RRR	RFR
Second graders	11.00 (2.14)	6.00 (1.78)	7.25 (1.96)	7.50 (1.71)	4.50 (1.24)	5.50 (1.68)
Sixth graders	6.00 (1.63)	7.50 (2.11)	10.00 (2.38)	8.00 (1.87)	8.50 (1.70)	5.50 (1.01)
Adults	4.25 (1.29)	2.75 (1.48)	6.00 (2.50)	7.50 (2.93)	4.75 (1.34)	1.50 (0.57)

Note. Results are shown as a function of cuing condition and age group separately for the three lists.

Intrusions

Table 1 shows intrusion rates as a function of cuing (RRR or RFR) and age group (second graders, sixth graders, or adults) separately for the three item lists. A list's intrusion rate represents the percentage of those items that were not recalled with the correct list but were erroneously recalled with one of the other lists and of those items that were not part of the employed item material. A $2 \times 3 \times 3$ ANOVA with the factors of cuing (RRR or RFR), list (List 1, List 2, or List 3), and age group (second graders, sixth graders, or adults) did not show significant main effects or interactions between any of the factors (all $ps > .173$), suggesting that cuing had no significant effects on intrusion rates across lists and age groups.

Discussion

This study is the first to indicate that selective LMDF develops later during childhood and adolescence than nonselective LMDF. Previous studies showed that nonselective LMDF is present from fourth grade onward but is still absent in first and second graders (Harnishfeger & Pope, 1996; Zellner & Bäuml, 2004). The current results confirm these findings by showing no LMDF at all in second graders and forgetting of (all) precue information in sixth graders. The current results go beyond this prior work, however, by showing that only the young adults, but not the sixth graders, revealed selective LMDF. In fact, whereas the young adults were able to forget the irrelevant precue information but to keep in mind the relevant precue information, the sixth graders forgot both types of precue information. Successful memory updating in sixth graders, thus, seems to be restricted to relatively easy nonselective tasks and to not hold in more demanding selective tasks.

Overall, the current results are in line with the inefficient inhibition hypothesis (Bjorklund & Harnishfeger, 1990). According to this view, younger children have problems at suppressing irrelevant information, but with increasing age children's inhibitory control processes become more and more efficient, leading to increasingly better performance in situations where irrelevant information needs to be targeted and suppressed. The finding that nonselective LMDF is present in older elementary school children but selective LMDF is still absent during middle childhood fits with this view, indicating that selective memory updating requires more elaborated inhibitory capabilities than nonselective memory updating. In fact, whereas sixth graders may already be able to exert inhibitory action on irrelevant precue information, they might not yet be able to restrict the inhibitory action to the irrelevant precue information when both irrelevant precue information and relevant precue information were encoded. This view agrees with other results indicating that the maturation of prefrontal brain regions and executive control functions, both of which have been linked to the efficient application of inhibitory control processes (Conway & Fthenaki, 2003; Hanslmayr et al., 2012), continues on into adolescence and even adulthood (e.g., Diamond, 2002).

In contrast, the current findings do not support the context change account of LMDF (Sahakyan & Kelley, 2002). Indeed, because a forget cue should induce a mismatch between the context at encoding and the context at test, and this mismatch should affect all precue items regardless of whether the items are to be forgotten or consist of a mixture of relevant and irrelevant information, no selectivity should arise in response to a forget cue, which of course contrasts with the finding of selectivity in young adults (e.g., Delaney et al., 2009; Kliegl et al., 2013). In their own, however, the results for the second and sixth graders may well be explained by (in)efficient context change, being attributed to inefficient mental context change in second graders and efficient context change in sixth graders (but see Aslan & Bäuml, 2008). Context change, thus, may serve as an alternative explanation of the children's results, raising the possibility that adults implement memory updating by inhibition, whereas children (try to) implement memory updating by context change. Future work may examine in more detail whether memory updating is triggered by qualitatively different processes in adults and children or whether the same (inhibitory) process underlies memory updating in adults and children, albeit in different degrees of maturity.

The current study showed a significant enhancement effect for the postcue list in adults but no reliable enhancement effects in second and sixth graders. To conclude from this pattern that the enhancement effect in selective LMDF increases with age, however, might be premature. Indeed, prior work has shown that postcue enhancement effects in young adults are typically enhanced when the postcue items are recalled first and the precue items are recalled last (see Pastötter, Kliegl, & Bäuml, 2012). In contrast, we chose a list output order where the precue items were recalled prior to postcue items, and as a result we may have underestimated potential postcue enhancement effects in second and sixth graders. Therefore, to get a more clearcut answer on possible developmental trends in the enhancement effect, future work is required in which postcue items are recalled prior to the precue items.

To conclude, the results from this study indicate that selective LMDF develops later during childhood than nonselective LMDF. Although sixth graders may well be able to forget irrelevant precue information, the forgetting may extend to relevant precue information, indicating that the children are not yet capable of targeting the irrelevant information. The indication that children during middle childhood do not yet show selective memory updating is consistent with the inefficient inhibition hypothesis, supporting the view that inhibitory capabilities mature into adolescence and early adulthood.

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