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Aspects of Code-Specific Memory Development

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Abstract We investigated the development of code specific representations of different kinds of information in long term memory. Forty second graders, 40 sixth graders and 40 adults learned the associations between 12 pictures and one position each in a 4×3 grid of squares, 12 pictures and 1 of 12 monosyllabic words each or 12 pictures and 1 of 12 faces. After a 3 min distractor task, a picture was presented in the retrieval phase, and the associated position, word or face had to be selected. Performance in the verbal condition improved as a function of age, while performance in the spatial condition turned out to be independent of age, and the performance in the facial condition showed a difference between both child groups and the adults. The results revealed a developmental difference of code specific representation of different kinds of information.

Keywords Long-term memory · Children · Code-specific representation · Spatial · Verbal · Facial

It is a key topic in general memory research whether distinct memory storage systems exist for different kinds of information (for example, Allen et al. 2006). There are a lot of empirical studies favouring a code specific long-term memory representation (see for example, Rösler and Heil 2002). Furthermore, neuroanatomical evidence suggests that stored information is reactivated in multiple anatomically distinct brain areas.

The neocortical process-storage theory of McClelland et al. (1995), which does not differentiate between short- and long term memory representations, postulates different cortical modules which are specialized for the processing as well as the representation of different kinds of information, as color, form and localization of objects. The authors assume that permanent long-term engrams are consolidated and reactivated in the very same neocortical cell assemblies in which information is also

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processed on-line during perception. Consistent with this theory there are recently a lot of neuroimaging (Nyberg et al. 2000) and ERP-studies (Heil et al. 1994, 1997; Khader et al. 2005) demonstrating that domain-specific perceptual cortices that were engaged during encoding of a specific stimulus are reactivated when this stimulus is retrieved from memory.

Concerning the development of code-specific representation of information in long-term memory, empirical evidence is almost completely missing until now. The developmental literature focuses much more on the investigation of the difference between a verbal and visual-spatial working memory (Pickering et al. 1998), the fractionation of the visual-spatial working memory system (Hamilton et al. 2003), or the binding of item and location memory in children (Kail and Siegel 1977).

In our own work we developed a so-called pair-associate learning task to investigate the development of code specific long-term memory representation in more detail (Jansen-Osmann and Heil 2007). Sixty second graders, 60 sixth graders and 60 adults learned the associations between 32 pictures and either a position or a word. Sixteen pictures had each to be associated with one position in a 4×4 grid of squares (spatial condition); the other 16 pictures had each to be associated with 1 of 16 monosyllabic words (verbal condition). Each of the 32 associations was presented for 2 s. After a 3 min distractor interval, a picture was presented in the retrieval phase, and the associated position or word had to be selected. Performance in the verbal condition improved as a function of age, while performance in the spatial condition turned out to be completely independent of age.

These results show that different kinds of associated information are processed and stored differently dependent upon the age of the subjects. The results can be traced back to the idea that spatial feature binding is a cognitive function maturating early during one's life span. Moreover, it supports the idea of children as experts in spatial associate learning (Baker-Ward and Ornstein 1988; Schumann-Hengsteler 1996) and confirms the result that age changes for spatial associate learning were either absent or surprisingly small (for example, Park and James 1983).

The main goal of this study was to evaluate and extend these results by expanding the pair-associate learning of spatial and verbal information through an additional condition where face information had to be learned. This is an important question at least because of two reasons: First of all, there is a developmental improvement of the short term recognition of faces from age 5 to 12 years (Ellis and Flin 1990). This seems to reflect the children's encoding transition from a featural to a configurational approach (Carey and Diamond 1979). However, it is still unknown whether this effect is mirrored in a developmental improvement of paired associate long-term memory improvement. Secondly, on a physiological level a dissociation between the binding of a word and a spatial position and a word and a face was shown (Khader et al. 2005). Further, investigating the ERP components in a short term memory experiment with words and faces, children between the age of 11 and 14 years showed both increased latencies and decreased amplitudes in the early components of faces compared to words (Hepworth et al. 2001). These results suggest that a qualitative difference in memory development depending upon the kind of information to be retrieved might exist.

Therefore, it seems noteworthy to examine whether there is an age dependent dissociation between the association of spatial, verbal and face information in long-term memory. We compared 7- and 11-year-old children as well as adults, respectively, in their performance in a spatial-, a verbal- as well as a face-paired associate learning task. In all three conditions, presented randomly intermixed, the associations had to be learned with visual items as cues.

Methods

Participants

Forty first and second graders (mean age: 6.9 years; 17 females), 40 sixth graders (11.6 years; 23 females) and 40 adults (25.2 years; 22 females) participated in this study. Children were recruited from two public schools in Duisburg, Germany. Adults were recruited on campus of the University of Düsseldorf. Prior to testing, all parents gave their informed written consent for participation.

Stimuli and Procedure

Individual sessions lasted about 30 min. The experiment was conducted using a PC computer with a 17 in. touch screen. Participants had to learn the associations between 36 colored pictures chosen and scanned from the Ravensburger "Mein erstes Memory" ("my first Concentration game") and either a position in a 3×4 grid of 12 squares, a word out of 12 monosyllabic words carefully selected from the German basic vocabulary book of the first grade "Findefix" or a face of a standardized picture series (courtesy of S. Sporer, see Sporer 1999). None of the words had any obvious semantic or linguistic relation to any of the pictures.

The experiment consisted of a learning phase, a 3 min distraction interval and a retrieval phase.

Learning phase In this phase, the 12 picture–position, 12 picture–word and 12 picture–face combinations were presented in random order for 4 s each (see Fig. 1), with an intertrial interval of 2 s. Participants were instructed to learn the association between the concentration game card presented on the left and the highlighted position (spatial condition), the highlighted word (verbal condition) or the

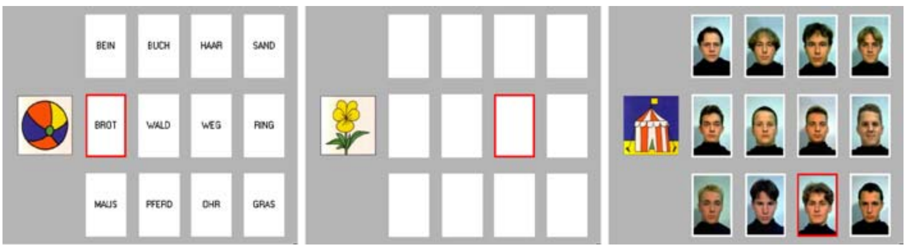

Fig. 1 Screenshot of the paired associate learning trials in the verbal, the spatial and the facial condition. The *picture presented on the left* had to be associated to the highlighted word, position, or face, respectively. The 36 associations to be learned were presented in random for 4 s each with an intertrial interval of 2 s

highlighted face (face condition), respectively. They were also informed that the words and faces were presented at random positions changing from trial to trial, and that the position of the word and the face was completely irrelevant for the task.

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 ten differences between the drawings.

Retrieval phase In the retrieval phase following the distraction interval, the 36 concentration game cards were presented individually in random order in the left part of the touch screen. Depending upon the kind of association, in the right part of the screen the 3×4 grid was presented with 12 empty squares (spatial association), with the 12 words (verbal association) or with the 12 faces (facial association) arranged in random order. Participants had to select the associated position, the associated word or the associated face by touching one of the fields of the grid. All 36 trials had to be completed with no feedback given and no time pressure.

Results

A repeated analysis of variance with the mean number of errors as dependent variable revealed a significant interaction between the factors age group and type of condition, $F(4,234)=9.196$, $p<0.001$, $\varepsilon^2=0.136$, as well as main effects of age group, $F(2,117)=16.72$, $p<0.001$, $\varepsilon^2=0.222$, and type of condition, $F(2,234)=16.31$, $p<0.001$, $\varepsilon^2=0.122$. Figure 2 shows, that there was no difference of the learning in the spatial condition between younger children ($\bar{x}$ = 10.15, SE=0.19), older

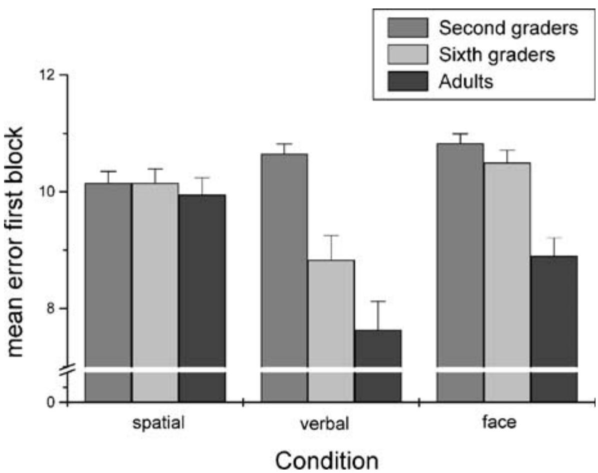

Fig. 2 Mean number of errors in the retrieval phase as a function of age group and type of condition (*error bars* indicate standard errors). In the retrieval phase, the 36 pictures were presented individually in random order in the left part of the touch screen. Participants had to select the associated position, the associated word or the associated face by touching the respective field of the grid

children ($\bar{x}$ = 10.15, SE=0.24) and adults ($\bar{x}$ = 9.95, SE=0.29), $F(2,117)=0.22$, n.s., $\varepsilon^2=0.004$). In the verbal condition the mean error was smaller for the adults ($\bar{x}$ = 7.63, SE=0.49) than for the older ($\bar{x}$ = 8.83, SE=0.43) and younger children ($\bar{x}$ = 10.7, SE=0.17), $F(2,117)=15.97$, $p<0.001$, $\varepsilon^2=0.215$, but the difference between adults and older children failed to reach significance, $F(1,78)=3.34$, $p=0.069$, $\varepsilon^2=0.042$. In the face condition, the mean error was smaller for adults ($\bar{x}$ = 8.9, SE=0.31) than for older ($\bar{x}$ = 10.55, SE=0.21) and younger children ($\bar{x}$ = 10.85, SE=0.17), $F(2,117)=19.11$, $p<0.00$, $\varepsilon^2=0.246$, which did not differ in their performance, $F(1,78)=1.63$, n.s., $\varepsilon^2=0.02$.

Discussion

The results confirm and extend our previous work (Jansen-Osmann and Heil 2007): First of all, performance in the spatial pair-associate learning turned out to be independent of age. 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 and the facial condition we now have matched control conditions that only differ with respect to the kind of association to be learned.

The age-independent performance in the spatial condition might be traced back to the idea that spatial associate learning is a cognitive function maturating (at least partly) early during life span, pretty much in line with the theoretical position of Hasher and Zacks (1979). Children seem to be spatial experts, at least regarding the learning of pictorial spatial information. We surely know that spatial memory as well as spatial behaviour improves with age. This is true for large-scale environmental space, as found in numerous studies carried out both in real space (for example, Cornell et al. 1994) and in virtual environments (for example, Jansen-Osmann and Fuchs 2006).

Secondly, verbal associate learning improved as a function of age, showing a gradual achievement with increasing age. Performance improvement as a function of age in the verbal associate learning condition is not surprising. This finding is in line with the numerous studies showing improvement of cognitive efficiency throughout childhood, some of which are mentioned in the introduction. Finally, younger and older children did not differ in their performance in the paired-associate picture-face task, but the performance of both children groups turned out to be worse than that of the adults. Whereas older children seem to acquire a memory strategy to achieve their improved performance in the verbal condition they did not do so in the face condition. This finding contrasts with former studies revealing a holistic strategy in both adults and older children during face processing (Schwarzer 2000).

One reason for the performance of the older children might be traced back to the difficulty of the task. One hint in this direction stems from the performance difference of the older children in the verbal condition between our first study (Jansen-Osmann and Heil 2007) and the present one. While there was no performance difference between older and younger children in the verbal condition of Jansen-Osmann and Heil (2007) when 16 associations had to be learned, older children outperformed younger ones in the present study with only 12 associations to be learned. It can be assumed that the learning of the verbal condition was too difficult for both age groups in our former study. This assumption might also be attributed to the face condition in the experiment presented here and has to be investigated in more detail.

One might argue, however, that the spatial associate learning task is not completely equivalent to the non-spatial ones with respect to interference both during learning and during retrieval. Because the capacity for inhibition of irrelevant information improves across childhood (see for example, Elliott 2002), some of the developmental effects observed here might be traced back to improved inhibition instead of improved memory. In the learning phase of the non-spatial conditions, irrelevant spatial information was present which had to be ignored. In the retrieval phase of the non-verbal conditions, participants had to scan several non-target words or faces in order to find the target item.

This aspect, however, turned out to be irrelevant. Although in Experiment two of Jansen-Osmann and Heil (2007), interference for the verbal condition was eliminated both during learning and during retrieval, the results were nevertheless replicated. Interference during learning was eliminated by presenting the word to be associated to the picture side-by-side with no other words present. Interference during retrieval was eliminated by asking participants to recall the word with the picture as a cue. Thus, possible differences in interference between the different kinds of information did not affect the results.

This study revealed a code-specific speed in the development of representations in long-term memory. The results suggest a different development of the encoding and retrieval of spatial, verbal and visual (here facial) information. Whereas the verbal stimuli can be recoded easily in a phonological or linguistic format this was not the case for the other kind of information. We might assume that the older children were able to use more often a verbal memory strategy in the verbal condition than the younger children. But in contrast to the adults they had more difficulty using a memory strategy in the visual conditions. This is consistent with the fact that children had more difficulty spontaneously using an elaboration strategy during associate learning (Pressley 1982). Maybe it was too difficult to encode the facial stimuli in a verbal format because the stimuli were too similar (see Fig. 1). It seems reasonable to investigate the associate learning of concrete visual material in the form of pictures of real objects or faces which differ in many more aspects and could be verbalized more easily.

To summarize, we showed the development of a code-specific representation in long-term memory. This is one of the first studies that investigated this question from a developmental perspective. Further neurophysiological studies should follow in attempts to validate the neocortical process-storage theory under a developmental perspective. We expect that the age-dependent development of different cortical modules itself should turn out to be dependent on the kind of encoded and represented information in long-term memory.

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