A Brief Review of the Determinants of Memory Development and Application to Educational Situations

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Abstract

The purpose of the present study was to review the recent research on memory development for applications to educational situations. Recent studies of memory during childhood have indicated that the quantity, the quality, and especially the flexibility of memory strategies are critical for memory performance. Some research has stressed that the most critical factor is the use of a memory strategy which takes into account the resources or stage of development of an individual. Because effective memory strategies use more mental resources, there are fewer residual mental resources for remembering information about a target and therefore the memory of the target may be poorer. Memory strategies may be unsuitable for children, who have limited resources, but it may be possible to teach effective alternative strategies. It is critical to examine how to teach effective memory strategies taking into consideration of resources available to children.

1．Determinants of Memory Development

Numerous studies of memory development have been conducted on memory capacity, memory strategy, and metamemory. Recently, DeMarie and Ferron (2003) revealed a model for explaining memory performance across two groups of children, ages 5 to 8 years and 8 to 11 years. This model proposed that the most important factor for recall is memory strategy. Many studies have indicated that children do not use an optimal strategy for all types of memory tasks, but often apply several strategies to different types of memory task (Coyle & Bjorklund, 1997). The report of DeMarie, Miller, Ferron, and Cunningham (2004) has noted the variability in strategies used by children and that using multiple strategies led to better memory performance. Other research (Toyota & Morimoto, 2000, 2001) has also noted that children with high academic performance (good achievers) used many more memory strategies than poor achievers. In addition, a good achiever could assign an optimal strategy to each learning situation, e.g., reading, summarizing, or memorizing. These results suggested the importance of flexibility in selecting and using different strategies for different tasks. Unfort-unately, it is difficult to facilitate flexibility in selection of memory strategies; first, it is necessary to teach strategy variation, and to teach about the effectiveness of each strategy for remembering different types of information.

2．Use of Strategy and Resources

According to the model of DeMarie and Ferron (2003), it seems that an effective way to improve the memory performance of children is to teach them a single effective memory strategy. Generally, a memory task requires two responses: choice of a memory strategy and memorization of the target. Both components require learning resources or capacity (Kee & Davies, 1988). Because young children have fewer resources, they may not be able to allocate sufficient resources or capacity to both components of the task. If they are taught a strategy that requires more resources, they may allocate all their resources to the strategy, leaving too few resources for memorizing the target. Memory performance would then be poor, despite possible use of an effective type of strategy. This dual requirement of resources for the two components of a

task has been reported in studies about the elaboration of strategies for paired associate learning (Beuhring & Kee 1987, Kee & Davies, 1988). These research reports suggest that one must take into consideration the limited cognitive resources of children.

Recently, it has been proposed that the concepts of limited resources or limited capacity mentioned above should be modified to cohere with concepts regarding working memory (Baddeley & Hitch, 1974). Although working memory is not the same as cognitive resources, both similarly postulate a limited capacity to process the material to be memorized. Some investigations have assessed the working memory of young children by using a working memory test battery (Gathercole & Pickering, 2000). The structure of working memory and its development in children ages 4 to 15 years has also been investigated (Gathercole, Pickering, Ambridge, & Wearing, 2004). These reports indicated that the size of children's working memory should possibly be assessed in relation to various educational situations. One barrier to such measurement and assessment is that there are 13 different working memory tests (Gathercole & Pickering, 2000). Although research on the working memory of children is not reviewed here, clarification of the relationships among similar concepts, such as capacity, resources, and working memory is needed.

3．Metamemory in Older Children

According to previous studies (Flavell & Wellman, 1977, Schneider, 1985), metamemory consists of knowledge about: the memory demands required by different tasks; the limited capacity of the memory system to meet demands; and the alternative strategies which are available, taking into account the demands and limited capacity (Beuhring & Kee, 1987). The model of DeMarie and Ferron (2003) also illustrated that the effect of metamemory on recall depends on the age of the participants: the effect is greater for older children than for younger children. DeMarie and others (2004) also report that metamemory (ability to choose the most effective strategy for remembering material) is more important for older children, because they have to study more information about varied topics. It was proposed that the most important factor in memory performance is the ability to choose an effective strategy which takes into consideration the limitations of one's resources and the type of material to be remembered.

Stein, Bransford, Franks, Vye, and Perfetto (1982) trained poor achievers to use a particular memory strategy. In this training, the poor achievers were presented with a base sentence, e.g., "The hungry man got into the car," and they were asked to generate a sentence corresponding to an answer to a question, e.g., "Why did that particular man do that?" After being given all of the base sentences and generating the sentences, e.g., "to go to the restaurant," they were then asked to recall the target words, e.g., "hungry," in the base sentences. The investigators explained what type of generated sentence, that is, what type of answer to a "why" question, led to correct recall of a corresponding target. The relationship between the target word, e.g., "hungry," and an answer, e.g., "to go to the restaurant," is critical for the recall of each target. During these procedures the poor achievers noticed that a precise answer to a "why" question led to the correct recall of a corresponding target. After this training the poor achievers were able to generate precise answers and their performance in recalling targets was the same as that of good achievers. The poor achievers therefore understood that precise answers led to better recall. This understanding is an aspect of metamemory. Consequently, for young children, it is not sufficient to teach a strategy; they must experience that use of the strategy leads to better recall.

The more children experience that using a particular strategy leads to a successful performance, the more they use that strategy. This might involve a motivational factor. Recent research in Japan (Maki, Sekiguchi, Yamada, & Nedate, 2003; Toyota, 2006) showed that contingent experience, i.e., the experience that one's efforts lead to successful results, increases self-esteem and self-efficacy in interpersonal relationships. The same experience is needed in learning situations, i.e., that contingent experience using a new strategy leads to better performance. However, it is not known if an educational program providing contingent experience would be effective, or how such experience would be planned.

4．Providing Effective Context For Remembering

Although training metamemory is important, young children have limited resources for executing a strategy. Therefore, an effective situation or context for remembering the targets must be prepared.

4．1．Semantic constraints of context

Toyota (2000) examined the effects of semantic constraints of sentence frames on memory. In this study, the semantic constraints were manipulated in terms of interchangeability (Hall & Crown, 1970, 1972): two types of sentence frames were provided, interchangeable (weaker constraint) and non-interchangeable (stronger constraint). The interchangeable sentences were constructed so that the meaningfulness would be preserved if associates were substituted for the corresponding target words. For example, in the case of the target word "dark," and its associate "light," the sentence was "This room is dark." In a non-interchangeable sentence, a similar substitution of the associate for the target word would result in a less meaningful sentence, e.g., "Switching off makes dark" (Toyota, 1984). Undergraduate university students and children in Grades 2 and 6 studied targets embedded in interchangeable or non-interchangeable sentences, and then were given free recall tests. The undergraduates and Grade 6 students recalled the target words in non-interchangeable sentences more often than those in interchangeable sentences. But the difference effect between responses to the two sentence types was not as large for undergraduates. No difference between responses to the two sentence types was observed in Grade 2 children. These results mentioned above could be indicative of developmental changes in spreading activation in memory of targets with semantic constraints. In Grade 2 students there apparently was no difference in activation of targets between the two types of sentence. Grade 6 students could encode the target words using the stronger semantic constraints of non-interchangeable sentences, but Grade 2 students could not. For the Grade 6 students, the activation of the target words in the non-interchangeable sentences might have been greater than that in interchangeable sentences, and therefore more target words were recalled for non-interchangeable sentences. Undergraduate university students, in comparison, could use the weaker constraints of interchangeable sentences just as well as the stronger constraints of non-interchangeable sentences. They recalled the targets in interchangeable sentences equally well as those in non-interchangeable sentences. The activation of each target word in the interchangeable sentences was higher for undergraduates than for Grade 6 students. That the words in sentences with stronger semantic constraints were recalled more often supports previous research (Frase & Kammann, 1974; Battig & Einstein, 1977; Klein & Saltz, 1976; Stein, Morris, & Bransford, 1978; Toyota, 1984, 2000) and indicates that semantic constraints facilitate the recall of target words.

4．2．Syntactic constraints of contexts

Toyota (2001) used another manipulation of the contextual constraint. Three different types of sentences were used for each target, as in the following examples for the target word "elder sister." For a semantic and syntactic/congruous sentence, "Elder sister is a good friend to me" was used. For the semantic/incongruous and syntactic/congruous sentences, "Elder sister is my child" was used. It should be noted that this type of sentence has an odd meaning, but it is syntactically correct. For the semantic and syntactic/incongruous sentences, "Elder sister a good friend me is with" was used. This type of sentence is both grammatically incorrect and has no obvious meaning. The contextual constraint is strongest in the first sentence because there are both types of constraint: semantic and syntactic. The second type of sentence has less constraint than the first because this sentence has syntactic constraint only. The third type of sentence has very little constraint because there are no semantic and syntactic constraints on the context. University undergraduate, Grade 6 and Grade 2 students studied the targets embedded in these three types of sentences and then were administered tests of free recall and cued recall. Within each age group, although there were no differences in performances of the free recall by sentence type, differences were observed in cued recall performances. For Grade 5 and undergraduate students, the targets for both semantically and syntactically congruous sentences, and semantically incongruous and syntactically congruous sentences, were recalled more often than those for semantically and syntactically incongruous sentences. Among Grade 2 students, the targets in semantically and syntactically congruous sentences were recalled more than those in the other two sentence types. The observed differences in recall across age groups, indicated that constraint of semantic and syntactic congruity may affect the spreading activation of targets in memory. Providing strong constraints on the contextual meaning of targets seems to reduce the activation of a target so that the participant's cognitive resources can be shifted to

memorize the targets. In preparing effective educational materials, there is a need for research and development of materials with this type of control on contextual constraint.

5．Providing an Opportunity For Choice

Pressley, McDaniel, Turnure, Wood, and Ahmad (1987) provided base sentences containing arbitrary relations between a person and a behavior. Participants were exposed under one of two conditions. A base-questioned condition included a base sentence, e.g., "The hungry man got into the car," followed by an interrogative which needed elaboration, e.g., "Why did that particular man do that?" An imposed precise-elaboration condition involved a base sentence, e.g., "The hungry man got into the car," that was followed by a precise elaboration which clearly explained the significance of the action, and which was imposed by the experimenter, e.g., "The hungry man got into the car to go to the restaurant." Participants' performance responding to a "who" question, e.g., "Who got into the car?" was better when both incidental and intentional instructions were given in the base-questioned condition. That the based-questioned condition (self-generated elaboration) was superior to an imposed precise elaboration condition (experimenter-provided elaboration) is called the self-generated elaboration effect (Stein & Bransford, 1979) and has been observed in other studies (Stein & Bransford, 1979; Pressley, Symons, McDaniel, Snyder, & Turnure, 1988; Wood, Pressley, & Winne, 1990; Toyota, 1993). Toyota and Tsujimura (2000a) noted that although self-generated elaboration could be effective for encoding targets, sometimes participants had difficulty generating correct answers (i.e., precise elaborations) to an elaborative interrogative regarding the base sentences. It may be especially difficult for participants with fewer cognitive resources to use self-generated elaboration and per-formance would be concomitantly inhibited. Some studies have indicated that a failure to produce correct answers (precise elaborations) could be associated with a low recall performance (Pressley, et al., 1987, Pressley, et al., 1992).

Self-choice elaboration has been proposed by Toyota and Tsujimura (2000b) as a solution to the problem outlined above. This method required the participant to choose one of two alternative answers to the elabo-rating interrogative for each sentence. The results showed the superiority of self-choice elaboration to experimenter-provided elaboration. This superiority was called the self-choice elaboration effect, in which the words chosen by the participants were recalled more often than those chosen by experimenter. Previous studies examining the self-choice elaboration effect on memory have shown that available choices produced better memory performance. The self-choice effect has been reported in free recall tests (Watanabe, 2001; Hirano & Ukita, 2003; Watanabe & Soraci, 2004) and in recognition tests (Monty, Perlmuter, Libon & Bennet, 1982; Perlmuter & Monty, 1982). According to Perlmuter and Monty (1982), choosing an elaboration enhances motivation or attention (Monty, et al., 1982). Although motivation and attention are critical factors in research of the self-choice effect, the effect also has been interpreted in terms of the quantity and the quality of information retrieved from the knowledge bases of the individual participants. Specifically, self-choice elabo-ration led to a more precise elaboration than experi-menter-provided elaboration, because the participants were provided with an opportunity to choose the sentence with a target that could be integrated more easily into their peculiar knowledge base (Toyota & Tsujimura, 2000b).

Toyota and Tsujimura (2000a) indicated that a self-choice elaboration effect was found only for partici-pants who had low scores on the Information subtest of the Wechsler Adult Intelligence Scale-Revised. This result showed that the participants' knowledge, or crystallized intelligence as assessed by the Information subtest, was a factor in the effectiveness of self-choice elaboration. In other research (Toyota & Takaoka, 2001), a self-choice elaboration effect was observed in cued recall of targets rated by participants as difficult to encode. This result was interpreted as showing that encoding difficulty, was a separate factor in the effectiveness of self-choice elaboration. More interest-ingly, Toyota and Tatsumi (2003) showed that the self-choice elaboration effect among children occurred only for bizarre sentences. Because the target was incon-gruous in the context of the bizarre sentences, it was difficult to integrate the bizarre sentence frame into a cognitive structure. It was posited that Grade 2 students, with fewer cognitive resources, could not integrate the targets; but because Grade 6 students had more resources and more information as a basis for

integrating the targets into their cognitive structures, the sixth graders benefitted from the self-elaboration. In common (non-bizarre) sentences, children in both age groups were able to integrate targets into their cognitive structures, because the targets were meaningful in the common sentence frame. For this reason, self-choice elaboration effects for common sentences were not observed in participants of either grade.

Toyota and Konishi (2004) examined the effects of imagery in common and bizarre sentences on memory performance. "Image" and "no-image" sentence frames were used, the former being a sentence frame which arouses a vivid image, whereas the latter type does not. When participants chose the image sentence frame, two images corresponding to the two image sentence frames (common and bizarre) would be evoked. For Grade 2 students, with comparatively limited cognitive resources, the two images would interfere with each other and decrease the likelihood of retrieving the target. Toyota and Tatsumi (2003) demonstrated that for self-choice elaboration among Grade 2 students, by choosing one of the two bizarre-image sentence frames, e.g., "Baby drinks beer" vs. "Baby drinks wine", led to worse free recall than an experimenter-provided elaboration. Toyota and Konishi (2004) observed that only adults had better recall of targets with an image sentence and self-choice elaboration, rather than experimenter-provided elaboration. However, self-choice elaboration was superior in Grade 2 students only when they recalled targets with non-image sentences. An interpretation is that for Grade 2 students, an inhibition between two common images would occur because, due to their smaller processing capacity or resources, they could not simultaneously use two images as retrieval cues. In contrast, in Grade 6 students and adults, dual images could provide more effective retrieval cues for each target. In particular, adults could not only better use the two images as cues but also make the two images more vivid so that the best fit could be more easily selected. A vivid image would therefore be a more effective cue for retrieving a target. Taking into consideration the discussion outlined above, it is important for all with limited resources to be provided an opportunity for choosing or selecting the information about context.

6．Providing Opportunity For Correction

Craik and Tulving (1975) found a semantic congruity effect in which targets in a congruous context were recalled more than targets in an incongruous context. They interpreted the effect as follows. The targets in congruous contexts are integrated into a cognitive structure, and they are elaborated and recalled well. However, targets in incongruous contexts are not integrated into a cognitive structure and are not elaborated, and so performance of their recall is poor. This semantic congruity effect has also been observed in many other studies (Moscovitch & Craik, 1976; Goldman & Pellegrino, 1977; Toyota, 1996). However, if a target is presented in an incongruous sentence frame, and a participant corrects the target by replacing it with another word that fits the sentence frame, the replacement word should be integrated and elaborated. In this case, the target might also be recalled more effectively, because the target was elaborated by a replacement word that could serve as a retrieval cue. The target would effectively be elaborated with the replacement word. As an example of this, Toyota (2004) studied self-corrected elaboration. Participants were asked to elaborate the targets by generating congruous information as a replacement. Specifically, a target, e.g., "baby", may be an incongruous word in one context, e.g., "__drinks beer," but could be a congruous word in another context, e.g., "__ drinks milk." In the generated-correction condition, the participants generated a replacement word for the target within each incongruous sentence frame. In the chosen-correction condition, they were asked to choose one of the two replacement words for the target in each incongruous sentence frame. The targets in the generated-correction condition were recalled more often than those in a no-correction control condition, but no difference in recall performance between the chosen-correction and no-correction conditions was observed. Recently, Toyota (2007) has examined the developmental changes in the effects observed earlier (Toyota, 2004). In their investigation which examined whether the correction of misinformation influences anaphoric inference during reading, Johnson and Seifert (1998) indicated that although corrected, misinformation continued to influence the reading process. Some other studies (Wyer & Budesheim, 1987; Wilkes & Leatherbarrow, 1988; Johnson & Seifert, 1994) have also suggested that corrected information continues to influence later cognitive activity. As these studies suggested, the activity of correction is critical to reading. As mentioned

above, in some cases the influence of correction is negative, while in incidental memory the influence of correction may be positive.

Toyota (2007) compared the performance of Grade 2 and Grade 6 students for three types of elaboration. For Grade 6 students, self-corrected elaboration led to better free recall than the self-generated and the experimenter-provided elaborations, whereas for Grade 2 students, there were no differences in recall among the three types of elaboration. The effectiveness of a self-corrected elaboration seems to change with the participants' age. As Kail (1990) explained, Grade 6 students could use a replacement word to retrieve the class of a target and its sentence frame, using their rich knowledge and metamemory of an effective strategy. However, Grade 2 students have poor knowledge, weak metamemory (Flavell, Friedrichs, & Hoyt, 1970; Wellman, 1977; Goodman & Gardiner, 1981; Pressley, Levin, Ghatala, & Ahmad, 1987; Dufresne & Kobasigawa, 1989) and fewer cognitive resources, so they did not use replacement words effectively as retrieval cues. In the second experiment of Toyota (2007), participants were undergraduate university students. Using a longer word list, a difference between self-corrected and the self-generated elaborations was not observed; either one led to better free recall than the experimenter-provided elaboration. Undergraduates could not only use a replacement word, but also generate a word to retrieve a target and the sentence frame involving the generated word. This simply represents undergraduates' greater knowledge base, metamemory, and resources compared to school children. Usually the generated word has a strong association with each target. Therefore this word would facilitate retrieval of the target. A replacement word could be used by sixth graders to retrieve a sentence frame, especially when the presented word was incongruous, e.g., small, for the sentence frame. Because the replacement word would have a strong association to the target, the replacement word could be an effective cue for retrieval of the target. However, they could not use a generated word as a cue to retrieve the target, because they would not know that a generated word was an effective cue for retrieval, or they may not be able to use a generated word effectively. These results suggest that the activity of correction facilitates recall performance of the participants who have fewer resources (in these studies Grade 6 participants) to integrate the targets into cognitive structures.

7．Conclusion

The previous studies have highlighted that the strategy is the most important factor for recall and that metamemory is a critical factor in memory performance for older children. However, it is difficult to teach a strategy to children, particularly younger children because of their limited cognitive resources. The present study has proposed some methods or contexts to resolve this problem. Proposals include the provision of contexts with strong constraints, an opportunity for choice, and an opportunity for correction. These methods are expected to be supports for facilitating memory performance in children.

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