Cross-Modal Matching Memory in Young Children: An Exploratory Study with a Long Retention Interval

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ABSTRACT

Fifty-two young children (aged 4 years to 6 years, 4 months) were tested with cross-modal matching and within-modal matching of shapes with two delay conditions. Children were given either visual (V) or tactual (T) acquisition training and then tested for visual recognition (V-V, T-V) or tactual recognition (T-T, V-T) with two retention intervals (0-delay or 1-week-delay). T-V was remembered more easily than V-T with 0-delay, whereas V-T was easier with a 1-week-delay.

The ability to integrate information from different sensory modalities has been referred to as cross-modal matching and is considered the basis for spatial cognition and various sensoimotor skills. This ability, particularly between vision and touch, has been demonstrated in infants as well as in human adults (Rose, Blank, & Bridger, 1972; Gottfried, Rose, & Bridger, 1977; Rose, Gottfried, & Bridger, 1978; Rose, Gottfried, & Bridger,1981a; Rose, Gottfried, & Bridger, 1981b; Rose & Orlian, 1991) and non-human primates (Gunderson,1983; Gunderson, Rose, & Grant-Webster, 1990).

There are some interesting indications that cross-modal matching is easier in one direction than in the opposite direction. For example, Connoly & Jones (1970) found that kinesthetic-visual matching was easier than visual-kinesthetic matching. They showed that a matching a visual comparison stimulus to a previously presented kinesthetic standard (k-v) resulted in fewer errors than did matching a kinesthetic comparison to a visual standard (v-k). A similar asymmetry of cross-modal matching between vision and touch has been reported by Rose et. al. (1981a, 1983) and Streri (1987). Asymmetries in cross-modal matching are useful for understanding the perceptual/cognitive processes that underlie cross-modal matching. Some of these phenomena may be explained in terms of different memory systems in different modalities. In fact, Posner (1967) presented evidence of a difference in visual and kinesthetic memory. He compared retention (20-sec. interval) of kinesthetic information from blind positioning movements with information from similar visually guided movements. He concluded that visual and kinesthetic short-term memory (STM) codes have different central processing requirements.

Milewski and Iaccino (1982) used cross-modal matching and within-modal matching with either a 5-sec. or a 20-sec. delay imposed between standard and comparison stimuli in adult subjects. The task was a same-different judgment of line lengths. There was a significant effect of delay, indicating better overall performance with the 5-sec. delay than with 20-sec. delay. With both delay conditions, however, the visual-visual condition was the easiest of all of the conditions, and the haptic-haptic condition was easier than the haptic-visual condition, but no easier than the visual-haptic condition. Rose et al. (1972) tested three-year-old children using cross-modal and withinmodal matching of shapes in the visual and tactual modalities. They reported that when there were no memory demands whatsoever, performance was equally good in all four conditions: visual- visual (V-V), visual-tactual (V-T), tactual-visual (T-V), and tactual-tactual (T-T). However, imposition of a delay condition (15-sec.) increased error in all conditions, with ease of memory in order V-V, V-T, T-V, and T-T. Rose et al. (1972) concluded that the young children's difficulty in retaining tactual information is a major determination of their established difficulty in intersensory integration.

However, only a short delay paradigm was used in the reports described above. In general, it is thought that memory consists of short-term memory and long-tern memory. Although it has been demonstrated that even very young infants display remarkably robust memory for visual features, which can endure delays of up to 2 weeks, there have been no reports regarding long retention intervals for tactual features.

The purpose of the present study was to explore: 1) whether young children could retain the memory of object shapes acquired through a tactual modality and 2) what kind of interaction between a1-week delay and different modalities will occur in the performance of cross-modal and within-modal matching. In general, it is difficult to directly test memory after a long delay in young children, since their verbal reports are sometimes not clear. Therefore, in the present study we designed doll-searching game as a type of associative learning.

Methods

Subjects

Fifty-two children (31 male, 21 female) ranging in age from 48 months to 76 months (mean=60.8 months) served as subjects. The children were randomly selected from kindergartens close to the University of Tokyo, Komaba campus.

Stimuli

The stimuli consisted of "codons" (Hoffman & Richards, 1982). The codons provide a complete basis for describing any wiggle curve and hence can be used to enumerate a class of silhouettes. Codon quardruples were chosen as stimuli (Fig. 1, see Richard, Koenderink, & Hoffman, 1987).

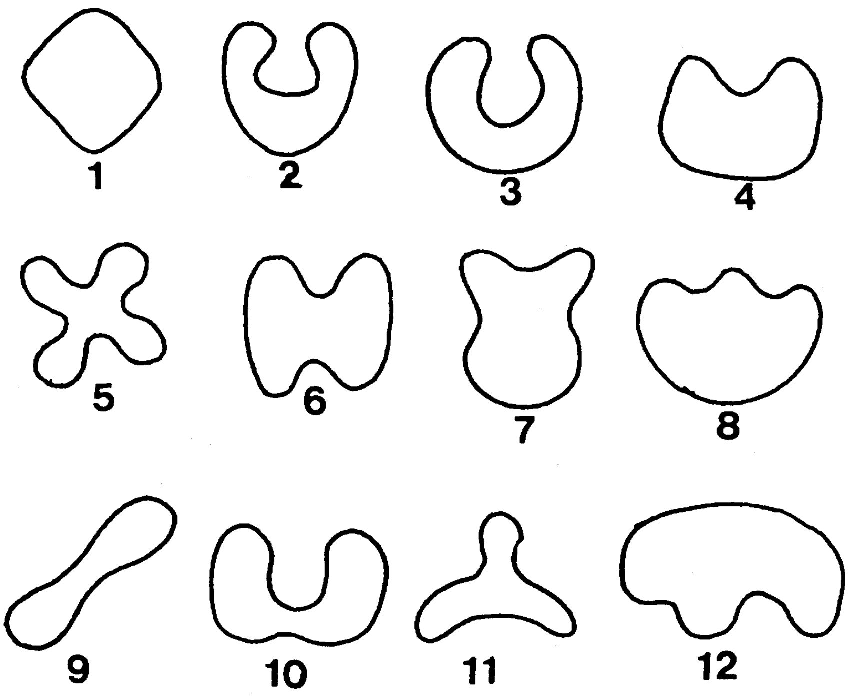

Figure 1 Shapes of 12 codons used in experiments as stimuli

The benefits of using codons as stimuli were as follows:
1) They are not easy for children to label verbally; 2) the 12 shapes selected for the present experiment were geometrically equivalent in a theoretically explicit sense; 3) because these shapes were drawn with a curved lines, with no corners, so the number of corners could not be a cue to memorization. Each codon had an ID number from 1 to 12 solely for the experimenter's convenience.

A codon quadruple was made of white plastic board, 0.7 cm thick and about 6 cm across. Each stimulus was stuck on a black paper panel (8 x 8 cm). Four of the twelve codon quadruples were chosen randomly to be target stimuli. Before this experiment, a preliminary discrimination test of these shapes was performed by 10 young children (aged 4years to 6years) visually and tactually to investigate the discriminability of all of these stimuli in young children. The subjects were tested by a within-modal matching paradigm; half of the12 codons visually, and the others tactually. The stimuli were presented randomly across the modality. The total number of trials (both visual and tactual, 60 trials each) was 120 and only three errors were made. Thus, these stimuli were discriminable by young children. Four small plastic dolls, "Kitty," "Frog," "Boy," and "Penguin", were used as symbol stimuli that were associated with the target stimuli.

For tactual presentations, the stimulus was presented within a 7 x 10 x 20 cm enclosed box. Each box contained an opening through which the subjects could manipulate the stimuli without being able to see it. The top of the box was covered with a white paper cup that was employed to hide the doll. For visual presentation, the stimuli were presented on these boxes directly in front of the child.

Procedure

The children were given 10 min. to become habituated to the testing room and the experimenter. All of the children received two tasks, V-V and V-T, or T-T and T-V. In other words, the children received single modality acquisition training (either V or T) and two modality recognition tests (both V and T). Two different delays (0-delay or 1-week-delay) were used.

Acquisition. In visual acquisition, a trial was initiated by putting the sample stimulus on top of the enclosed box and covering it by the cup. The experimenter then opened the cup and pointed to the doll, and told the child that Frog (one of the dolls) would always be associated with this shape. After about 10-sec. the sample stimulus was withdrawn, and two comparison stimuli were presented on each box. The child was required to choose the shape that was associated with the doll. If the child answered correctly, the experimenter gave a positive verbal feedback to the child. If the child made an error, the cup that held the doll (associated with the wrongly chosen stimulus) was opened and the doll was shown to the child. When the child was able to choose correctly for three consecutive trials, the experimenter began training with another shape. Thus, four of the twelve codons were used as target stimuli. When the child reached this criterion for all of the shapes, the acquisition session was over.

In tactual acquisition, a trial began when the child's right hand touched the sample stimulus in the box while looking at a doll in the cup. The stimulus was withdrawn after about 10-sec. for exploration. Two comparison stimuli were then presented. The child was required to manually explore each stimulus for 10-sec. successively and to point to the box that included a doll. The numbers of target stimuli, type of feedback, and criteria were the same as in the visual training. Children who could not explore well were shown how to touch the object by the experimenter.

Recognition test. After the assigned delay (0 or 1-week), all of the subjects underwent recognition tests (four trials because of the four target stimuli). Each subject underwent the test in two modalities; two tactual test trials and two visual test trials. In the recognition tests, the experimenter presented the doll in the opened cup on the box and asked "Do you remember this doll? What is its name?". When the child responded to such questions with something, for example, "Yes, it is penguin" or "No, I do not remember," the box was withdrawn and two boxes including codons were presented. The children were then required to explore each stimulus visually or tactually according to the experimental conditions and to point to the target stimuli that corresponded to the doll. During tactual exploration, children were allowed to touch the stimuli repeatedly. The same procedures were repeated for the other three target stimuli. Only one test trial was given for each target stimulus.

Results

The results of the recognition test are shown in Figure 2.

Although the subjects were divided into four groups, the results are shown according to the

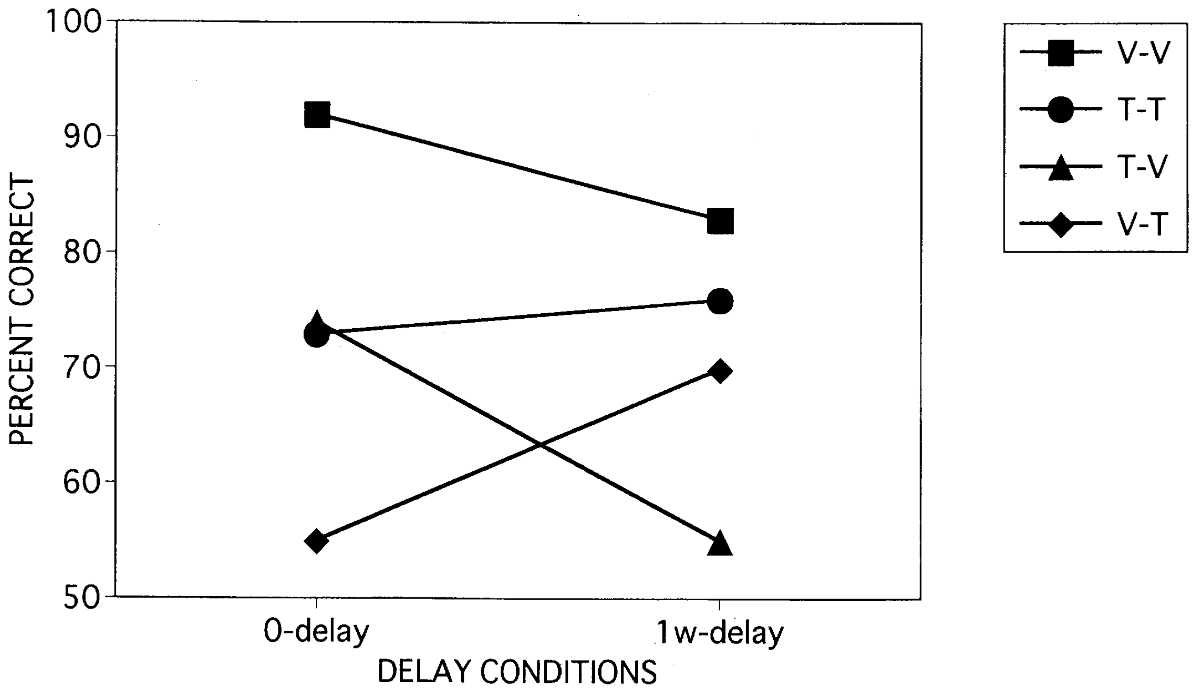

Figure 1 Results of recognition tests

experimental conditions.

Figure 2 shows that under the 0-delay condition V-V was the easiest, V-T was the hardest, and T-T and T-V were intermediate in difficulty. However, the order of difficulty changed with al-week delay. Furthermore, when the comparison modality was tactual, the percentage of correct responses was higher than that with 0-delay. These results are paradoxical, because the number of errors would, in general, be expected to increase with the length of the delay in ordinary memory experiments.

These results were subjected to a three-way analysis (Log-Linear-Model Analysis) in which the main terms were modality of standard (visual and tactual), modality of comparison (visual and tactual) , and delay (0 and 1-week). The interaction of Modality of standard x Modality of Comparison was significant (X=9.95, df=1, p 〈0.01). This indicated that the cross-modal condition was more difficult than the within-modal condition. The interaction of Modality of Comparison x Delay was also significant (X=4.19, df=1, p〉0.05). This appeared to be due to the fact that when the modality of comparison was visual, the tendency to make errors increased with a 1-week delay; however, when the modality of comparison was tactual, the performance after a 1-week delay was better than with 0-delay (see Fig. 2).

Discussion

There are three main results in this study. First, the average intramodal performance was superior to cross-modal performance in both 0-delay and 1-week delay conditions, which is consistent with previous studies. However, order of difficulty was different between the 0-delay and 1-week delay conditions. In the 0-delay condition, V-V was the easiest to remember, and T-T was easier than the V-T cross-modal transfer; although T-T was just as difficult as T-V transfer, T-V was easier than V-T. In contrast, with 1-week delay, the order of the task difficulty of T-V and V-T was reversed; i.e., there was cross-modal asymmetry which T-V was easier than V- T with 0-delay, while the direction of this asymmetry was reversed in with al-week delay. Finally, the performances in the T-T and V-T conditions with al-week delay were superior to those with 0-delay. In other words, when the modality of comparison was tactual, the performances with a 1-week delay were superior to those with 0-delay.

The relative difficulty of conditions with 0-delay was similar to those reported by Rose and Orlian (1991) in experiments with infants. T-T recognition was no more difficult than T-V cross-modal transfer, and was considerably easier than V-T recognition. However, with a 1-week delay, performance in the T-V cross-modal transfer was inferior to that in V-T transfer. Thus, the direction of asymmetry was reversed with time. Furthermore, when the modality of comparison was tactual, performance with al-week delay was superior to that with 0-delay, especially in the V-T condition. How do we interpret these results?

Cross-modal asymmetry may be caused by either failure to recognize equivalencies across modalities or difficulties in intramodal functioning (Rose & Orlian, 1991). In older children, failures in cross-modal matching are often attributed to intramodal difficulties in perceiving, encoding, and retaining tactual information. In our study, the subjects showed considerable intramodal transfer even in tactual conditions, as did the infants studied by Rose & Orlian (1991). Thus, it is unlikely that cross-modal difficulty depends only on intramodal difficulties.

Although the basis for cross-modal asymmetry is unclear, Rose and Orlian (1991) suggested some possibilities. One possibility is that the subjects sampled different characteristics of objects in each modality (Goodnow,1971). If the subject focuses on different characteristics of the objects under visual and tactual modalities, cross-modal matching depend on the overlap between the properties noticed during acquisition and testing (Rose & Orlian, 1991). Our subjects might have paid attention to the planar outline during visual acquisition and to curves and edges during tactual acquisition, since they were instructed to associate the shapes of the objects to the doll. During tactual acquisition, young children perceive shape partially. Several subjects were tested on whether they could draw a shape completely after tactual acquisition. Most of them could draw the shape partially correct, but not completely. Thus, they could only feel the shape partially, or in fragment. On the other hand, after visual acquisition, they could draw the shape almost perfectly.

A second possible explanation for cross-modal asymmetry is that the eyes and hands actually pick up the same properties, but the modalities differentially affect processing and storage (Rose & Orlian,1991). Fredes (1974) and Pick (1974) have suggested that visual information is maintained in its original code; while, tactual information is recorded via some system.

Again, how do we interpret our results? In our tasks, since young children were instructed to pay attention to the shapes of objects, may have tried to memorize the shapes. Therefore, they might have memorized the same properties during both visual and tactual acquisition. The relative difficulties of the V-T and T-V conditions were reversed after a 1-week delay. If modality-specific memory storage exists, then the memory in each modality (visual or tactual) which was coded during acquisition might have decayed differently with the different modalities. Performance may also depend on the balance between a change in memory and the perception of properties during the test-modality. For example, in the V-T condition, a great deal of information may have been noticed during acquisition, and it may have been confusing to match this to tactual information. One week later, however, the information from visual acquisition may match the level of tactual information because of moderate memory decay. On the other hand, in the T-V condition, young children notice enough information during tactual acquisition to match visual information with 0-delay. However, there may have been too little tactual information to withstand memory decay and be matched to visual information after one week.

Admittedly, all of these speculations are far from convincing, yet they raise the intriguing possibility that memory-transfer from short-term memory to long-term memory is qualitatively different between vision and touch.

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