Research Article

Memorial Consequences of Environmental Context Change in Children and Adults

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Abstract. Changing environmental context during encoding can influence episodic memory. This study examined the memorial consequences of environmental context change in children. Kindergartners, first and fourth graders, and young adults studied two lists of items, either in the same room (no context change) or in two different rooms (context change), and subsequently were tested on the two lists in the room in which the second list was encoded. As expected, in adults, the context change impaired recall of the first list and improved recall of the second. Whereas fourth graders showed the same pattern of results as adults, in both kindergartners and first graders no memorial effects of the context change arose. The results indicate that the two effects of environmental context change develop contemporaneously over middle childhood and reach maturity at the end of the elementary school days. The findings are discussed in light of both retrieval-based and encoding-based accounts of context-dependent memory.

Keywords: episodic memory, context-dependent memory, environmental context change, memory development, cognitive development

Previous work with adults has shown that changes in environmental context can influence episodic remembering, in both a beneficial and a detrimental way. Corresponding evidence comes from studies using *first-order* (or *context reinstatement)* and *second-order* (or *interference reduction)* paradigms (Bjork & Richardson-Klavehn, 1989; Smith & Vela, 2001). In first-order paradigms, participants study a single list of items in a particular context (e.g., under water) and are later tested in a retrieval context that is either the same as (under water) or different from (on land) the original learning context. Recall of the list is typically poorer when the environmental context is changed between study and test, compared to when the context is not changed (Godden & Baddeley, 1975; Smith, Glenberg, & Bjork, 1978). In contrast, in second-order paradigms, the context change occurs already during study and participants are provided with multiple lists in different contexts. Recall of a target list is typically facilitated when the list is studied in a different – rather than the same – context as the interpolated lists (Bilodeau & Schlosberg, 1951; Dallett & Wilcox, 1968; for a review, see Smith & Vela, 2001).

Intriguingly, there is relatively little research that examined environmental context-dependent memory in children and the results are fairly inconsistent. Whereas some studies reported memorial effects of environmental context change already in preschoolers (Wilkinson, 1988), other studies failed to find effects even in older elementary school children (Pipe & Wilson, 1994). In particular, the studies were typically nondevelopmental in design, examining one or at most two children groups and no adult control group (Hazen & Volk-Hudson, 1984; Pipe & Wilson, 1994; Wilkinson, 1988; but see Jensen, Harris, & Anderson, 1971), and thus do not suggest strong inferences on age-related changes in environmental context-dependent memory. Moreover, by using exclusively first-order paradigms, prior work with children investigated only the detrimental effects of environmental context change, leaving it open of whether children can also benefit from the change in context. This lack of research is surprising given that knowledge about beneficial effects of environmental context change in children would be of relevance for applied settings, like, for example, educational practice. Teachers, for instance, would like to know whether context changes during learning could be used to improve pupils' memory for target material.

Although the results from the prior work do not allow drawing firm conclusions on whether environmental context changes affect young children's memory, there is evidence suggesting that generally young children's memories are less well associated with context information than those of older children or adults. For instance, young children's recognition of an event has been found to be primarily based on a feeling of familiarity, and to a lesser degree on vivid recollection of contextual details surrounding the event (e.g., Billingsley, Smith, & McAndrews, 2002; Ofen et al., 2007). Similarly, young children have been shown to reveal particular difficulties in source memory tasks, that is, tasks testing memory for contextual details of an original event, as compared to memory for the event itself (e.g., Cycowicz,

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Friedman, Snodgrass, & Duff, 2001; Foley, Johnson, & Raye, 1983). Although indirect in nature, the evidence arising from these findings suggests that young children may be less sensitive to environmental context changes than older children or adults. The goal of the present study is to test this proposal more directly.

Context changes typically come with a beneficial and a detrimental memorial effect. Following common theories of context-dependent memory (e.g., Anderson & Bower, 1973; Estes, 1955; Mensink & Raaijmakers, 1988), these two opposite effects reflect two sides of the same coin. In fact, both effects are typically explained by assuming that memories become associated to contextual information during study, which later, at test, can serve as a retrieval cue to activate the memories *(contextual cuing*; Smith, 1994, 2007). The detrimental effects of environmental context change then arise because the context change between study and test leads to a (larger than normal) mismatch between the contextual cues present during retrieval and those present during encoding (Tulving & Thomson, 1973). The beneficial effects arise because the study of multiple lists in different contexts leads to specific contextual cues for each list, supposed to reduce interference between lists and facilitate recall of a particular target list. Although these (retrieval-based) theories are silent about the development of context-dependent memory, they predict that, due to the same underlying mechanism, the two effects of context change should emerge contemporaneously in development and show the same developmental trajectory.

More recent work, however, indicates that the two effects of context change may be mediated by different mechanisms with different developmental trajectories. Corresponding evidence comes from studies using a second-order mental context-change paradigm that allows to examine detrimental and beneficial effects of context change simultaneously (Sahakyan & Kelley, 2002). In this paradigm, participants study two lists of items and, between the two lists, receive an imagination task supposed to create a change in mental context. Relative to a no-imagination control condition, the imagination task impairs later recall of List 1 and improves recall of List 2, reflecting the memorial costs and benefits of imagination (e.g., Pastötter & Bäuml, 2007; Sahakyan & Delaney, 2003; Sahakyan & Kelley, 2002).

Although the two effects of imagination are basically consistent with a retrieval-based account of context-dependent memory – the detrimental effect arising from an encoding/retrieval mismatch in contextual cues and the beneficial effect from the existence of specific contextual cues for each list – more recent work suggests that the benefits of imagination arise due to a change in people's encoding strategy with improved encoding after a mental context change. Consistently, Sahakyan and Delaney (2003) found that controlling participants' encoding strategies for the two lists eliminates the benefits of imagination, but leaves its costs unaffected. Measuring oscillatory brain activity during encoding, Pastötter, Bäuml, and Hanslmayr (2008) reported an increase in alpha and theta power from List 1 to List 2 when there was no context change between the two lists, but found no such increase in activity when an imagination task was interpolated. Mimicking findings from single-list paradigms (Sederberg et al., 2006), these results point to impaired attention (reflected by the increase in alpha power) and increased memory load (reflected by the increase in theta power) during List-2 encoding in the no-change condition, and an elimination of such impaired encoding when a context change is introduced between the two lists. Finally, examining the effects of imagination in children, Aslan and Bäuml (2008) found that although children showed adult-like List-1 costs from first grade on, even fourth-grade children did not show any List-2 benefits. Together, these findings challenge purely retrieval-based accounts of context-dependent memory and indicate that, at least the benefits of mental context change reflect an encoding-based effect that emerges later in development than the (retrieval-based) detrimental effect.

Because current research is inconclusive (detrimental effect) or even silent (beneficial effect) on children's memorial consequences of environmental context change, we examined environmental context-change effects in kindergartners, first and fourth graders, and young adults. Following Sahakyan and Kelley (2002), we used a second-order paradigm in which participants studied two lists of items, either in the same room (no-context-change condition) or in two different rooms (context-change condition), and subsequently were tested on the two lists in the room in which List 2 was encoded. On the basis of prior work, we expected that, in adults, the environmental context change impairs recall of List 1 and improves recall of List 2. Because previous related work indicates that, in young children, memories are less well associated with context information than in older children and adults (Billingsley et al., 2002; Foley et al., 1983), we expected that young children should be less sensitive to environmental change. Following the (purely) retrieval-based view on context-dependent memory, young children therefore should show reduced detrimental and beneficial effects of a context change, with the two effects showing roughly the same developmental trajectory. Alternatively, if the environmental context change mimicked the effects of a mental context change, with the detrimental effect reflecting impaired retrieval and the beneficial effect improved encoding, the memorial costs of environmental context change should arise earlier in development than the benefits.

Method

Participants

Forty 4- and 5-year-old kindergartners ($M = 4.4$, $SD = 0.5$ years; 22 females), forty 6- and 7-year-old first graders ($M = 6.9$, $SD = 0.4$ years; 22 females), forty 9- and 10-year-old fourth graders ($M = 9.8$, $SD = 0.4$ years; 24 females), and 40 young adults ($M = 25.3$, $SD = 3.7$ years; 27 females) took part in the experiment. The children were recruited from two kindergartens and two elementary schools in Regensburg, Germany and participated on a voluntary basis. The adults were students of Regensburg

University and received course credit. All participants were tested individually.

Materials

Four study lists were constructed (see Appendix), each consisting of six unrelated items from word norms for children (Hasselhorn, Jaspers, & Hernando, 1990; Posnansky, 1978).

Design

The experiment had a mixed design with the between-subjects factor of Age Group (kindergartners, first graders, fourth graders, and adults) and the within-subjects factor of Condition (context change and no context change). For each participant, the experiment consisted of two parts which differed in which Condition was provided. In each part, two lists were presented for study and should be recalled. In the no-context-change condition, the two lists were presented in the same room (both lists in room B); in the context-change condition, the two lists were presented in different rooms (List 1 in room A and List 2 in room B). In both conditions, the test took place in the room in which List 2 was studied (i.e., in room B).

Procedure

Participants were tested in their own homes. They were informed about the general nature of the experiment and were told that they were asked to learn and recall several lists of items. No mention was made with regard to any room changes that would occur.

The procedure in each part was as follows: The items of List 1 were read out individually and in random order by the experimenter at a rate of 3 s per word. Following the last item, the experimenter accompanied the participant out of the room and either returned back to the same room (no-context-change condition) or moved to a different room (context-change condition). Thereafter, the second list was presented in exactly the same way as the first list. The time interval between List 1 and List 2 (~ 45 s) was filled with slight conversation (to prevent rehearsal) and was matched in duration between the two conditions. After study of List 2, participants engaged in an irrelevant 90-s painting task. Following the painting task, a recall test for all of the previously studied items was conducted. Half of the participants were asked to recall List-1 items first, and half were asked to recall List-2 items first. Participants had 1 min per list but were given extra time when needed. The verbal responses were noted by the experimenter. After a 3-min break, the other part of the experiment was carried out. The order of the context-change and the no-context-change condition was counterbalanced across participants, as was the assignment of lists to Condition (context change or no context change) and list position (List 1 or List 2).

Results

The results for the four age groups are shown in Figure 1. Following prior work (e.g., Sahakyan & Kelley, 2002), we analyzed List-1 and List-2 performances separately. For all analyses reported below, the significance level was set to $a = 5\%$. We used a lenient scoring criterion, that is, an item was counted as correctly recalled if it was named at any time during the test phase, provided that it was part of the current condition's lists (Aslan & Bäuml, 2008).[1]

Regarding List-1 performance, a 2×4 analysis of variance with the factors of Condition (context change and no context change) and Age Group (kindergartners, first graders, fourth graders, and adults) revealed a significant main effect of Condition, $F(1, 156) = 13.7$, $MSE = .028$, $p < .05$, reflecting reduced recall in the context-change as compared to the no-context-change condition and a significant main effect of Age Group, $F(3, 156) = 106.5$, $MSE = .043$, $p < .05$. Follow-up pairwise comparisons revealed higher overall recall in adults than in fourth graders, higher overall recall in fourth graders than in first graders, and higher overall recall in first graders than in kindergartners (all p's < .05). Importantly, there was a significant interaction between the two factors, $F(3, 156) = 3.8$, $MSE = .028$, $p < .05$, indicating that the detrimental effect of the context change differed between the age groups. Single comparisons revealed that the context change impaired List-1 recall only in fourth graders and adults (both p's < .05), but not in first graders and kindergartners (both p's > .05).

Regarding List-2 performance, a 2×4 analysis of variance with the factors of Condition (context change and no context change) and Age Group (kindergartners, first graders, fourth graders, and adults) revealed a significant main effect of Condition, $F(1, 156) = 12.5$, $MSE = .023$, $p < .05$, reflecting improved recall in the context-change as compared to the no-context-change condition and a significant main effect of Age Group, $F(3, 156) = 99.8$, $MSE = .043$, $p < .05$. Follow-up pairwise comparisons revealed higher overall recall in adults than in fourth graders and higher overall recall in fourth graders than in first graders (both p's < .05); although first graders showed higher overall recall than kindergartners, this difference did not

[1] The same conclusions were reached when we used a strict scoring criterion. We also analyzed cross-list intrusion errors (i.e., recall of List-2 items when List 1 was tested and vice versa). The overall intrusion rates were relatively low and, within each age group, did not differ reliably across conditions (all p's > .05). Intrusion rates, however, varied with age group, with adults and fourth graders showing fewer intrusion errors (1.4% and 3.3%) than first graders and kindergartners (6.0% and 8.4%; $p < .05$).

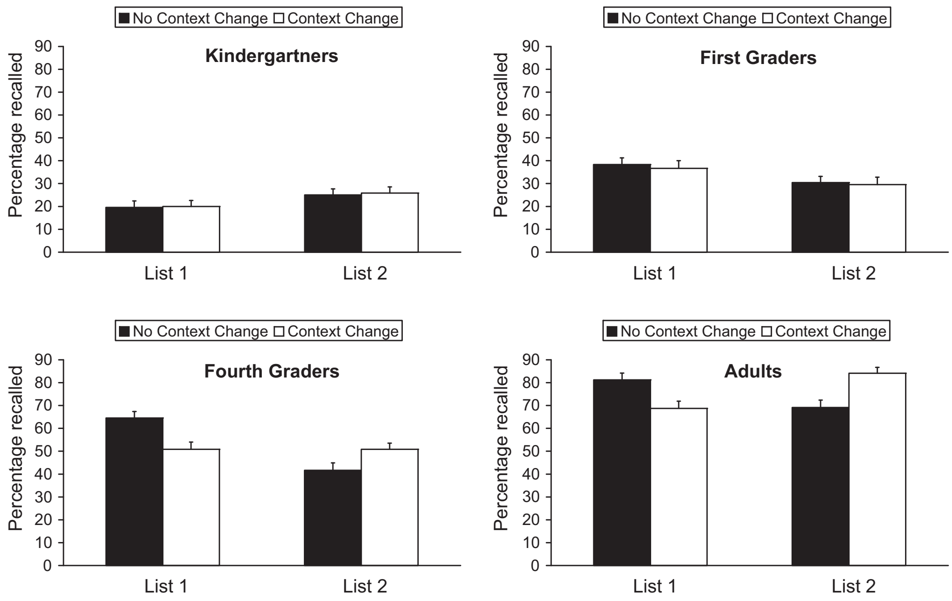

Figure 1. Recall performance in the four age groups as a function of condition (context change and no context change) and list position (List 1 and List 2). The error bars represent standard errors.

reach significance ($p > .05$). Importantly, there was again a significant interaction between the two factors, $F(3, 156) = 4.7$, $MSE = .023$, $p < .05$, indicating that the beneficial effect of the context change differed between age groups. Single comparisons revealed that the context change improved List-2 recall only in fourth graders and adults (both p's < .05), but not in first graders and kindergartners (both p's > .05).

Further Analyses

To examine whether differences in overall recall performance might have affected the results in the present study, we conducted two further analyses. Specifically, we split the participants in each age group according to their overall recall performance into a subgroup of *high-performing* and a subgroup of *low-performing* participants, and examined whether the subgroups differed in the magnitude of the detrimental and beneficial effects of environmental context change.[2] Although overall recall level was of course higher in high-performing than in low-performing participants, in none of the four age groups did high- and low-performing participants differ with respect to either the detrimental or beneficial effect of environmental context change (all p's > .05).

Finally, we directly compared detrimental and beneficial effects of environmental context change in high-performing first graders and low-performing fourth graders. This comparison is interesting because the two groups, though differing in age, did not differ in overall recall performance. Indeed, despite comparable recall levels (42.9% vs. 42.7%, $p > .05$), List-1 forgetting was present in the (low-performing) fourth graders (19.2%, $p < .05$) and absent in the (high-performing) first graders (−4.2%, $p > .05$). Similarly, reliable enhancement was present only in the (low-performing) fourth graders (10.0%, $p < .05$), but not in the (high-performing) first graders (0.8%, $p > .05$). Apparently, recall level did not play a major role in the present pattern of results.

Discussion

Testing children of three different age groups and young adults as controls, this study used a modified second-order paradigm to examine the detrimental *and* beneficial effects of environmental context change. In both young adults and fourth graders, the between-list context change impaired recall of List 1 and improved recall of List 2. In contrast, neither kindergartners nor first graders showed any memorial effects of the context change. These findings indicate that the two effects of environmental context change develop contemporaneously over middle childhood and reach maturity at the end of the elementary school days.

Following retrieval-based accounts of context-dependent memory, the beneficial effect of context change arises because the study of multiple lists in different contexts leads to specific contextual cues for each list, which reduces interference between lists and facilitates recall of a particular target list (e.g., Mensink & Raaijmakers, 1988; Sahakyan &

[2] The detrimental effect of environmental context change was calculated by subtracting List-1 recall in the context-change condition from List-1 recall in the no-context-change condition; and the beneficial effects of environmental context change was calculated by subtracting List-2 recall in the no-context-change condition from List-2 recall in the context-change condition.

Kelley, 2002). In contrast, the more recent encoding-based account attributes the beneficial effect to a change in people's encoding strategy with improved List-2 encoding after a context change (e.g., Pastötter et al., 2008; Sahakyan & Delaney, 2003). The present data are basically consistent with both accounts. However, recent work suggests that encoding-based benefits of context change may emerge relatively late in development and be deficient in fourth-grade children (Aslan & Bäuml, 2008). The present finding of significant beneficial effects of environmental context change in fourth graders thus favors a retrieval-based explanation of the benefits, indicating that, at the end of the elementary school days, children possess an important memory tool to reduce interference between competing episodes.

Previous work using paradigms like source monitoring and recognition memory had indicated that, in young children, memories are less well associated with context information than in older children or adults (Billingsley et al., 2002; Foley et al., 1983). The present finding of reduced detrimental effects of environmental context change in younger children is consistent with this indication. In particular, our results replicate previous studies, which, using first-order paradigms, also reported reduced detrimental effects of environmental context change in young children (Pipe, Gee, Wilson, & Egerton, 1999; Pipe & Wilson, 1994). Pipe and Wilson (1994), for instance, found that when 5- to 6-year olds' memory for a staged event (visiting the magician) was tested, the children's reports did not depend on whether the testing occurred in the original environmental context or not. However, because different previous studies reached different conclusions regarding the detrimental effects of environmental context changes, naturally the present results also disagree with some of the previous results. Such disagreement may help deducing sophisticated hypotheses on the conditions under which detrimental context effects may be present in younger children.

Indeed, Wilkinson (1988) found detrimental effects of environmental context change when taking 3- to 5-year-old preschoolers for a walk during which several predetermined activities took place. Notably, during both encoding and retrieval, children interacted actively with their environment and their attention was explicitly drawn to the context. This procedure contrasts markedly with the present one in which we neither emphasized nor even mentioned the environmental context at any time of the experiment, suggesting that context effects may be observed at an earlier age when the context is more integrated with the to-be-studied item material, rather than when it is incidental (Baddeley, 1982; Geiselman & Bjork, 1980).[3]

Item-context integration may also be enhanced if opportunity to encode context information is improved, as, for instance, may occur with criterion learning. If so, possible differences in context-dependent memory between children and adults may be eliminated if opportunity to encode context information for children was increased. Corresponding evidence arises from a study by Jensen et al. (1971). Jensen et al. used criterion learning during acquisition and, as expected, found younger children to need more learning trials to reach criterion than older children. More interesting, with more opportunities to encode contextual information for the younger children than the older children, Jensen et al. found second graders to be equally susceptible to the detrimental effects of environmental context change as twelfth graders. The results from the present and prior work thus converge on the view that, in general, detrimental effects of environmental context change are reduced or absent in young children, but that such effects may be induced if exceptional effort is dedicated to children's strengthening of the contextual representation.

The suggested picture that context effects may not be observed in young children contrasts with findings from the infant literature. Indeed, Rovee-Collier and colleagues reported robust environmental context effects in 6- to 18-month-olds using the *train task* (Hartshorn & Rovee-Collier, 1997) and even in 3- to 6-month-olds using the *mobile conjugate reinforcement task* (Butler & Rovee-Collier, 1989). These tasks represent operant conditioning paradigms in which nonverbal infants learn to press a lever to produce movement in a toy train, or to kick their foot to produce movement in an overhanging mobile, and therefore differ markedly from the verbal list-learning procedure used in the present study. It thus seems that the nonverbal tasks used in infant research are more sensitive to contextual changes than the verbal tasks typically used in research with preschoolers and school-aged children. To address the issue in more detail, future developmental work is needed that directly compares the role of environmental context in nonverbal implicit and verbal explicit memory tasks.

In the present study, we tested participants in two randomly chosen rooms in their own homes rather than in two fixed laboratory rooms at the university. Although we are aware that it is not the standard procedure for examining environmental context-dependent memory in adults, for two reasons, we believed that the present procedure is more appropriate for children. First, because children might show more anxiety in unfamiliar laboratory settings than adults, we judged it wiser to examine children in a familiar setting in which they feel more comfortable. Second, we intended to roughly match participants' familiarity with the experimental rooms across age groups. In fact, all of our adult participants were psychology students and most of them had participated in previous experiments in our laboratory rooms, which was not the case for the children.

Retrieval-based views on context-dependent memory assume that the beneficial and detrimental effects of context change are reflections of the same mechanism, that is, contextual cuing at retrieval (Smith, 1994, 2007), and thus should develop simultaneously. The present finding that each age group showed either both context effects (adults and fourth graders) or none of the two effects (kindergartners

[3] In contrast to the present study, in this work no second age group was examined. Thus, in principle, the preschoolers may have shown a reduced detrimental effect of context change when compared to older children or adults.

and first graders) is consistent with this view. The present finding, however, contrasts with the results of a recent study on the memorial consequences of mental context change (Aslan & Bäuml, 2008). In this study, the beneficial effect of mental context change was found to develop after fourth grade and thus much later in time than its detrimental effect, which was present from first grade on. The developmental dissociation was taken as evidence that the two effects of mental context change arise from different mechanisms with different developmental trajectories: The detrimental effect from an encoding/retrieval mismatch in contextual cues and the beneficial effect from a person's shift to a superior encoding strategy.

Accounts of context-dependent memory typically do not distinguish between the effects of external (environmental) and internal (affective, pharmacological, and mental) context change (but see Eich, 1985, 1995), because often the two types of context change reveal parallel patterns of results (e.g., Smith, 1994). While different forms of context change may in fact differ only quantitatively, so that, for example, an internal context change can lead to a stronger detrimental effect than an external one and thus may be more easily observed in first graders (Aslan & Bäuml, 2008), external and internal context changes may also differ qualitatively. Indeed, internal, but not external, context changes may affect the encoding of subsequent material (Sahakyan & Delaney, 2003) and the suggested deliberate shift in encoding strategy may develop later than the retrieval-based beneficial effect of an external change (Aslan & Bäuml, 2008). Unfortunately, little is yet known about the exact relationship between the effects of external and internal context changes. It is, therefore, a high priority for future research on context-dependent memory to investigate in more detail whether the effects of external and internal context changes differ qualitatively or quantitatively.

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Appendix

The four original study lists used in the experiment (English translations in parentheses):

(a) Stuhl, Ball, Sonne, Käfer, Auto, Papier (Chair, Ball, Sun, Beetle, Car, Paper)
(b) Apfel, Zelt, Schere, Pfanne, Kerze, Hose (Apple, Tent, Scissors, Pan, Candle, Trousers)
(c) Bruder, Vogel, Milch, Puppe, Buch, Fuß (Brother, Bird, Milk, Doll, Book, Foot)
(d) Schloss, Kirsche, Hammer, Bus, Gabel, Spiegel (Palace, Cherry, Hammer, Bus, Fork, Mirror).