Are Primary-School-Aged Children Experts in Spatial Associate Learning?

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Abstract. In two experiments (Experiment 1: *N* = 180, Experiment 2: *N* = 150), we investigated the anecdotal observation that school age children are assumed to be experts in spatial associate learning. In the first experiment, second graders, sixth graders, and adults learned the associations between 32 pictures and either a position or a word. 16 pictures had each to be associated with one position in a 4-by-4 grid of squares (spatial condition); the other 16 pictures had each to be associated to one of 16 monosyllabic words (verbal condition). After a 3 min distractor interval the associated position or word had to be retrieved with the pictures as cues. In Experiment 2, the results were replicated in principle with modifications in the experimental details. Performance improvement as a function of age turned out to be substantially larger in the verbal condition compared to the spatial one. The results are traced back to the idea that spatial associate learning is a cognitive function maturating early during life span.

Keywords: spatial memory, verbal memory, concentration game, children, paired associate learning

Despite several quite astonishing examples of children's highly complex cognitive achievements even very early in life (e.g., Baillargeon, 2004; Quinn, 2004), it is an almost ubiquitous finding that cognitive efficiency improves considerably throughout childhood (e.g., Siegler, DeLoache, & Eisenberg, 2003). Examples include motor behavior (e.g., Thelen, 1995), working memory (e.g., Gathercole, Pickering, Ambridge, & Wearing, 2004), long-term memory (e.g., Peterson, 2002), spatial cognition (e.g., Newcombe & Huttenlocher, 2000), language skills (e.g., Guasti, 2002), as well as problem solving (e.g., Zimmerman, 2000). All the more surprising, and therefore the topic of the present study, is the widespread conviction of many adults that children are experts in spatial learning; a claim usually substantiated by the anecdotal observation of children outperforming adults in the game "Concentration" "on a quite regular basis." Interestingly, the empirical evidence supports this folk psychology's conviction at least partially: Using a reduced version of the game played individually by participants in a noncommunicative situation, Baker-Ward and Ornstein (1988) found that performance was independent of age when tested with 6- to 10-year-olds and adults. Schumann-Hengsteler (1996), however, used a more realistic version of the game with 2 participants of comparable age playing against each other. No age dependent performance improvement for 5- to 10-year-old children was observed but adults outperformed the children. Additionally, strategic aspects of performance were superior for adults.

Two alternatives might save the folk psychology's conviction of children being experts in spatial associate learning: Alternative 1 stresses social and higher cognitive aspects, while Alternative 2 is based on learning and memory. According to Alternative 1, adults abstain from using their full strategic cognitive power when playing with children, and as a consequence, children might win more often than they should. Additionally, adults may focus more on the cases when children won and may thus over-represent these instances mentally. Therefore, according to Alternative 1, the anecdotal observations are to be traced back to two kinds of biases, a social and a cognitive one.

According to Alternative 2, however, children are indeed experts in spatial associate learning as suggested by Baker-Ward and Ornstein (1988). The higher strategic cognitive power of adults, on the other hand, may have produced the pattern of results observed by Schumann-Hengsteler (1996).

We will restrict our empirical investigation to Alternative 2, for at least two reasons: First of all, experimental psychology offers a theory to explain the "children as experts in spatial learning"-idea: According to Hasher and Zacks (1979), some stimulus attributes are encoded and entered into memory automatically, and spatial location is assumed to be one. Moreover, spatial cognitive processes are assumed to be in some way "neurally prewired" and do not show developmental changes beyond an early age. At least some empirical evidence exists for this idea. Ellis, Katz and Williams (1987) found that location memory (after both incidental as well as intentional associate learning) did neither vary with age beyond the 3 to 4 year range nor with intelligence level when mentally retarded persons were compared with nonretarded ones (see also, e.g., Ellis, Woodleyzanthos, & Dulaney, 1989; Jones, Vaughan, & Roberts, 2002). Moreover, numerous studies have reported age changes for spatial associate learning that were surprisingly small (e.g., Park & James, 1983). For a fair evaluation of

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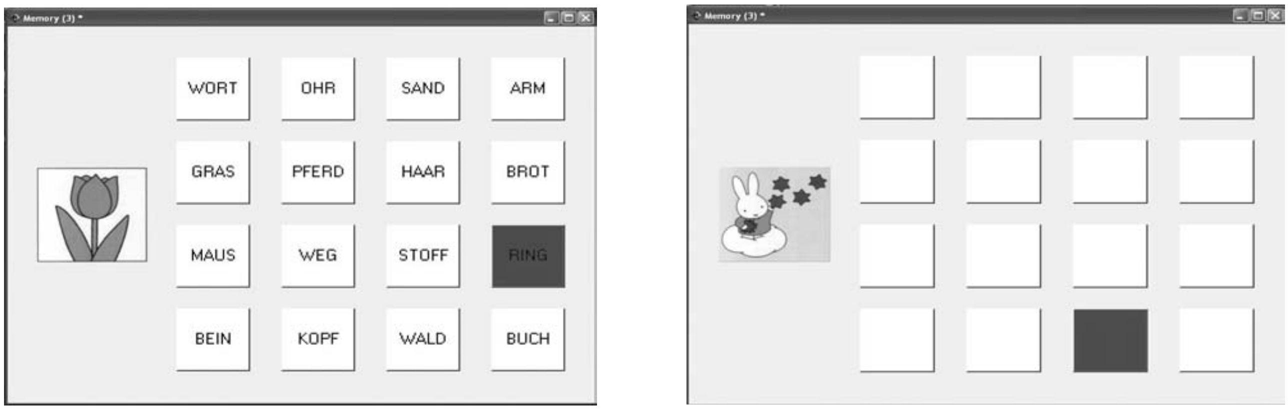

Figure 1. Screenshot of learning trials in the verbal (left) and the spatial (right) condition (Experiment 1).

whether or not children are experts in spatial associate learning, however, a direct comparison with a different associate learning task, e.g., a verbal one, is needed. Ideally, the two conditions should only differ according to the nature of the association to be learned.

To investigate the validity of the second alternative as an account for the anecdotal observations of surprisingly good performance of children in spatial associate learning, we expanded the concentration game by using the long experimental tradition of paired associate learning. An association between a concentration game card on the one side and a position or a noun on the other side had to be learned by 7- to 8-year-old and by 11- to 12- year-old children as well as by adults in Experiment 1. Experiment 2 took into account some criticism regarding experimental details while the pattern of results was replicated in principle. In both experiments, the concentration game card served as a cue for the two learning conditions, which were presented randomly intermixed. Because of the nature of the concentration game, a visual paired-associate learning test resulted, which implies that the presentation of the simple words required reading abilities. For that reason only school age children were chosen to participate.

Experiment 1

Methods

Participants

A total of 60 second graders (age ranged from 7 to 8 years, mean age: 7.5 years; 35 males, 25 females), 60 sixth graders (age ranged from 11 to 12 years, mean age: 11.4 years; 31 males, 29 females), and 60 adults (age ranged from 18 to 44 years, mean age: 28.3 years; 28 males, 32 females) participated in this study. Children were recruited through advertisements in local newspapers, adults were recruited on campus. Prior to testing, all parents gave their informed written consent for their children's participation in the study. All participants were rewarded for participation. Because of their additional journey children were paid 5 EUR, whereas adults received 3 EUR.

Stimuli and Procedure

Individual sessions lasted about 30 to 60 minutes. The experiment was run on a PC with a 17-inch touch screen. Participants had to learn the associations between 32 colored pictures chosen and scanned from the Ravensburger "Mein erstes Memory" ("My First Concentration Game") and either a position in a 4-by-4 grid of 16 squares or a word out of 16 monosyllabic nouns carefully selected from the German basic vocabulary book of the first grade "Findefix." None of the words had any semantic or linguistic relation to any of the pictures.

Participants had to complete one or more experimental blocks, each consisting of a learning phase, a 3-minute distraction interval and a retrieval phase, until they reached a prespecified learning criterion of less than five errors in either the verbal or the spatial condition, or until they worked on the task for an hour.

Learning Phase

In this phase, the 16 picture-word and the 16 picture-position combinations were presented intermixed in random order for 2 s each (see Figure 1), with an inter-trial interval of 2 s. Participants were instructed to learn the association between the concentration game card presented on the left and the highlighted noun (verbal condition) or the highlighted position (spatial condition), respectively. They were also informed that the words were presented at random positions changing from trial to trial, and that the position of the word was irrelevant for the task. Thus, all 16 words were presented in each learning trial at random positions, and the instructions stressed to ignore all but the highlighted word.

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Distraction Interval

The learning phase was followed by a distraction task where subjects had to compare two drawings which where almost identical. They had to find 10 differences between the drawings. The distraction interval lasted for 3 minutes to investigate the more long-term effect of paired associate learning.

Retrieval Phase

In the retrieval phase following the distraction interval, the 32 concentration game cards were presented individually in random order in the left part of the touch screen. In the right part the 4-by-4 grid was presented either with empty squares or with the 16 words arranged in random order. Participants had to select the associated position or the associated word by touching one of the fields of the grid. All 32 trials had to be completed with no feedback given. As soon as participants made less than five errors in either the verbal or the spatial condition, the experiment was finished. Otherwise, more experimental blocks had to be completed. Associate learning performance was uniformly operationalized for the three age groups as the number of errors in the first block [1].

Results and Discussion

The performance for the retrieval of positions and verbs was clearly above chance level (positions: $t(179) = 16.43$, words: $t(179) = 20.47$, both $p < .001$). There was no difference in the number of learning blocks between age groups, $F(2, 177) = 1.28$, *ns*, $\varepsilon^2 = .014$. Younger children needed 3.92 ($SE = 0.13$) learning blocks, older children needed 4.32 ($SE = 0.25$) and adults needed 3.98 ($SE = 0.17$). 118 participants reached the criterion in the verbal condition, 15 in the spatial one, and 47 participants in both conditions at the same time. This pattern of result did not differ between age groups.

Mean Number of Errors

A repeated analysis of variance revealed a significant interaction between the factors Age group and Type of condition, $F(2, 177) = 3.45$, $p < .05$, $\varepsilon^2 = .038$, as well as main effects of Age group, $F(2, 177) = 4.73$, $p = .01$, $\varepsilon^2 = .051$, and Type of condition, $F(1,177) = 112.07$, $p < .001$, $\varepsilon^2 = .388$. Figure 2 shows, that only in the verbal condition the mean error was significantly smaller for the adults ($\bar{x} = 8.35$, $SE = 0.59$) than for the older ($\bar{x} = 10.48$, $SE = 0.51$), $F(1, 118) = 7.48$, $p < .01$, $\varepsilon^2 = .06$, and younger children ($\bar{x} = 10.45$, $SE = 0.42$), $F(1, 118) = 8.86$, $p < .01$, $\varepsilon^2 = .07$. There was no such difference in the spatial condition (adults, $\bar{x} = 12.57$, $SE = 0.37$; older children $\bar{x} = 13.10$, $SE = 0.31$, and younger children $\bar{x} = 12.98$, $SE = 0.31$; $F(2, 177) = .79$, *ns*, $\varepsilon^2 = .01$).

The results of Experiment 1 are straightforward: First, performance in both conditions was well above chance level with no risk of floor- or bottom-effects. Second, performance in the verbal associate learning condition improved with age. This improvement is not too surprising and is in line with the numerous studies showing improvement of cognitive efficiency throughout childhood, some of which are mentioned in the introduction (see also for example Durand, Hulme, Larkin, & Snowling, 2005; Hitch, Halliday, & Littler, 1993). It is an interesting aspect, however, that the performance improvement in our study was present only for the adults. The 11- to 12-year-olds did not differ from the 7- to 8-year-olds. Therefore, it is implausible to assume that our effects are due to age changes in verbal competence itself. The interesting finding is in fact the observation that despite the age-related improvement in the verbal condition, no such thing was found for spatial associate learning in spite of both conditions being highly similar.

The results are in line with the "children as spatial experts" hypothesis. However, to address this hypothesis effectively, we must exclude alternative explanations. Unfortunately, the two conditions of verbal versus spatial associate learning are not completely equivalent. In the verbal condition, irrelevant spatial information is present, too. While the instructions emphasized that the spatial position of the words is irrelevant (and changed from trial to trial), it cannot be excluded that in the verbal condition some degree of interference occurred between verbal learning and (irrelevant) spatial learning. Moreover, substantial empirical evidence suggests that the capacity for inhibition of irrelevant information improves across childhood (see, e.g., Dempster, 1992; Elliott, 2002). Thus, if children are more susceptible to interference than adults, one would expect the pattern of results obtained in the present study even when the associate learning performance for verbal versus spatial information would *not* depend upon age[2]. Therefore, in Experiment 2 we changed the details of the experimental procedure with respect to the verbal condition: The word to be associated to the memory card was now presented next to the card, and no other words were present during a verbal learning trial. Thus, no spatial interference was present in the verbal learning condition anymore.

However, the "capacity for inhibition as a function of age" hypothesis does not only apply to the learning phase but also to the retrieval phase. In order to find the associated word in the matrix of 16 words, participants had to scan 7

1 The same pattern of results was observed, when the performance was measured as the average number of errors obtained in either the first 2 blocks or in all blocks a participant needed in order to reach 50% correct responses.

2 We gratefully acknowledge that this alternative explanation was brought forward by Tom Beckers.

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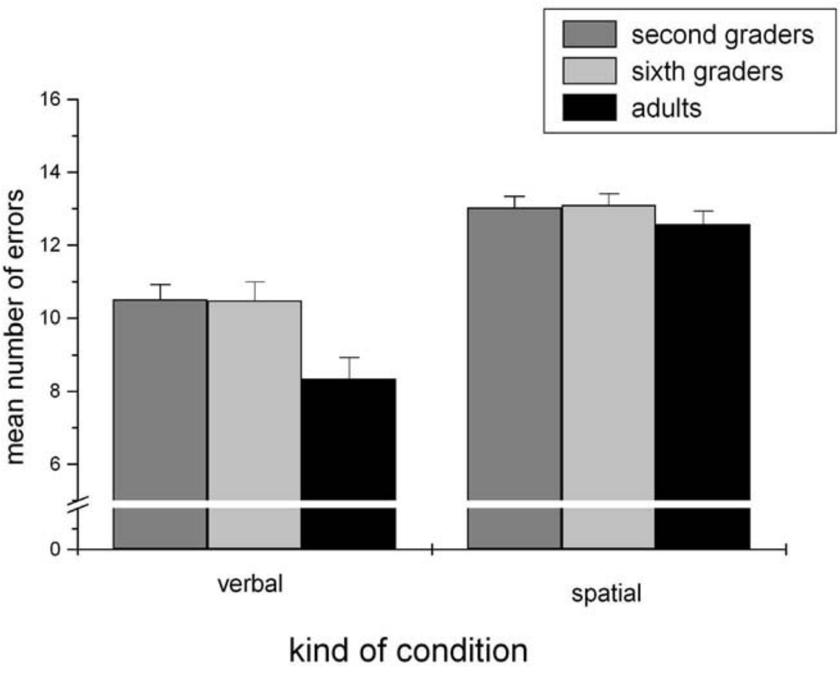

Figure 2. Mean number of errors as a function of Age group and Type of condition (error bars indicate standard errors) in Experiment 1.

or 8 nontarget words on the average. This word scanning process might have caused interference with word memory retrieval. One might assume that interference might be larger when the capacity for inhibition is smaller, and one might additionally assume that this might be the case for the younger participants. Therefore, in Experiment 2 the retrieval phase was also changed for the verbal condition such that participants now had to recall the associated word with the memory card as the cue. The spatial condition, however, remained completely unchanged. If the "capacity for inhibition as a function of age" hypothesis is able to explain the pattern of results obtained in Experiment 1, then in Experiment 2, associate learning performance should not depend upon the interaction of age and type of condition anymore.

Experiment 2

Methods

Participants

A total of 50 first and second graders (age ranged from 7 to 8 years, mean age: 7.7 years; 26 males, 24 females), 50 sixth graders (age ranged from 11 to 12 years, mean age: 11.58 years; 25 males, 25 females), and 50 adults (age ranged from 18 to 38 years, mean age: 24.34 years; 23 males, 27 females) participated in this study. Younger children were recruited from a public school in Bonn, Germany; older children through advertisement in local newspaper and adults were recruited on campus. Prior to testing, all parents gave their informed written consent for participation. Again, all participants were rewarded for participation. All children were paid 5 EUR, whereas adults received 3 EUR.

Stimuli and Procedure

Stimuli and procedure were based on the first experiment. Again, participants had to learn the associations between one of 32 concentration game cards and either a word out of 16 monosyllabic nouns or a position in a 4-by-4 grid of 16 squares (see Experiment 1). In this experiment, participants had to complete only two experimental blocks, again each consisting of a learning phase, a 3-minute distraction interval and a retrieval phase.

Learning Phase

In this phase, the 16 picture-word and the 16 picture-position combinations were presented in random order for 2 s (see Figure 3), with an intertrial interval of 2 s. The learning of the positions was the same as in Experiment 1; the learning of the words was changed such that only the one associated word was presented in the middle of the screen next to the concentration game card.

Distraction Interval

See Experiment 1.

Retrieval Phase

The retrieval phase for the positions was the same as in Experiment 1. Concerning the retrieval of the words, a concentration game card was presented and participants had to

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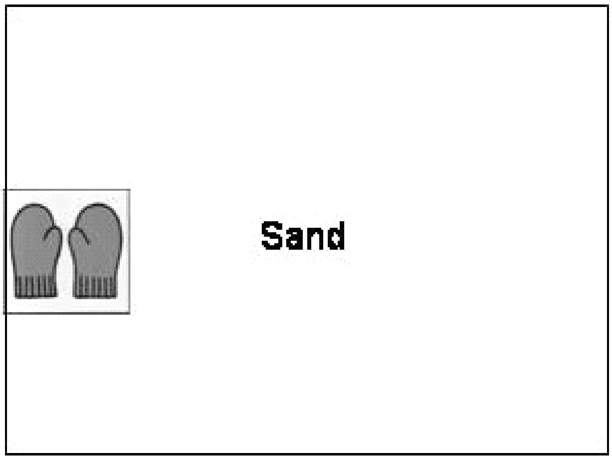

Figure 3. Screenshot of a learning trial in the verbal condition of Experiment 2.

recall the associated word which was registered and judged as correct/incorrect by the experimenter. Again, the concentration game cards were presented individually in random order, and no feedback was given and there was no time pressure. As in Experiment 1 associate learning performance was uniformly operationalized for the three age groups as the number of errors in the first block.

Results

The performance for the retrieval of words and positions clearly was above chance level (positions: $t(149) = 17.21$, words: $t(149) = 16.67$, both $p < .001$).

Mean Number of Errors

A repeated analysis of variance revealed a significant interaction between the factors Age Group and Type of Condition, $F(2, 147) = 21.54$, $p < .001$, $\varepsilon^2 = .23$, as well as main effects of Age group, $F(2, 147) = 57.91$, $p < .001$, $\varepsilon^2 = .44$, and Type of condition, $F(1, 147) = 92.42$, $p < .001$, $\varepsilon^2 = .38$. Figure 4 shows that in the verbal condition the mean error was significantly smaller for the adults ($\bar{x} = 6.18$, $SE = 0.59$) than for the older children ($\bar{x} = 9.48$, $SE = 0.52$), $F(1,98) = 17.81$, $p < .001$, $\varepsilon^2 = .15$, which in turn was significantly smaller than the one for the younger children ($\bar{x} = 13.56$, $SE = 0.34$), $F(1, 98) = 43.44$, $p < .001$, $\varepsilon^2 = .31$. In the spatial condition the retrieval did not differ between adults ($\bar{x} = 10.94$, $SE = 0.38$) and older children ($\bar{x} = 11.74$, $SE = 0.35$), $F(2, 147) = 2.33$, *ns*, $\varepsilon^2 = .02$; but both age groups made less errors than the younger children ($\bar{x} = 14.12$, $SE = 0.2$), $F(2, 147) = 52.70$, $p < .001$, $\varepsilon^2 = .35$ for adults and younger children and $F(2, 177) = 33.61$, $p < .001$, $\varepsilon^2 = .26$) for older and younger children.

Thus, the performance increase as a function of participant's age was *substantially* smaller for spatial associate learning than for verbal associate learning. Moreover, the age-dependent performance increases in Experiment 2 were larger than the respective ones in Experiment 1. In the verbal condition, this might be due to the change from a situation where subjects had to select the respective target word out of 16 presented candidate words to a recall procedure. It is a matter of debate which of the two situations in fact resembles the spatial condition more closely. Howsoever, these results show that the children's performance in Experiment 1 was *not* underestimated due to the "capacity for inhibition as a function of age" hypothesis. In Experiment 2, no interference was present, neither as irrele-

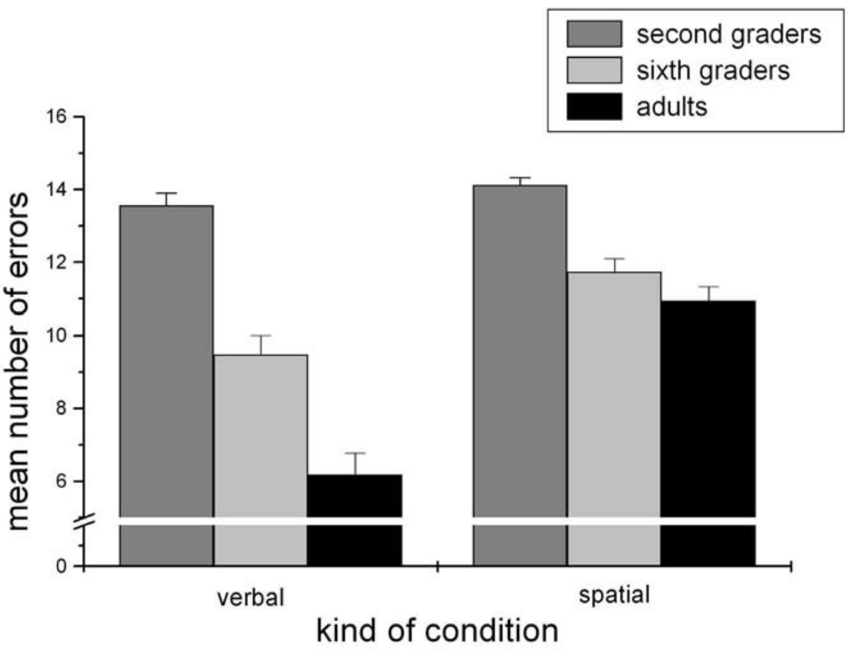

Figure 4. Mean number of errors as a function of Age group and Type of condition (error bars indicate standard errors) in Experiment 2.

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vant spatial interference during learning nor as interference due to distractor words during retrieval. Whereas the inhibition hypothesis would have predicted smaller performance increases as a function of age for the interference-free verbal condition, we actually observed even larger ones in Experiment 2. Thus, the inhibition hypothesis as an alternative explanation for the findings of Experiment 1 can successfully be ruled out.

In contrast to Experiment 1, we also observed performance increases as a function of age in the spatial condition. Although they were quite small compared to the ones in the verbal condition, these results were not predicted given that the spatial condition did not change at all between the two experiments. Both small (e.g., Park & James, 1983) and even no performance increases at all (Baker-Ward & Ornstein, 1988) in spatial learning as a function of age were described in the literature before. At the moment, we can only speculate about the reasons for this change in results. One hypothesis might be related to the (at least superficially) higher similarity between the verbal and the spatial condition in Experiment 1 compared to Experiment 2. Thus, it might be possible that the larger difference in Experiment 2 might have helped especially the older participants to separate both conditions in mind.

General Discussion

Taken together, both experiments consistently show that children seem to be "relative experts" in a certain kind of spatial memory, i.e., spatial associate learning. In this sense "relative expert" means that the performance of the children was not worse than the one of adults in this kind of task. One might also say that adults are nonexperts in this kind of task. Irrespective of this, what is evident is that the performance improvement for verbal associate learning as a function of age was consistently present in both experiments, a performance improvement as a function of age was either absent at all (Experiment 1) or substantially smaller than the one in the verbal condition (Experiment 2). For one thing, this finding validates the results of, among others, Ellis et al. (1987) and Baker-Ward and Ornstein (1988). Moreover, it substantially extends their observation in that with the verbal condition we now have a similar control condition that differs with respect to the kind of association. For that it was the first study, were the verbal and spatial associative learning was compared directly. Therefore, we can suggest that the observation that performance in the spatial condition only slightly improves with age should be traced back to the idea that spatial associate learning is a cognitive function maturating (at least partly) early during life span, is pretty much in line with the theoretical position of Hasher and Zacks (1979). Surely, at this point one has to be cautious, however, not to over-generalize. Spatial memory as well as spatial behavior improves with age. This is true for large-scale environmental space, as found in numerous studies carried out both in real space (e.g., Cornell, Heth, & Alberts, 1994) and in virtual environments (e.g., Jansen-Osmann, 2007), and it is also true for landmark memory in large-scale space (e.g., Jansen-Osmann & Fuchs, 2006). These data in contrast to the present finding might point toward the distinction between cue learning (what is where) and place learning (distance and direction of an object with respect to landmarks), made by e.g., Newcombe and Huttenlocher (2000). Moreover, with working memory, age-related improvement has been shown for verbal as well as for visuo-spatial information (see e.g., Gathercole et al., 2004). More empirical work is needed to clarify whether or not a special status of paired associate learning of spatial locations as a form of cue learning exists, but unfortunately, at present paired associate learning is not very prestigious anymore outside neuroscience and animal research. It would be interesting to know, however, how the performance improvement as a function of age would look like for additional types of associate learning, like colors, faces, or movement patterns. This study and the method implied here provides an excellent framework for further studies in which associate learning could be investigated for different kind of information. Furthermore we also obtained a framework where the development of code-specific representation in long-term memory could be investigated under a neuroscientific point of view.

Let us return to the anecdotal observation that children are at least "equipollent rivals"“in playing the concentration game. We cannot rule out that some of this appraisal is due to adults' lack of strategic motivation or reduced attention when playing against children. Our data, however, suggest an additional source for the widespread conviction: First of all, we propose that children's spatial associate learning performance is not substantially reduced compared to that of adults. Moreover, since adults might be familiar with their superior memory performance evident in e.g., verbal associate learning (also evident in our data), the real performance level of children – although in itself lower than that of adults – is higher than their *expected one*, based on the age-related improvement function observed for other instances of memory achievement. Further studies are needed to evaluate this explanation in detail.

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