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ABSTRACT

Second graders (n=60) and adults (n=60 college students) solved word problems containing relevant information, irrelevant numeric information, and nonrelevant linguistic information. Recall and recognition tasks, along with cued and uncued word stem completion were used to test subjects' memory for relevant versus nonrelevant information. Recall and recognition data show that children inhibit irrelevant information less efficiently than adults do. Word stem data, however, show no such differences. Word problems were numeric irrelevant information were more difficult for children than relevant or linguistic problems, but there were no such differences for adults. Posing the question as the first sentence of the problem did not affect memory or solution accuracy for children, but degraded performance for adults. Memory for nonrelevant information was not related to solution accuracy. An appendix contains sample problems. (Contains 1 table and 39 references.) (SLD)

Running Head: MEMORY FOR IRRELEVANT INFORMATION IN WORD PROBLEMS

Differential Memory for Relevant and Irrelevant Information in Arithmetic Word Problems

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Abstract

Second-graders and adults solved word problems containing relevant information, irrelevant numeric information, and non-relevant linguistic information. Recall and recognition tasks, along with cued and uncued word stem completion were used to test subjects' memory for relevant versus non-relevant information. Recall and recognition data show that children inhibit irrelevant information less efficiently than adults do. Word stem data, however, show no such differences. Word problems with numeric irrelevant information were more difficult for children than relevant or linguistic problems, but there were no such differences for adults. Posing the question as the first sentence of the problem did not affect memory or solution accuracy for children, but degraded performance for adults. Memory for non-relevant information was not related to solution accuracy.

Memory for Irrelevant Information in Arithmetic Word Problems

This research is an attempt to explore how the efficiency of filtering out non-relevant information contributes to the accuracy of solving arithmetic word problems. Arithmetic word problems are more difficult for children to solve than mathematically equivalent numeric problems, especially if the word problems contain irrelevant information (Littlefield & Reiser, 1993; Muth, 1992). Research has shown that children may be less efficient than adults at inhibiting irrelevant information from working memory (Bjorklund & Harnishfeger, 1990; 1995; Harnishfeger, 1995; Harnishfeger & Pope, 1996; Lorsbach & Reimer, 1997). Although the potential relationship between efficiency of inhibition of irrelevant information and solution accuracy on irrelevant word problems has received little attention; Passolunghi, Cornoldi and deLiberto (1999) provide evidence that poor problem solvers recall more irrelevant information and less relevant information than good problem solvers

The hypothesis of this study is that children, as less efficient than adults at filtering out non-relevant information, will demonstrate comparable memory for relevant and non-relevant information; whereas adults will demonstrate significantly greater memory for relevant than for non-relevant information. Also, the likelihood of interference from non-relevant information supports a predicted negative relationship between memory for non-relevant information, and solution accuracy on arithmetic word problems containing non-relevant information. This research draws from two separate bodies of research; that on inhibition of non-relevant information, and that on arithmetic word problems.

The terms cognitive suppression and cognitive inhibition have not been explicitly distinguished from one another in the literature. Both are used to describe a cognitive process whereby non-relevant information is removed from or denied access to working memory. There is a distinction (Kane, May, Hasher, Rahhal & Stoltzfus, 1997; May, Kane & Hasher, 1995) between attentional inhibition, a forward-acting process, and episodic retrieval, a backward-acting process, although both processes produce negative priming effects. Whereas Harnishfeger and Pope (1996) conceive of cognitive inhibition primarily as a mechanism affecting retrieval, Kane, et al. (1997) conceive of cognitive inhibition primarily as a mechanism affecting attention. According to Hasher and Zachs (Hasher & Zachs, 1979), inhibition of non-relevant information can operate in three ways. First, the non-relevant information can be restricted from ever entering working memory, as demonstrated in studies of selective attention (e. g. Tipper, 1985). Second, the activation of non-relevant information within working memory can be dampened, as demonstrated in studies of cognitive suppression (e.g. Gernsbacher, Varner & Faust, 1990). Third, non-relevant information that has been encoded may be prevented from returning to working memory, as demonstrated in studies of directed forgetting (e.g. Harnishfeger & Pope, 1996; Lehman, McKinley-Pace, Wilson, Slavsky & Woodson, 1997). Inhibition has sometimes been considered to be an automatic, or pre-conscious process; and other time been considered to be an intentional, deliberate process (Harnishfeger, 1995).

Gernsbacher and Faust (1995) demonstrated that subjects, regardless of comprehension skill, activated all possible meanings of polysemous words, but skilled comprehenders quickly suppressed the non-relevant meanings. Gernsbacher (1993), and Gernsbacher, Varner and Faust (1990), found that more-skilled comprehenders suppress the activation of non-relevant meanings of ambiguous words so that they no longer cause interference; but less-skilled comprehenders retain the activation of non-relevant meanings, and continue to experience their interference in comprehension. This is consistent with earlier theories of selective attention (Neill, 1977; Tipper, 1985) which posit two mechanisms -- one for activation, which facilitates memory of selected information; and one for suppression, which inhibits memory of non-selected information. Relevant information therefore receives continuous activation, whereas the activation of non-relevant information is diminished.

There is a growing body of evidence for Bjorklund and Harnishfeger's (1990) hypothesis that inhibition of non-relevant information improves with development, so that older children experience less interference than younger children from task irrelevant information. With development, inhibition becomes more efficient, resulting in less irrelevant information entering working memory so that more resources are available for processing relevant information. Lorsbach and Reimer (1997), using a high-cloze sentence completion task, tested this hypothesis. Results indicated that second graders remembered more of the irrelevant information than the relevant information; sixth graders remembered the irrelevant and relevant information equally, and college students remembered more relevant than irrelevant information.

A similar result was found by Harnishfeger and Pope (1996), in a directed forgetting task using recall and recognition patterns to measure retrieval inhibition of to-be-forgotten words. Harnishfeger and Pope were concerned with demonstrating inhibition as a process by which retrieval of non-relevant information is blocked, as opposed to a process of selective attention, therefore block cueing was used instead of item cueing, to ensure that items to be remembered and items to be forgotten were equally encoded. College students and fifth graders efficiently inhibited non-relevant information, as evidenced by efficient forgetting of the to-be-forgotten items; but third graders showed weaker evidence of forgetting and first graders showed no evidence of forgetting.

In contrast, Lehman, et al. (1997) used an item-cued directed forgetting task, measuring inhibition of to-be-forgotten words through word stem completion; and found evidence of efficient retrieval inhibition for 3rd-graders, 4th-graders, and college students. It is possible, however, that the use of item-cueing allowed subjects to inhibit their memory for the to-be-forgotten items through selective attention or differential encoding processes.

Whichever process is used for filtering out non-relevant information: selective attention, differential encoding, or retrieval inhibition; the result should be decreased memory for non-relevant information as compared with relevant information. However, all non-relevant information is not alike. Some incoming information may be irrelevant at the outset, whereas other information my have been relevant at the outset, but become irrelevant due to a change in goals. It would be logical to expect that, in subjects who are efficient inhibitors, the former would be prevented form entering working memory, but the latter would be allowed to enter working memory but be inhibited once it had become irrelevant, then prevented from re-entering working memory.

The filtering out of non-relevant information is an important component in the creation of a mental representation. According to Gernsbacher's (1997a, 1997b) structure building framework, three processes occur during comprehension. Laying a foundation for the structure involves using the information presented in the first sentence of the text as a groundwork for the structure. Subsequent information is then mapped onto the foundation. When incoming information is non-relevant or incoherent, a new sub-structure is begin, marking a shift in comprehension. These processes occur via the two mechanisms of activation and suppression. Incoming stimuli activate a set of memory cells, and the spreading activation either enhances or dampens nearby cells. Suppression dampens the activation of cells representing the non-relevant information. If the structure building process is applied to arithmetic word problems, and the inclusion of non-relevant information causes the reader to construct a new sub-structure, it is obvious that the mental representation of an arithmetic word problem containing non-relevant information would necessarily be more complex that that of an arithmetic word problem containing only relevant information. In most word problems, the information that will be relevant to the problem's solution is determined by the problem question, which is conventionally posed as the last sentence of the problem. If the problem question were posed as the first sentence of the problem, the relevant information would be so designated at the outset, allowing for more efficient and more coherent structure building.

How a child approaches a particular word problem, both his choice of strategy and his level of success in problem solving, are directly related to how accurately he has created a mental representation of that particular problem (Kintsch & Greeno, 1985, Mwangi & Sweller, 1998). According to Kintsch's (1988) model of text comprehension, the reader constructs a mental representation of the text base incrementally. Each new increment is integrated into the existing representation. In the case of word problems, numeric information and information about units of measurement must also be encoded into the text base. From this text base, another level of representation, the semantic network representation, is created to represent the meaning of the text. The solver of word problems then creates a third level of representation, the mathematics-specific representation (Hegarty, Mayer, & Monk, 1995). The solution of the word problem is then calculated based on this mathematics-specific representation. As modeled by Kintsch, & Greeno (1985), the final representation involves three sets of knowledge: 1) the set of propositions which are constructed from the problem text, 2) the schema which represent sets and relations between sets and 3) the schema which represent arithmetic operations. Hegarty, Mayer & Green (1992) provided evidence that the difficulty of solving word problems is in the phases that involve comprehension of the problem.

How well children understand the problems they solve has consistently been found to be an important factor in how accurately they select problem-solving strategies. In several studies, re-wording problems to make the known and unknown quantities more explicit significantly improved performance by enabling the problem solver to select the correct problem-solving strategy (Bernardo, 1999; Davis-Dorsey, Ross, & Morrison, 1991; Fan, Mueller & Marini, 1994; LeBlanc, & Weber-Russell, 1996). For some problem types, the problem action can be easily demonstrated using manipulatives or pictures, thus enhancing the accuracy of comprehension. According to Carpenter and Moser (1983), one reason that some problems are more difficult is that the children have no available strategy for solving those problem types that cannot be directly modeled. Stern (1993) provided evidence that 1st grade children do not understand the symmetry of language, thus have difficulty translating the wording of inconsistent compare problem such as "There are n more x than y" into the mathematically equivalent language that may be more readily modeled, "There are n fewer y than x".

An alternative explanation for the difficulty of word problems involves the limited nature of working memory resources. However, Rabinowitz and Woolley (1995) found that the cognitive demands of comprehending the problem text, combined with the computational demands of solving the math problem did not overload working memory, as there was not a significant interaction between the effects of problem size and semantic type on solution accuracy. This is consistent with earlier research by Swanson, Cooney, and Brock (1993), in which there was not a significant interaction between working memory span and ability to classify word problems by semantic type. In discussing their results, Swanson, Cooney, & Brock consider the possibility that individual differences in cognitive inhibition weaken the relationship between working memory and problem solving, but note that their subjects' level of recall of non-relevant information from word problems was comparable to their level of recall on relevant information, which would not be predicted by a cognitive inhibition hypothesis.

Although there has been little research focused directly on word problems containing irrelevant information, two important ideas have emerged. First, telling subjects to look for irrelevant information seems to improve their solution accuracy. Second, all irrelevant information is not alike

Muth found that the presence of non-relevant information increased the difficulty of arithmetic problems for 6th graders (1984), and increased the difficulty of geometry problems for 8th graders (1991). However, when the 8th-grade subjects were told that "word problems sometimes contain numbers that are not needed to get the correct answer" (Muth, 1991, p. 173), their solution accuracy rates were similar on problem with or without non-relevant information. Low, Over, Doolan and Michell (1994) compared 11th-grade subjects' solution accuracy on problems that contained sufficient, missing or non-relevant information with similar results. Solution accuracy was lower for problems with non-relevant information than for problems containing only relevant information; but subjects who were cued to expect non-relevant information had significantly higher solution accuracy than subjects who were not so cued. Cueing subjects, however, did not improve their accuracy as much as training them to classify the problems.

The idea that all non-relevant information is not alike has been studied in various ways. Littlefield and Rieser (1993) used word problems that contained a non-relevant agent, a non-relevant action, or non-relevant objects, and all combinations thereof, to test 5th-grade subjects' ability to discriminate relevant from non-relevant information. As predicted, results indicated that word problems that included non-relevant information related to the same agent and non-relevant information related to the same action were most difficult; although the presence of any non-relevant information presented more difficulty than problems containing only relevant information. Also, subjects were more successful in discriminating the relevant information when it was presented first in the problem statement, rather than last. However, subjects were not required to solve the word problems.

Bachor (1989) varied the non-relevant information in word problems according to whether it was set-irrelevant, signaled by both a noun change and a verb change, or set-relevant, signaled by a verb change only. Sixth-grade subjects were presented with problems containing only relevant information, set-relevant information that was non-relevant to the problem solution, set-irrelevant information, and both of the latter information types. Problems containing both types of non-relevant were most difficult. Problems with set-irrelevant information were more difficult than problems with non-relevant information that was set-relevant, and problems with only relevant information were easiest.

Enlgert, Culatta and Horn (1987) used arithmetic word problems containing an irrelevant agent, irrelevant objects, non-relevant information that was non-numeric, and problems containing only relevant information. Solution rates of 2nd grade and 4th grade subjects, some learning disabled and some normal, indicated that, for all subjects, problems containing irrelevant objects were most difficult, and problems containing irrelevant agents were more difficult than problems containing only relevant information. However, problems with non-relevant information that was non-numeric were no more difficult than problems containing only relevant information. Taken together, these studies provide evidence that the effects of non-relevant information vary according to its position within the problem text; whether it is numeric or linguistic; and whether it is related to the agent(s), the object(s) or the action of the problem.

In this study, the nature of the non-relevant information has been controlled as follows: One third of the problems contain only relevant information, one-third contain numeric non-relevant information, and one-third contain linguistic, non-numeric non-relevant information. The non-relevant information is always presented in the last statement of the problem. In the canonical question-last problems, this statement precedes the problem question. In the non-canonical question-first problems, this statement is the last sentence of the problem. The non-relevant information is always of the irrelevant object type. For example, the following problems show irrelevant objects that are numeric, and non-numeric, respectively.

> Jackie heard 11 sneezes. She heard 4 more sneezes than Julie.
> Jackie heard 9 howls, how many sneezes did Jackie hear?
> Abby saw 5 monkeys at the zoo, She saw 3 monkeys on the ground, and the rest of them in trees. She saw some ponies, too. How many monkeys did Abby see?

In an arithmetic word problem, it is the problem question that designates which of the problem information is relevant to the problem solution. Therefore, if the problem question appears as the first sentence, rather than in the canonical position as the last sentence of the problem; the problem solver should be able to inhibit the irrelevant information from ever entering working memory.

The hypotheses of this study were as follows: (a) that adults will demonstrate greater memory for relevant information than for irrelevant information; whereas children will demonstrate similar memory for relevant and irrelevant information; (b) that non-relevant information that is non-numeric, hereafter called linguistic distracter information, will not increase problem difficulty, so that solution rates on linguistic distracter problems and relevant problems will not be significantly different; (c) that posing the question first in a word problem will aid in inhibiting irrelevant information, thereby facilitating solution accuracy, so that subjects will have significantly higher solution accuracy on question-first problems than on question-last problems; and (d) that more efficient inhibitors of irrelevant information will be more accurate solvers of word problems with irrelevant information, so subjects' solution accuracy on irrelevant problems will be significantly negatively correlated with their memory for irrelevant information.

In addition, this study uses two separate measures of memory, to enable further exploration of the question of whether irrelevant information is filtered at encoding, or at retrieval, for adults and for children. Differential encoding is measured by recall of relevant information versus recall of irrelevant information as compared with recognition of relevant information versus recognition of irrelevant information. If subjects recall significantly more relevant information than irrelevant information, and also recognize significantly more relevant information than irrelevant information, that is evidence of differential encoding. More relevant information is encoded than irrelevant information, thus more relevant information is present in memory.

If irrelevant information is filtered at retrieval, then the recall/recognition pattern will show greater recall for relevant information than for irrelevant information, but equivalent recognition of relevant and irrelevant information. If equivalent amounts of relevant and irrelevant information are encoded, but irrelevant information is subsequently suppressed, subjects will recall more relevant information than irrelevant, but recognize equivalent amounts.

However, because recall and recognition are both tests of explicit memory (Lehman, et al., 1997), evidence of inhibition of irrelevant information at retrieval will come from a word stem completion task in which subjects are randomly assigned to a cued or uncued condition. If relevant and irrelevant information are encoded similarly, but irrelevant information is subsequently suppressed, then explicit memory will contain more relevant than irrelevant information, but implicit memory will contain equivalent amounts of relevant and irrelevant information. Thus, subjects who complete a cued word stem task, a measure of implicit memory, should complete similar numbers of relevant target words and irrelevant target words; whereas subjects who complete an uncued word stem completion task should complete equal numbers of relevant and irrelevant target words.

Method

Participants

Participants were 60 college students (21 males, 39 females), recruited through their psychology classes at a small, Midwestern, private university; and 60 second-graders (30 males, 30 females) from a Midwestern, rural, public school district. The mean age of child subjects was 8 years, 4 months.

Materials

Arithmetic problems were constructed as sets of three problems, each containing a target word that was designated as relevant, irrelevant or linguistic distracter. The target words within each problem set used the same word stems in order to allow comparisons of word stem completion frequency. In addition to varying in information type (relevant, irrelevant, linguistic), problems varied in the position of the question (as first or last sentence of the problem), in arithmetic operation required, and in semantic structure (Carpenter & Moser, 1983).

Each subject solved 36 arithmetic word problems. Twenty-four of these were one-step problems for children, but two-step problems for adults. The first step of the adult problems required multiplication or division; the second step of the adult problems was identical to the one-step problems for children, which required addition or subtraction of single digits with sums ranging from 12 to 19. Twelve of these problems were change problems, and twelve were compare problems with consistent language. Six problems were identical for adults and children, and were one-step compare problems with inconsistent language. These problems were predicted to be difficult for children, but relatively easy for adults (Rabinowitz & Woolley, 1995). Finally, there were six change problems, with sums no larger than 6, to be solved by children only. These were predicted to be easy problems. There were six time/distance or work problems based on problems used by Nathan, Kintsch and Young (1992) to be solved by adults only. These were predicted to be difficult problems. Sample problems are provided in Appendix A.

The 36 arithmetic problems were arranged into 12 different presentation orders ensuring that the three problems within each set were solved on different days. In addition, each problem block included no more than one easy problem (for children) or difficult problem (for adults). Each problem block included at least two information types, and two arithmetic operations. Subjects were randomly assigned to presentation orders.

Procedure

Subjects met individually with the examiner. Adult subjects solved six word problems per block, and solved two blocks of problems on each of three days. Child subjects solved four word problems per block and completed one block per day. All subjects solved 36 word problems, with the exception of 2 adults who did not complete the study.

Each problem was printed on an 8 ½ x 5 ½ paper. Subjects were instructed to work the problems as quickly and accurately as possible, and to ask questions about any unfamiliar language. If children appeared to have difficulty reading the problems, they were asked to read the problem aloud so that the examiner could clarify any difficult words. If they had difficulty reading the problem aloud, the examiner read the problem aloud. After solving each block of problems, subjects were given a spatial reasoning task (Tiffin, 1969) to interfere with any rehearsal or recency effects.

This was followed by a word stem completion task. One-half of the subjects were randomly assigned to cued word stem completion, in which they were directed to think of words from the math problems they had just solved; the other half to uncued word stem completion, in which they were directed to write the first word that came to mind. For the child subjects, the examiner offered to assist with spelling if needed. The word stems to be completed were the stems of the relevant, irrelevant and linguistic target words from the arithmetic problems solved in that block, along with filler word stems. Word stems were arranged in a randomized order. Word stem scores were calculated as the number of completed stems that match the target words for each information type (relevant, irrelevant, linguistic), minus one-third of the number of correct words that do not match the target words. This scoring procedure spreads the adjustment for non-target words across the three information types (Lehman, et al., 1997). This yielded an adjusted word stem score for each information type.

Subjects were then asked to recall the problems they had solved. To elicit recall the examiner provided the names of the agents in each of the problems in the most recently solved block. For example, the examiner would say, "You solved a problem about Taylor, Hunter and Martha. Tell me that problem, or as much of it as you remember". In this manner, the examiner asked subjects to recall each of the word problems they had solved. If subjects were unable to recall any problem information, the examiner provided the numbers given in the problem.

Following recall, subjects were tested on their recognition of relevant, irrelevant and linguistic target words. They were directed to "look at each word presented and check yes if you saw that word in one of the math problems you just solved, and check no if you did not see that word in any of the math problems you just solved". Child subjects were told to ask about any words that they were unable to read. The recognition word list included the relevant, irrelevant, and linguistic target words present in the arithmetic problems solved that block, plus filler words.

Recognition scores were calculated as follows. First, the number of target words recognized was calculated for each information type - relevant, irrelevant and linguistic. Recognition errors were categorized as either "no errors", in which a target word was not recognized, or "yes errors", in which a non-target word was recognized. The effect of yes-errors was spread across the three information types, to yield an adjusted recognition score for each information type.

Results

Recall, recognition and word stem scores were calculated across the three information types. Descriptive statistics are presented in Table 1. A 3 x 2 x 2 x 2 (information type x question position x age group x cue condition) repeated measures MANOVA was conducted on the dependent variables of recall, recognition, word stem completion and solution accuracy. Results indicated a significant main effect of age group, Pillais' $F(4, 113) = 20.57$, $p < .001$, $\eta^2 = .42$; cue condition, Pillais' $F(4, 113) = 10.18$, $p < .001$, $\eta^2 = .27$; information type, Pillais' $F(8, 109) = 32.77$, $p < .001$, $\eta^2 = .71$, and question position, Pillais' $F(4, 113) = 3.94$, $p = .005$, $\eta^2 = .12$. There were also significant two-way interactions between age group and question position, Pillais' $F(4, 113) = 5.23$, $p = .001$, $\eta^2 = .16$; between age group and information type, Pillais' F

(8, 109) = 6.14, $p = .001$, $\eta^2 = .31$; and between age group and cue condition, Pillais' F (4, 113) = 6.08, $p < .001$, $\eta^2 = .18$. There were no other significant interactions.

Each of the significant two-way interactions included age group, so 3 x 2 x 2 (information type x question position x cue condition) repeated measures MANOVAs were conducted separately on adults and children. The results for adults indicated a significant main effect of cue condition, Pillais' F (4, 55) = 14.96, $p < .001$, $\eta^2 = .52$. Univariate testing on the effect of cue condition indicated that cued adults completed more target word stems than uncued adults, F (1, 58) = 49.21, $p < .001$, $\eta^2 = .46$. There was also a significant main effect of question position, Pillais' F (4, 55) = 8.05, $p < .001$, $\eta^2 = .37$. Univariate testing on the effect of question position indicated adults recognized more target words from the question-last problems than from the question-first problems, F (1, 58) = 5.55, $p = .022$, $\eta^2 = .09$; and adults had significantly higher solution accuracy on question-last problems than on question-first problems, F (1, 58) = 31.03, $p < .001$, $\eta^2 = .35$. There was also a significant main effect of information type, Pillais' F (8, 51) = 21.14, $p < .001$, $\eta^2 = .\ 77$. Univariate testing indicated that the information type had a significant effect on recall, F (2, 116) = 105.85, $p < .001$, $\eta^2 = .65$; on recognition, F (2, 116) = 30.15, $p < .001$, $\eta^2 = .34$; and on word stems, F (2, 116) = 4.35, $p = .015$, $\eta^2 = .07$.

Follow-up testing using paired-samples Bonferroni t-tests on the effects of information type indicated that adults recalled significantly more relevant target words than irrelevant target words, t (59) = 12.75, $p < .001$, $d = 1.71$, and recalled significantly more relevant target words than linguistic target words, t (59) = 13.04, $p < .01$, $d = 1.74$ but recalled similar numbers of irrelevant and linguistic target words. Adults recognized significantly more relevant target words than irrelevant target words, t (59) = 6.88, $p < .001$, $d = .87$ and recognized significantly more relevant target words than linguistic target words, t (59) = 6.21, $p < .001$, $d = .78$, but recognized similar numbers of irrelevant and linguistic target words. Adults completed significantly more word stems with relevant target words than with linguistic target words, t (59) = 2.67, p = .010, but there were no significant difference between the numbers of word stems completed with relevant target words versus irrelevant target words, or the irrelevant target words versus linguistic target words.

Results of the 3 x 2 x 2 (information type x question position x cue condition) repeated measures MANOVA on children only indicated a significant main effect of information type, Pillais' F (8, 51) = 20.53, $p < .001$, $\eta^2 = .76$. There were no other significant main effects. Neither were there any significant interactions. Univariate testing indicated that information type had a significant effect on recall, F (2, 116) = 33.71, $p < .001$, $\eta^2 = .36$; on recognition, F (2, 116) = 21.94, $p < .001$, $\eta^2 = .27$; on word stems, F (2, 116) = 18.68, $p < .001$, $\eta^2 = .24$; and on solution accuracy, F (2, 116) = 26.25, $p < .001$, $\eta^2 = .31$.

Follow-up testing using paired-samples Bonferroni t-tests on the effects of information type indicated that children recalled significantly more relevant target words than irrelevant target words, t (59) = 4.88, $p < .001$, d = .57; recalled significantly more relevant target words than linguistic target words, t (59) = 7.29, $p < .001$, d = .85; and recalled significantly more irrelevant target words than linguistic target words, t (59) = 3.98, $p < .001$, d = .47. Children recognized significantly more relevant target words than irrelevant target words, t (59) = 4.50, $p < .001$, d = .57; and recognized significantly more relevant target words than linguistic target words, t (59) = 6.74, $p < .001$, d = .94; but recognized similar numbers of irrelevant and linguistic target words. Children completed significantly more words stems with relevant target words than with irrelevant target words, t (59) = 3.97, $p < .001$, and completed word stems with significantly more relevant target words than linguistic target words, t (59) = 5.77, $p < .001$, but completed word stems with similar numbers of irrelevant and linguistic target words. Children had significantly higher solution accuracy rates on relevant problems than on irrelevant problems, t (59) = 6.58, p < .001, and significantly higher solution accuracy rates on linguistic problems than on irrelevant problems, t (59) = 4.77, p < .001; but similar solution accuracy rates on relevant and linguistic problems.

In order to analyze how individual differences in memory for irrelevant information relate to the efficiency of arithmetic word problems with irrelevant information, three measures of memory for irrelevant information were calculated for each subject. Memory-recall was calculated as the difference between recall of relevant information and irrelevant information. Memory-recognition was calculated as the difference between recognition of relevant information and irrelevant information. Memory-word stems was calculated as the difference between relevant target word stems completed and irrelevant target word stems completed. Each of these measures was then correlated with solution accuracy on the irrelevant problems. There were no significant correlations. In an attempt to partial out effects of overall math ability, partial correlations were calculated between each measure of irrelevant memory and solution accuracy on irrelevant problems, partialling out scores on relevant problems and linguistic problems. None of these partial correlations was significant.

Discussion

Adults did demonstrate greater memory for relevant information than for irrelevant information, both when memory was measured by recall and by recognition; but not when memory was measured by word stem completion. Children also demonstrated greater memory for relevant information than for irrelevant information; and did so regardless of whether memory was measured by recall, recognition, or word stem completion. The recall and recognition patterns provide evidence that both adults and children are differentially encoding irrelevant information. A comparison of the effect sizes for adults versus children provides evidence that adults are doing so more efficiently. Although children completed more relevant target word stems than irrelevant target word stems, there was no effect of cue condition; thus there is no evidence of retrieval inhibition for either children or adults.

Adults' memory for non-relevant linguistic information was similar to their memory for numeric irrelevant information across all measures of memory. This is evidence that adults differentially encode non-relevant linguistic and numeric irrelevant information in the same way. Children have similar memory for non-relevant linguistic and numeric irrelevant information when memory is measured through recognition or word stem completion; but children recalled less non-relevant linguistic information than numeric irrelevant information. This suggests that non-relevant linguistic information is the least salient in children's explicit memory. It is particularly interesting that children recall linguistic information in even lesser amounts than irrelevant information; but recognize similar amounts of linguistic and relevant information; whereas adults recall and recognize linguistic and irrelevant information in similar amounts. This may occur because children are more inclined to perceive the numeric irrelevant information in a word problem as relevant, and therefore not filter that information. This suggests that different types of non relevant information may be filtered through different mechanisms, and that the nature and efficiency of inhibition may be influenced by both the type of the non-relevant information and the age of the subjects.

Posing the problem question as the first sentence of the word problem, rather than in the canonical position as the last sentence, did not facilitate memory; nor did it facilitate solution accuracy. For adults, posing the question first had the opposite effect – it degraded both their recognition of target words, and their solution accuracy. Question position had no effect on children's performance. The degraded performance of adults on question-first problems may be attributable to the adults' expectation that the problem question would appear as the last sentence of the problem. Adults may have experienced some confusion when the problem question appeared in an unusual place. Children, having less experience with word problems, would have experienced no such confusion.

Although it would be logical to assume that efficient filtering of non-relevant information would be related to solution accuracy on arithmetic word problems containing irrelevant information, this data shows no such relationship. There is evidence that adults are more efficient at children at differential encoding of irrelevant information, and that adults are more accurate in solving arithmetic word problems with irrelevant information, but those two characteristics appear to be unrelated.

Based on this study, there is no reason for educators to delay the introduction of word problems containing irrelevant information. Although those problems are more difficult for children than relevant word problems, there is no evidence from this data that the ability to solve irrelevant word problems is related to the development of ability to efficiently inhibit irrelevant information. Problems containing non-relevant linguistic information are not as difficult as problems containing numeric irrelevant information, thus linguistic problems may be a useful tool for helping children learn to consider which elements of a word problems are and are not relevant. For children, posing the question first did not facilitate solution accuracy, but neither did it degrade solution accuracy. This suggests that a teacher may experiment with posing the question first, without thereby making the problem more difficult to solve.

Why are arithmetic word problems containing irrelevant information so difficult for children? According to this data, the answer to that question is not because of inefficient inhibition of irrelevant information. The question remains unanswered.

Further research should continue to explore the mechanisms by which irrelevant information is filtered, and the developmental nature of memory for irrelevant information. It is also critical that research is directed at exploring classroom applications of cognitive research. This study underscores the fact that a potential classroom application which may be logical, may not, in fact, be warranted.

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Table 1: Mean Percent

Dependent Variable	Relevant QL	Relevant QF	Irrelevant QL	Irrelevant QF	Linguistic QL	Linguistic QF
Adults						
Recall	59	55	24	25	26	21
	23	*26*	*20*	*21*	*23*	*21*
Recognition	64	63	50	45	51	45
	24	*25*	*28*	*26*	*29*	*27*
Word Stems Cued	46	44	37	36	36	37
	26	*26*	*22*	*25*	*21*	*22*
Word Stems Uncued	20	24	19	19	15	16
	18	*19*	*16*	*13*	*15*	*18*
Solution Accuracy	89	70	83	70	86	70
	25	*19*	*27*	*21*	*26*	*18*
Children						
Recall	63	60	46	50	37	41
	24	*21*	*27*	*30*	*27*	*25*
Recognition	74	75	63	63	53	63
	18	*20*	*24*	*27*	*26*	*27*
Word Stems Cued	32	37	19	22	14	20
	15	*17*	*21*	*24*	*14*	*19*
Word Stems Uncued	26	24	21	17	17	18
	20	*19*	*17*	*14*	*16*	*17*
Solution Accuracy	81	77	60	62	74	75
	20	*25*	*31*	*32*	*23*	*23*

Note: Standard Deviations appear in italics.

APPENDIX A: Sample Problems

Relevant problems

For adults: Doug got 35 robots. Dan got one-fifth as many robots as Doug. Then Dan got 5 more robots. How many robots were does Dan have now?

For children: Dan got 7 robots. Then Dan got 5 more robots. How many robots does Dan have now?

Irrelevant problems

For adults: Nancy has 121 pencils. Fred has $1/11^{th}$ as many pencils as Nancy. Lynn has 3 fewer pencils than Fred. Lynn has 6 marbles. How many pencils does Lynn have?

For children: Fred has 11 pencils. Lynn has 3 fewer pencils than Fred. Lynn has 6 marbles. How many pencils does Lynn have?

Linguistic problems

For adults: Sam had 36 toads. Dirk had one-fourth as many toads as Sam. Alex had 3 more toads than Dirk. Alex had some milk. How many toads did Alex have?

For children: Dirk had 9 toads. Alex had 3 more toads than Dirk. Alex had some milk. How many toads did Alex have?

Easy problem for children only

On Halloween, Sadie saw 1 kitten. Then she saw 5 more kittens. She saw 2 devils. How many kittens did Sadie see in all?

Difficult problem for adults only

If Tina and Kelly work together, how long will it take to mow the lawn? Tina can mow the lawn in 6 hours and Kelly can mow the lawn in 3 hours. They both work in aprons.

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