COGNITIVE STRATEGIES:

GOOD STRATEGY USERS COORDINATE METACOGNITION AND KNOWLEDGE

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For the past three decades, many cognitive researchers have busied themselves studying cognitive strategies. The vast preponderance of this research was concerned with single processes (e. g., rehearsal, clustering, imagery) in limited learning domains (e. g., list learning, paired-associate acquisition, prose recall). More recent investigations have zeroed in on other factors, such as metacognition and schematic knowledge. It was apparent by the mid-1970s that just being able to execute a variety of cognitive processes was not sufficient to be considered a good strategy user, and that strategic, metacognitive, and knowledge variables were related in complex ways (e. g., Brown, Bransford, Ferrara, & Campione, 1983; Pressley, Heisel, McCormick, & Nakamura, 1982; Pressley, Forrest-Pressley, Elliott-Faust, & Miller, 1985). The Good Strategy User (GSU) model presented here was motivated to capture these skills and knowledge as they are coordinated by capable thinkers.

There are five components of good strategy use: (1) A sophisticated thinker has many strategies that can be tapped, some general, some specific, but all useful for obtaining goals. (2) The GSU knows how, when, and

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where to apply each of these various techniques. (3) The GSU possesses the general understanding that good performance is tied to effort, particularly effort expended in carrying out appropriate strategies. They also know that in general, strategic actions are most likely to be successful if strategies are shielded from competing behaviors, distractions and emotions. (4) GSUs have non-strategic knowledge about the world (i. e., that includes many domains from the alphabet to Gary Carter's batting average). When activated, domain-specific knowledge often makes strategy use unnecessary, prompts the use of a strategy that the learner might not think of otherwise, and improves the efficiency of strategy execution. (5) GSUs have automatized the first four components and their coordination.

The importance of strategies, metacognitive knowledge about specific strategies, general strategic tendencies and general strategic knowledge, the thinker's nonstrategic knowledge base, and automaticity will become clearer as each component in the Good Strategy User is reviewed in detail. What we attempt here is to abstract a framework that is more than any of its components due to complex interactions between the individual pieces. These interactions are taken up at appropriate points in the discussion of each component. We first discuss the role of specific strategies from the perspective of the GSU model.

SPECIFIC STRATEGIES

There are three broad categories of specific strategies. There are a variety of *goal-specific strategies* for different types of memory, comprehension, and problem-solving tasks. *Monitoring* strategies are responsible for regulation of goal-specific strategies. The individual procedures suitable for achieving performance goals are often combined by *higher-order sequencing strategies.*

Goal-Specific Strategies

A GSU knows how to execute a variety of goal-specific strategies. Although debate continues about the fundamental nature of such strategies, (Pressley, Forrest-Pressley, & Elliott-Faust, in press), there are certain features that are indisputable. The aim of a strategy user is always to accomplish a purpose beyond simple execution of a strategy, such as understanding a passage, learning materials for later recall, communication, or finding the answer to a problem. Strategies are operations over and above the processes that are a natural consequence of doing a task. Thus, simply turning a page or looking at text do not qualify as reading strategies.

The most controversial definitional issue concerns whether strategy execution requires conscious intention (cf., Paris, Lipson, & Wixson, 1983). We believe, as do other strategy researchers (e.g., Zembar & Naus, 1985a), that rigid adherence to conscious intentionality as an attribute of strategic behavior would result in many behaviors long considered strategic to be classified as nonstrategic (e.g., the automatic sophisticated processing of a text by good readers). Strategies are, however, almost always *potentially conscious* (e.g., skilled readers can stop and think about their strategic re-readings) and *potentially controllable* (e.g., good readers can re-read parts of text that they fail to comprehend, if they choose do to so). See Searle (1980) for a thorough analysis of intentionality as an attribute that is often unconscious and not the principal motivation for actions that accomplish goals. We emphasize that this conception of a strategy is conservative. It is very similar to Miller, Galanter, and Pribram's (1960) cognitive plans, which are often executed unconsciously. Belmont (1984) provides interesting commentary on the similarity of cognitive strategies to cognitive plans.

As their name implies, most goal-specific strategies are domain specific. For instance, memorization strategies include rehearsal of to-be-learned materials (e.g., Flavell, 1970), grouping organizable materials into clusters that "go together" because of semantic interrelationships (e.g., Moely, 1977), and making to-be-associated materials more learnable by creating relations (e.g., elaborations) between the separate elements that are to be linked (Pressley, 1982; Rohwer, 1973). Reading comprehension strategies include note taking, summarizing, underlining, and answering adjunct questions. There are also a number of goal-specific strategies for generating solutions to problems (Gagne, 1985, Chapter 6; Polya, 1973, 1981). For instance, when one knows little about a domain, reasoning by analogy from areas that one does know about is often helpful (e.g., Gick & Holyoak, 1980, 1983; Polya, 1954a, 1954b). Another form of expansion is brainstorming (Osborn, 1963), which involves generating as many solutions as one can think of, with criticism of the potential solutions suspended until after a large number of candidate solutions are generated. The best ones are then selected for further consideration.

In short, there are many different goal-specific strategies that GSUs can apply to a variety of content areas ranging from school-like cognitive tasks such as mathematical problem solving, (e.g., Carpenter, Moser, & Romberg, 1982; Ginsburg & Allardice, 1984) to mastering physical activities such as complex motor skills and sequences (e.g., Burton, Brown, & Fischer, 1984). Pressley and Levin (1983a, 1983b) and Pressley, Heisel, McCormick, and Nakamura (1982), have provided extensive reviews of the many goal-specific strategies.

Monitoring Strategies

Monitoring has been studied most extensively in a paradigm developed by Markman (1977, 1979). In the Markman studies, children heard prose passages that included inconsistencies, but often failed to note them; an outcome interpreted as a failure to monitor comprehension of the passage. In followup experiments, children were presented passages containing nonsense words, anomalous sentences, internal logical contradictions, and content that clashed with world knowledge (Baker, 1985b; Wagoner, 1983). In general, children often fail to notice these types of problems in text, but it should be emphasized that adults do not monitor their comprehension completely either (e.g., Baker, 1979; Baker & Anderson, 1982; Epstein, Glenberg, & Bradley, 1984; Glenberg, Wilkinson, & Epstein, 1982; Tikhomerov & Klochko, 1981).

Monitoring has also been studied in other paradigms, although not as extensively. For instance, Shaughnessy (1981) came to the counterintuitive conclusion that mature learners do not monitor differences in learning produced by different strategies that they are executing while studying. Intrigued by Shaughnessy's conclusion, Pressley, Levin, Ghatala and their associates (see Pressley, Forrest-Pressley, Elliott-Faust, & Miller, 1985, for a review) carried out a number of experiments in which learners used strategies that differed in potency. These investigators produced data substantiating that neither children nor adults accurately monitor differential strategy effectiveness *while executing strategies* (Pressley, Levin, & Ghatala, 1984). In addition, there is a growing body of data suggesting that learners are not good at monitoring the probability that they will remember text that was recently studied (Glenberg & Epstein, 1985; Maki & Berry, 1984; Pressley, Snyder, Levin, Murray, & Ghatala, in press).

Repeated demonstrations of monitoring inefficiency have resulted in a number of studies aimed at improving monitoring skills, most conducted within the error detection paradigm. There are now many demonstrations that children's monitoring can be improved with brief instruction. One especially inexpensive approach, in terms of instructional resources, is simply to make clear to subjects what constitutes a sensible passage versus an inconsistent passage. Markman and Gorin (1981) were the first to demonstrate that providing an appropriate standard of evaluation increases children's comprehension monitoring skills. Baker (1984a, 1984b, 1985a) extended Markman's and Gorin's finding, demonstrating that detection of lexical problems in text (i.e., use of nonsense words), detection of internal inconsistencies, and detection of external inconsistencies (i.e., violations of world knowledge) can be increased by instructing subjects to look for these problems and briefly explaining the nature of these difficulties.

Other training approaches work as well. Capelli (1985) reasoned that many monitoring errors were due to incomplete text processing. That is, children typically fail to use inferential, constructive processing commonly employed by adults. Third- and sixth-grade children were trained to generate and evaluate hypotheses as they read through texts. Trained children detected more inconsistencies than untrained children. Elliott-Faust and Pressley (1986) taught children to compare the meaning of each sentence as it was processed to the meaning of the immediately preceding sentence and to the meaning of the passage as a whole. Comparison training increased third graders' error detection skill. In short, there is considerable evidence that monitoring can be trained in error detection tasks.

Because monitoring plays an important role in good strategy use, is generally underdeveloped, and can be improved through simple instructions, it should be an important target for additional research. There are many potential instructional tactics. Children can be explicitly instructed to keep track of their ongoing performance and check their progress toward cognitive goals (e.g., Leal, Crays, & Moely, 1985). They can also be taught explicit counting strategies or external recording techniques to supplement internal monitoring processes (Pressley, Levin, Ghatala, & Ahmad, in press).

Despite our rather negative protrayal of children's spontaneous monitoring, there are occasions when even very young children detect that their cognitions are a bit off. This type of monitoring leads to strategy initiation and modification—children monitor some errors in speech, some problems of listening comprehension, and some errors while doing calculations (e.g., Evans, 1985; Revelle, Wellman, & Karabenick, 1985; Speer, 1984; Wilkinson, 1982). One important hypothesis is that children monitor effectively given very familiar tasks and familiar settings (e.g., Bronfenbrenner, 1977; Ceci & Bronfenbrenner, 1985). Understanding when young children monitor and appropriately shift strategies and when monitoring breaks down should be a high priority for future research.

There are two important outcomes that follow from monitoring. (1) Use of a particular strategy can be continued, terminated, or modified in light of the consequences produced by the strategy. This on-line decision making is the most frequently discussed role of monitoring (e.g., Davis, 1983; Krashen, 1978; Levelt, 1983). (2) Strategy knowledge can be enhanced. This second product of monitoring has potential for permanent effects on learning ability. When children actively monitor strategy implementation and performance, they can increase understanding of how to use the strategy and the benefits gained from it. In this sense, monitoring procedures are *metacognitive acquisition procedures* (Pressley, Borkowski, & O'Sullivan, 1984, 1985). Metacognitive acquisition procedures take other cognitive procedures (in this case, strategies) as their input and yield additional information about important strategy attributes. This information can be coded permanently as either general or specific strategy knowledge, both major components of monitoring that are covered later in the chapter.

High-order Strategies

GSUs rarely execute goal-specific or monitoring strategies in isolation. Instead they carry out a sequence of strategies. Planful sequencing is a strategy itself—a higher-order or metastrategy, in Chi's (1981) terminology. Planned sequences of strategies include both goal-specific and monitoring strategies. Brown, Bransford, Ferrara, and Campione (1983) refer to planned sequences of cognitive strategies and monitoring as self-controlled strategy use. Some of the best known self-controlled strategic sequences follow from Meichenbaum's (1977) theoretical position. Two examples derived from Meichenbaum's analyses illustrate the interweaving of higher-order planning, goal-specific strategies, and monitoring.

Bommarito and Meichenbaum (1978) designed an intervention to enhance children's reading comprehension. Seventh and eighth grade poor readers were instructed to use a series of cognitive strategies in a particular order with monitoring components intertwined. They were taught to remind themselves at the outset of reading to (1) discover the main idea of the story, (2) to learn important details of the story, (3) to learn the sequence of events, and (4) discover how the characters feel and why. As reading proceeded, subjects were taught to pause and think about what they were doing. They were also taught to monitor whether they were in fact discovering the main ideas, details, sequences, and feelings of the characters. They instructed themselves to keep trying, and to keep cool, calm, and relaxed. The self-controlled strategic sequence proved successful relative to a placebo control treatment.

A second example of integrated self-control training was provided by Harris (in press). The subjects were normal and learning disabled seven and eight year olds. The task given to the children was to assemble a difficult puzzle, made more difficult by rigging a major piece so that it would not fit. A main goal of the study was to increase the children's persistence and strategy use while working on the puzzle. Harris (in press) embedded specific strategies in a sequential cognitive plan. The plan specified that the subject should identify the problem early and should execute strategies such as turning the colored pieces of the puzzle up before beginning, turning the pieces to the correct orientation (i.e., body parts and letters in the puzzle go right side up), and matching the puzzle parts off the board before placing them on the board. Subjects were also taught to evaluate their performances as they went along and self-reinforce themselves when they were making progress (i.e., they were taught to monitor).

The main result of interest here was that persistence at the task generally increased following training to use the integrated sequence.

What are the essential attributes of a good sequence of strategies and how does one go about constructing it? Most importantly, it must accomplish the intended cognitive purposes. To design sequences that do so, thorough task analyses are essential (e.g., Butterfield, Siladi, & Belmont, 1980; Gagné & Briggs, 1979). Task analysis identifies the processes that are sufficient and necessary to accomplish the task or solve the problem. The higher-order strategies integrate these sufficient and necessary processes so that they are carried out in an efficient fashion, consuming as few intellectual resources as possible. Efficiency is important given the limited processing capacity of working memory (e.g., Kahneman, 1973). A common way to engineer a complex strategy so as to make it compatible with limited capacity is to sequence operations so that only a small part of the cognitive plan occupies working memory at any given time. These attributes of a good higher-order sequence can be illustrated by recent work on referential communications.

A typical referential communications task requires a child to confront an array of similar items—nonsense figures, colored geometric shapes, or words. The goal is to provide word clues so that another person can decide which of the objects is the referent. Careful task analyses of such clue generation have been conducted (e.g., Higgins, Fondacaro, & McCann, 1981; Rosenberg & Cohen, 1966), suggesting three essential processes that need to be executed sequentially: (1) Communicators should *generate* an associate to the referent. (2) They should *compare* the candidate clue to the referent and nonreferents to determine the extent of association to the two types of items. (3) Communicators should then *evaluate* whether a candidate clue has greater association with the referent than with any of the nonreferents. Without instruction, children do not execute this sequence of behaviors. Typically, they generate an associate to the referent, but fail to compare and evaluate the clue.

In a now classic study in the communications literature, Asher and Wigfield (1981) studied the effects of training children to evaluate clues. Word pairs were presented to third- and fourth-grade children (e.g., piano-violin). The task was to communicate to an imaginary listener which of the two words was the underlined referent. Children viewed a filmed model who produced clues with the evaluation component emphasized in modeling. The child and model alternately produced clues for a total of 20 training pairs. The children were provided feedback as to the adequacy of their clues. Over the course of practice trials, modeling was reduced to covert clue evaluation with children encouraged to do their evaluations silently. Trained children provided better clues on the post-training communication task than control children exposed to the practice pairs, but given no training, although positive effects were restricted to the pairs that adults found to be easy. This was a somewhat disappointing result compared to the goal of generally improving referential communications through strategy training.

Elliott-Faust, Pressley, and Dalecki (1986) hypothesized that the problem with Asher's and Wigfield's training was that it emphasized only evaluation, leaving comparison to inference (despite Asher's and Wigfield's use of the term comparison training to describe the instruction employed in their study). Elliott-Faust et al.'s (1986) experiment was aimed at determining whether adding comparison training to instruction would lead to more generally positive effects, as would be expected if the task analysis discussed earlier is correct.

There were three training conditions in Elliott-Faust et al. (1986). *Comparison emphasis* subjects were told to compare potential clues to referents and nonreferents. Instruction in the *evaluation emphasis* condition was similar to Asher and Wigfield's (1981) instruction. In the *complete instruction* condition, subjects were taught to use both the comparison and evaluation strategies after a candidate clue was generated. The experiment also included two control conditions, including one very similar to the control condition used by Asher and Wigfield (1981).

Although all three training conditions produced improved clue generation for easy items, only the complete instructions resulted in significantly better clue production for items with less obvious clues. In summary, unambiguous effects occurred only when children were instructed to carry out the sequence of processes specified by the task analyses.

It should be apparent from the discussion of higher-order processes that higher-order planning and sequencing strategies do not occur in isolation. They always integrate lower-level processes. It is not surprising that a number of recent reviews of the self-control literature have concluded that higher-order sequencing components are critical to effective execution of complex sequences (Brown, Bransford, Ferrara, & Campione, 1983; Cohen & Meyers, 1984; Deshler, Warner, Schumaker, & Alley, 1983; Meichenbaum, 1977; Meichenbaum & Asarnow, 1979).

SPECIFIC STRATEGY KNOWLEDGE

How, When, and Where to Use Strategies

Human beings have complex networks of knowledge about how, when, and where to carry out multiple actions (e.g., Cantor, Mischel, & Schwartz, 1982). Such is the case with strategic actions. Without specific strategy knowledge, a critical part of metamemory, a person could not recognize when to apply a strategy (Pressley, Borkowski, & O'Sullivan, 1984, 1985).

Specific strategy knowledge can be acquired from encounters with a variety of strategies, an assumption supported by experiments demonstrating that people abstract knowledge about strategies as they use them (e.g., Lewis & Anderson, 1985; Pressley, Levin, & Ghatala, 1984), and by development of artificial intelligence programs that detect rules which are helpful for solving particular problems (see Langley, 1985, for a recent example and a review). Abstracting information from strategy encounters, however, does not always occur automatically. Sometimes learners need to be taught how to monitor their use of strategies, as well as learn how to encode specific strategy knowledge that is abstracted from the situation (Lodico, Ghatala, Levin, Pressley, & Bell, 1983). The alternative to learners detecting specific strategy knowledge is for external agents to provide it (Belmont, Butterfield, & Ferretti, 1982). For instance, a strategy is better maintained following training if the strategy instructions include explicit statements that the use of the strategy affects performance in an important way (e.g., Black & Rollins, 1982; Borkowski, Levers, & Gruenenfelder, 1976; Cavanaugh & Borkowski, 1979; Kennedy & Miller, 1976; Lawson & Fuelop, 1980; Ringel & Springer, 1980). See Pressley, Borkowski, and O'Sullivan (1984, 1985) for detailed commentary on how to increase specific strategy knowledge.

The effects produced by specific strategy knowledge have been established most clearly in the context of true experiments. For instance, O'Sullivan and Pressley (1984) conducted a within-experiment analysis of the effects of adding specific strategy knowledge over and above the information that use of a particular trained strategy improved learning. It was hypothesized that adding information about how and when to use a strategy would increase transfer of the keyword method. Children in grades 5 and 6 were presented two memory tasks during the study, first learning city-product pairs and then the meanings of Latin vocabulary. Control subjects learned both sets of materials without strategy instructions. Subjects in four other conditions were taught to use the keyword method with the city-product pairs, with keyword instruction varying between conditions in the amount of "when" and "where" specific strategy information that was included. In general, more detailed information about the keyword strategy during city-product learning increased transfer of the keyword method to learning of Latin vocabulary, which were presented with only the instruction to learn the meanings of the vocabulary items. Although O'Sullivan's and Pressley's (1984) results permitted the conclusion that adding specific strategy knowledge increases generalized use of a trained strategy (see Heisel & Ritter, 1981, for data corroborating this point), much more work is needed to determine which aspects of specific strategy knowledge are particularly critical to transfer and to document exactly how information about a newly acquired strategy is represented in memory.

Motivational and Strategy-Attributional Strategy Knowledge

One aspect of specific strategy knowledge that is particularly critical for effective strategy use is that learners must know when their success is due to appropriate strategy use. They must also understand that some failures could have been avoided if they had used more appropriate strategies. These types of attributions about the specific causes of success and failure are coded into Specific Strategy Knowledge. For instance, author MP has observed many adult learners in his laboratory who know that their good performance on associative tasks following keyword method instruction is due to use of the keyword elaborative technique.

When people succeed or fail, there are many possible ways to explain the outcome. External explanations include attributing outcomes to luck, ease or difficulty of the task, and availability of external resources (e.g., teacher's assistance). Alternatively, people can blame or credit themselves, adhering to the belief that they are dumb or smart (either in most situations or selected situations), or success can be viewed as the product of effort, failure as the lack of effort. Discussions of effort, ability, luck, and task characteristic attributions abound (e.g., Weiner, 1985), with the general recognition that only effort is personally controllable. The attributions of GSUs are probably a mix of all four types, but with disproportionately more attributions that success follows from effort expended in application of task-appropriate strategies (Clifford, 1984; Cullen, 1985).

Attributing failures to insufficient effort, as GSUs do, is definitely psychologically healthier than attributing failure to poor ability or to factors over which the child has no control. When shortcomings are credited to low effort, the learner is likely to try new approaches to a problem or at least try harder (Diener & Dweck, 1978, 1980; Dweck & Bush, 1976; Dweck & Repucci, 1973; Licht, Kistner, Ozkaragoz, Shapiro, & Clausen, 1985; Weiner, 1985). In contrast, poor learners, particularly learning disabled students, often attribute their failures to lack of ability or to other external factors, and thus, are more likely than normal children to stop trying (e.g., Butkowsky & Willows, 1980; Pearl, 1982). For this reason, considerable attention has been paid to modifying the attributions of disadvantaged learners.

For instance, Fowler and Peterson (1981) taught learning disabled readers to interpret failures as occasions when they needed to try harder. Consistent with the position that attributions play a causal role in behavior change, readers who learned to use "try harder" attributions were more persistent on subsequent reading tasks than learning disabled readers who were not provided such training.

Reid and Borkowski (1985) worked directly on attributions about the importance of strategies. Hyperactive, underachieving second, third, and fourth graders were provided strategy instructional training using one of three teaching variations. Strategy control subjects were taught to use clustering-rehearsal strategies for list learning and to use an interrogative-elaborative strategy to learn associative materials. Self-control children were also taught higher-order sequencing and monitoring techniques to use in employing the rehearsal and elaborative strategies. The specific higher-order sequence was based on procedures developed by Kendall and his associates (e.g., Kendall & Braswell, 1982), a program similar to Bommarito and Meichenbaum's (1978) higher-order plan described earlier. The self-control plus attribution subjects received the same specific strategy instruction combined with higher-order strategies that occurred in the self-control group, except that they were also trained to attribute their performance success to strategy use and failures to lack of strategy use. This training was integrated with strategy instruction by providing discussion about the reason for good and poor performance.

The most important result in the Reid and Borkowski (1985) study was that the self-control plus attribution training produced more general and durable use of strategies than did either of the other two instructional variations. There was greater strategy maintenance in the self-control plus attribution condition both two weeks and ten months following training. In addition, subjects given the attribution training were more likely to apply the strategies to tasks not identical to the training tasks, but ones for which the strategies were appropriate. As expected, the attributional training affected children's beliefs about their behaviors, particularly their understanding that behavior is controllable. One of the more striking pieces of evidence—suggesting that newly acquired beliefs actually increased self-control—was a decrease in impulsivity by children who were most hyperactive at the outset of the study.

Despite the fact that most research to date on the effects of attributions on performance has been with learning disabled children, there are obvious individual differences among normal children in their propensity to attribute mediated performances to strategy use. There are important variations in behavior associated with these attributional differences. Fabricius and Hagen (1984) provided a nice demonstration of this point.

Children in the first and second grades of Fabricius' and Hagen's study were first given four trials of learning lists of categorizable items, two trials made under an incidental set and two under an intentional set. The lists were presented with items blocked by category, and subjects were induced to process these lists by categories for these first four trials. A fifth trial followed that involved learning a noncategorizable list of items. As was expected, learning of the categorizable lists was easier than learning the noncategorizable list. Subjects were then probed for their perceptions of their learning performance and for their understanding of the basis of differential performance. They were asked, (a) "Was it harder, easier, or the same to remember the pictures this time?" (b) "Why?" (c) "How does [whatever the child identified in response to question b] work to make it harder (easier, the same)?" A second session was held a week later. Another adult presented the children with an unblocked list of categorizable items. On this occasion, participants were instructed that they could do anything they wanted to remember the list.

About two-thirds of the children in Fabricius and Hagen (1984) attributed improvements in learning the categorizable list to use of the sorting strategy. Subjects who recognized that better performance was tied to strategy use were more likely to use the sorting strategy during session two than were children who did not make the preliminary strategy attribution. Even some second-grade children make strategic attributions in some situations, attributions which later influence strategy use.

Nonetheless, Ghatala, Levin, Pressley, and Goodwin (1986) demonstrated that the chain from strategically-mediated performance to attributions about strategies to proficient strategy use on a subsequent occasion is very fragile with young learners. They also demonstrated that there are ways to increase the likelihood that appropriate strategic attributions can guide future strategy deployment. Although only some of the manipulations in Ghatala et al.'s (1986) experiment can be covered here, all data converged on the same general conclusions. First, children were trained in one of four ways. In the 3-component condition, subjects were taught to attend to and *assess* changes in performance when using different strategies; to *attribute* changes in performance to the use of particular strategies; and to use the information gained from assessment and attribution to *select* the best strategy for a particular task. This 3-component treatment had been shown in a previous study to enhance selection of effective strategies in young children (Lodico, Ghatala, Levin, Pressley, & Bell, 1983). Two-component subjects were taught only the first two components, assessment and attribution. One component subjects were only taught assessment. The fourth group of subjects were in a control condition which contained none of the three components.

Immediately following training, children learned three paired-associate lists. One of the first two lists was studied using a moderately effective strategy, rehearsal of the paired items; and the other was studied using a very ineffective method, looking for matching letters in the pairs. The children then selected either the rehearsal or letter-selection strategy to learn the third paired-associate list. Metacognitive questions were posed at the time of choice to determine the children's rationale for strategy selection.

Although children in all four conditions learned more items on the rehearsed list than on the letter-matched list, only children who had been trained to assess, attribute, and select based on assessments chose the rehearsal strategy at above chance levels. Eighty-nine percent of the 3-component subjects selected rehearsal, versus 61%, 50%, and 44% in the two-, one-, and zero-component training conditions. In general, three-component subjects were more likely than subjects in the other conditions to use memory-related and strategy-attribution reasons to defend their choice of rehearsal. Making assessments and attributions was not enough to guarantee selection of the more effective strategy in a strategy-selection situation slightly more complicated than the one studied by Fabricius and Hagen (1984) (i.e., two strategies were trained in Ghatala et al., 1986, versus only one in Fabricius & Hagen, 1984). Explicit instructions were required in order for children to use the assessments and the attributions based on those assessments in making strategy selections. See Pressley, Ross, Levin, and Ghatala (1984) for evidence that even among older children (10- to 13-year-olds), efficient strategy selection does not follow automatically from assessment of and knowledge about strategy potency differences.

We think that the fragility of the assessment-attribution-selection chain with young children can be understood when considered in light of a large body of evidence on children's attributions about actions and reactions that they themselves are responsible for. Heckhausen (1982) identified four important components in recognizing that a reaction was due to one's effort and the development of a corresponding attributional behalf. (1) Children must attend to the self-produced outcome. (2) They must attribute the outcome of an action to their own competence. (3) They must distinguish between degrees of task difficulty and personal competence, and be particularly aware that high personal competence is needed with difficult tasks. (4) They must differentiate competence from performance, distinguishing between the causal concepts of ability and effort.

Although even 5- and 6-year-olds have accomplished the first two components, complete understanding of task ease/competence trade-offs is not completed until well into the second decade of life. Heckhausen (1982) has reviewed the relevant evidence on this point. If he is correct, it is perfectly sensible that younger children would not automatically identify strategic outcomes as due to their competence, or even more specifically, their effort rather than their ability. Because the understanding of task difficulty/competence and ability/effort distinctions is partially developed, it is possible, however, to lead children down the garden path to strategy attributions that affect behavior, as occurred in Ghatala et al. (1986). However, more research is required to precisely correlate the dynamics of strategy choice with the various components in Heckhausen's (1982) model. See Stipek (1984) for additional commentary consistent with Heckhausen's analysis, and Nicholls (1978) for especially relevant research conducted in a North American context.

In closing the discussion of attributional specific strategy knowledge, we want to emphasize the distinction between effort attributions and strategic effort attributions. Both are important, but we believe it is critical that children understand that hard work is not enough, that what is needed often is hard work deployed in a particular way—as a processing strategy matched to task demands. Such strategy attributions are especially important when a GSU fails at a task:

> They allow one to escape the guilt of not trying [which would follow from purely effort attributions], and the embarrassment and shame associated with being stupid [which might follow from purely ability attributions]. But perhaps most importantly, strategy explanations tend to turn failure outcomes into problem-solving situations in which the search for a more effective strategy becomes the major focus of attention. This search and exploration can be expected to elicit *increased* effort without the fear that subsequent failure will automatically imply low ability (Clifford, 1984, p. 112).

Consistent with Clifford's analysis of what it is adaptive for learners to believe, we hypothesize that GSUs have attached to many strategies a piece of knowledge of the following form: "I do well in situation X because I exert effort and use strategy Y. If I do not work hard and use strategy Y when I encounter situations similar to X, I may not do well on those occasions." See Cullen (1985) for an extended discussion of evidence relevant to this claim.

Specific Strategy Knowledge is More than Conditional knowledge

The fact that strategies are accompanied by specific strategy knowledge permits them to function something like production systems in artificial intelligence (Newell & Simon, 1972). The strategies specify an action that is executed when particular conditions are met; conditions encoded as specific strategy knowledge. Indeed, in discussing some of what we refer to as specific strategy knowledge, Paris, Lipson, and Wixson (1983) use the artificial intelligence term conditional knowledge. We emphasize, however, that specific strategy knowledge includes more than just conditional information. As an example, consider the richness of what children know about the strategic value of retrieval cues (Beal, 1985; Fabricius & Wellman, 1983). Good strategy users understand that retrieval cues should be associated with targets, that the cues should have been encountered before, but near in time to the desired retrieval, and that cues should be unambiguous (i.e., not equally relevant to nontargets as to targets). Obviously, knowledge about retrieval cue strategies is not limited to information about *when* to execute these procedures. See Pressley, Borkowski, and O'Sullivan (1985) for explicit development of the case that specific strategy knowledge includes diverse information, such as how to modify the strategy internally (e.g., how to modify paired-associate elaboration so it can be used with 4-tuples), whether the strategy is fun or easy to use, as well as episodic information such as who taught the learner the strategy.

GENERAL KNOWLEDGE ABOUT STRATEGIES AND ASSOCIATED GENERAL STRATEGIES

Although goal-specific, monitoring, and higher-order strategies have been the focus of interest for most strategy researchers and are believed to be at the heart of good strategy use, there are other, more general tendencies that facilitate implementation of specific strategies. Each of these tendencies is tied to particular pieces of general knowledge about strategies that learners can possess. A review of three important aspects of general metastrategic knowledge illustrates how general factors operate in highly competent strategy execution. Some readers might wonder why more general tendencies would be discussed after coverage of specific strategies. There are two reasons: (1) General tendencies can only affect performance by making specific strategy implementation more likely. (2) Some of these general tendencies follow from extensive use of specific strategies, and the general tendency can only be understood by consideration of its derivation from specific strategy experiences.

1. *General knowledge about strategies includes understanding that personal effort often increases the likelihood of success.* Knowing that one's fate can be controlled has been referred to as self-efficacy (e.g., Bandura, 1982), personal causation (e.g., deCharms, 1968), and self-agency (e.g., Martin & Martin, 1982). All of these positions hold that this type of knowledge is a powerful motivational force in human conduct and hence, an important determinant of behavior, a conclusion supported by an enormous volume of data (e.g., Bandura, 1983). For instance, learners who believe that performance is tied to effort in general are more likely to continue using strategies that they have been taught than are learners who do not recognize that effort and achievement often covary (e.g., Borkowski & Krause, in press; Kurtz & Borkowski, 1984), that is, they have a *general strategic tendency to deploy effort.*

2. *The GSU also understands that although effort per se is important, effort channeled into strategic activity is better than working hard.* This

realization follows (1) from experiencing occasions when hard work ended in failure because the effort did not include executing processes matched to the task, and (2) from other occasions when strategic effort congruent with task requirements produced success. This is the "general" form of the specific strategy knowledge that use of strategy *y* is helpful in situations that have *x* characteristics.

3. *The GSU understands that specific strategies are not tied to one task, but can be matched to new situations. If done properly, trained strategies can improve functioning in these new domains.* How does the GSU gain this insight? The GSU can use a number of specific strategies and possesses knowledge about each strategy in varying degrees. The GSU frequently and successfully applies specific strategies to "new" situations that possess the characteristics coded in specific strategy knowledge. Repeated success in using strategies when demands are not identical to training produces a general understanding that specific strategies can be used beyond training tasks. The result is a general tendency to stretch strategies to new realms. Thus, GSUs are likely to generalize strategies to near tasks even when they have been given scant opportunity to acquire much specific strategy knowledge about the particular strategy. Support for this position is in the form of positive correlations between knowledge about other strategies and the tendency to generalize newly acquired strategies. This correlation is obtained even with children (Borkowski & Peck, 1985; Borkowski, Peck, Reid, & Kurtz, 1983; Kurtz & Borkowski, 1985; Kurtz, Reid, Borkowski, & Cavanaugh, 1982).

4. *One of the most important pieces of general knowledge about strategies that GSUs possess is that if strategic actions and plans are to be successful, they should be shielded from competing behaviors, distractions and emotions.* This shielding is known as action control (Kuhl, 1984, 1985). The GSU knows to attend to current processing and is intent on carrying out a strategic plan. GSUs do not get upset when they detect difficulties, but instead realize that emotions should be controlled and either more of the current strategic processing should be applied or new processing tried to resolve the difficulties. When monitoring indicates success, the GSU does not respond with uncontrolled elation, but instead moves to the next goal-specific strategy in the plan that accomplishes the next subgoal. The GSU also knows environmental conditions conducive to good strategy execution and uses this knowledge to control his or her environment. For instance, author MP knows that he cannot execute cognitive strategies when rock music is playing, and thus he has engineered his study environment so that it is rock music free. Carrying out these action control strategies sets the stage for, and facilitates execution of, more specific strategies. People armed with many good specific strategies that accomplish specific

purposes, but who lack action control, are at risk for failing, simply because they are easily distracted from the task at hand.

Rudimentary action-control strategies are present even in very young children. For instance, children direct attention during a memory task as demonstrated recently by Baker-Ward, Ornstein, and Holden (1984). Those investigators presented 15 small, unrelated objects to 4-, 5-, and 6-year-olds. Subjects were given one of three directions. Free play subjects were told simply to play with the 15 objects. Target-play subjects were told to play with the objects, but especially to play with five target objects. Target-remember subjects were told to go anything they could to remember the five target objects. The main result was that target-remember subjects attended much more to the five target items than did the children in the other two conditions. They labeled and visually examined the target items more. These activities did not significantly enhance recall of the target items for 4- or 5-year-olds, but did so for 6-year-olds. There was no evidence that the 4- and 5-year-olds were deliberately creating mediators.

Our interpretation is that the children in Baker-Ward et al. (1984) possess very primitive action-control strategies, but not the specific strategies required to actually mediate memory. Baker-Ward et al. (1984) offered discussion consistent with this conclusion, suggesting that the 6-year-olds were more likely to be constructing representations that could mediate recall. Yussen (1974) and Wellman, Ritter, and Flavell (1975) provide other examples of 3- to 5-year-old children attending to to-be-remembered information and explicitly shutting out distraction.

More striking still are recent demonstrations that action control is present in even younger children. DeLoache, Cassidy, and Brown (1985) first introduced 18- to 23-month-old children to a stuffed animal, a character well known to the child (e.g., Big Bird). The child was told that Big Bird was going to hide and the child should remember where he was hiding, so she could find him when a bell rang four minutes later. Big Bird was then hidden under or behind an object in the room (e.g., under a chair, behind a pillow). During the delay period the child was brought to the center of the room and encouraged to play with attractive toys and crayons.

The child could get up and approach the hiding location if she wanted to do so, but was prevented from uncovering the toy or hovering over the hiding place for an extended period of time. The main findings were that children were active during the delay interval, striving to maintain attention to the hiding place. They verbalized about the hiding, looked at the hiding place, pointed to it, peeked, and tried to retrieve the toy. But were these behaviors strategic in any sense? If they were, the behaviors should disappear if memory demands were removed from the task. DeLoache et al. (1985) conducted two additional variations of the hide-and-seek procedure, neither of which required the child to remember where the object was. In one, the object was placed in the environment with delayed retrieval by the child required. This time, however, the object was placed in view. The second variation involved placing the object out of view, but instead of the child being responsible for retrieval, the experimenter retrieved the toy when the bell rang. Both of these variations produced less attention to the hidden object than occurred when the child had to remember Big Bird's location. Even children younger than two years of age mobilized their attention in the service of an intention to remember. This is exactly what action control is about; using general strategies like selective attention to insulate cognitive intentions. Selective attention shuts out potential interferences. See Day (1980) and Pressley, Levin, Pigott, LeComte, and Hope (1983) for two other demonstrations that preschoolers deploy attention to eliminate the effects of powerful distractors.

Preschoolers' knowledge about general action-control strategies is far from complete, however, with many important developments in early childhood. For instance, Mischel and Mischel (1983) mapped out the development of children's understanding that attention should be directed away from tempting stimuli when trying to delay gratification. In general, all of the data collected by Mischel and Mischel (1983) were consistent with the conclusion that although some preschoolers have good knowledge of variables that reduce distraction and arousal (and hence, temptation), there is rapid development of this knowledge during the early grade-school years. Patricia Miller and her associates have conducted an especially important series of studies complementary to Mischel and Mischel's (1983) conclusions, detailing children's knowledge about attention and distraction. Miller and Zalenski (1982) established that even three- and four-year-old children understand (1) that task performance can be disrupted by distracting noise in the environment, and (2) that people generally do better if they are interested in a task than if they are not. Particularly relevant to this discussion of general action-control strategies, preschoolers realized that distraction was not nearly so potent a debilitating force when interest in a task is high rather than low. See Guttentag (1985) for another good example of preschoolers shielding attention from irrelevant input. Much additional data consistent with conclusions offered here have been generated in studies of preschoolers' learning from television (e.g., Field & Anderson, 1985; Pezdek & Hartman, 1983).

Knowledge about attention and distraction continues to improve between 5 and 20 years of age, with concomitant developmental improvements in action control. See, for instance, Yussen and Bird's (1979) data on the growth of knowledge about attention from preschool to the early grade-school years. Children come to understand that debilitation due to noise varies with intensity of the distracting stimulus and that attention to task-irrelevant objects can disrupt learning (Miller & Weiss, 1982). Particularly interesting behavioral developments are (1) that children late in the grade-school years seem to focus attention intensely in the face of distraction, and thus, distraction can actually improve performance (Higgins & Turnure, 1984), and (2) with increasing age, children's shifting of attention is more efficient (e.g., Lane & Pearson, 1983).

It must be emphasized, however, that all problems of action control do not disappear in early childhood (e.g., Bray, Hersh, & Turner, 1985; Bray, Justice, & Zahn, 1983) or with development. Kuhl (1984, 1985) contends that an important source of individual differences in adult cognitive functioning is whether people have good action control strategies that set the stage for, protect, and serve other strategies. For instance, there are great individual differences in test anxiety. There is abundant evidence that during testing, test "anxious students worry that they are falling behind, scold themselves for forgetting the answers, and fearfully recall similar, previous test situations that ended in disaster (Covington, 1984, p. 39)." Such intrusive worry inhibits all other processing, including strategies that could be deployed to enhance test performance. See Morris, Davis, and Hutchings (1981), Sarason (1978), and Wine (1980) for detailed discussions of these cognitive intrusions.

Individual differences in action control are apparent in childhood as well, certainly by 2-years of age (Lee, Vaughn, & Kopp, 1983), and perhaps as early as the first year of life (e.g., Kopp & Vaughn, 1982). These individual differences in action control are linked with performance. Especially important are differences in children's selective attention to task relevant information, with selective attention deficits believed to be an important causal mechanism in hyperactivity and the behavioral problems associated with hyperactivity (e.g., Cullen, 1985; Rutter, Shaffer, & Sturge, 1975; Zentall & Shaw, 1980). See Ceci and Tishman (1984) for an especially analytic demonstration of poor selective attention and associated poor memory performance by hyperactive children.

A good deal of research effort has been expended in overcoming problems of action control. Curing deficiencies of action control, however, is at best a necessary, not a sufficient condition to affect cognitive performance in general. For instance, although there are treatments that improve attention in hyperactive children, these interventions usually do not affect learning, cognition, or academic achievement in general. This conclusion holds for drug treatments (Pelham, 1983), behavior therapy regimens (e.g., Ayllon, Layman, & Kandel, 1975; Christensen, 1975), but most relevant here, cognitive behavior therapies composed largely of attentional strategy instructions (e.g., Douglas, 1980; Pressley, 1979; Pressley, Reynolds, Stark, & Gettinger, 1983). See Keogh and Barkett (1980) and Whalen and Henker (1980) for excellent reviews.

In summary, general knowledge about strategies and general strategic tendencies facilitate the implementation of more specific strategies. Effort is required for most specific strategies. General knowledge of the relevant dimensions to consider for strategy use permits direction of a procedure even when learners have had little experience with the strategy. Action control protects these specific strategies from pejorative outside influences. For more fine-grained adjustments, however, specific strategy knowledge is required, and the relationship between new content to be mastered and current world knowledge must be assessed. We now turn to consideration of how that world knowledge affects operations on what we are about to learn.

KNOWLEDGE BASE

GSUs possess an extensive knowledge base, built up from years of experience with the world. Although debates persist about the forms of representations in this knowledge base, it is safe to claim that knowledgable people possess well integrated sets of information about episodes and commonly-encountered sequences (Mandler, 1983), such as going to a restaurant or a theatre or waiting for a bus. People also have a host of associations that are organized in decidedly nonrandom ways (e.g., Anderson, 1983). Some of these associations coalesce into hierarchical, category-based structures (e.g., Mandler, 1983), and many exist as more or less isolated, sometimes functional, sometimes personal episodes (e.g., cotton swabs remind some people of babies because swabs are often used in association with caring for infants).

In general, there are at least three ways that the knowledge base relates to strategy use. In describing these three mechanisms, we recognize that the distinctions between them are not entirely clear cut. Indeed, the phenomena cited to support any one mechanisms can often be reinterpreted as evidence for the operation of one of the other two mechanisms. Nonetheless, even if future research does not generate independent validation for these three mechanisms, their use here provides a concise way of categorizing contemporary research on the interaction of the knowledge base and specific strategies.

Knowledge Can Diminish the Need for Strategy Activation

Many instances of efficient learning occur without strategic assistance (Chi, 1981). The most substantial research effort establishing this point has been conducted by Bjorklund (e.g., 1985), who makes the case that grade-school children learn categorizable lists without conscious effort and strategy use. Items within categories are often associated with one another (e.g., cat and dog, spoon and fork). Associations that are salient in the young child's knowledge base are automatically activated when a categorizable list is presented. They facilitate learning and retrieval of categorizable lists even when learners make little or no strategic effort (e.g., Lange, 1973; 1978). Although the young child also possesses knowledge of hierarchical categorical relations (e.g., Perlmutter, Sophian, Mitchell, & Cavanaugh, 1981; Ross, 1980), this type of information is not as accessible as associatively-based knowledge (e.g., Gitomer, Pellegrino, & Bisanz, 1983; Ratner & Myers, 1981). Later in development, category knowledge becomes more extensive and is more easily accessible (e.g., Ford & Keating, 1981; Landis & Herrmann, 1980; Nakayama & Kee, 1980). Bjorklund (1985) contends that once the categorical knowledge base is extensively established, it is activated in the same automatic fashion that associative knowledge is triggered in the young child.

Consistent with Bjorklund's (1985) view of accessible knowledge, Frankel and Rollins (in press) factorially manipulated both category relatedness and inter-item associations. They found that fourth and tenth graders showed relatively high levels of organization in recall whenever category relatedness or associative strength between items was high. In contrast, kindergarten children displayed greater category clustering only for the lists with strong inter-item associations. These results are consistent with the conclusion that only associative relations are readily and automatically available for younger children, whereas older children have ready access to both associative and hierarchical information. See Bjorklund and de Marchena (1984) for additional evidence of this shift in knowledge type availability, as well as Roth (1983), who provides data that accessibility is directly related to the degree of knowledge possessed by a learner.

Rohwer, Rabinowitz, and Dronkers (1982), studying paired-associate learning, provided additional evidence consistent with the hypothesis that knowledge-base activation often occurs automatically in children. Fifth-grade children were presented one of two types of pairs to remember, either ones that are closely related in the knowledge base (e.g., ranch-cowboy, fish-seaweed) or ones that were not so closely related (ranch-floor, fish-napkin). They were presented the pairs with only the instruction to learn them, or they were instructed to generate a story to join the paired items (i.e., construct a verbal elaboration; Pressley, 1982; Rohwer, 1973). The instruction to generate the story boosted learning of unrelated pairs, but did not boost learning of related materials. If the fifth graders had used elaboration strategically and spontaneously, then the story generation instruction should have had no impact at all. Thus, the boost in learning of unrelated pairs due to instruction is consistent with outcomes in other studies of elaboration instruction. Fifth graders do not spontaneously use elaboration to learn unrelated materials (e.g., Pressley & Levin, 1977a), but can be induced to do so (Pressley & Levin, 1977b). The strategy is apparently not necessary when the to-be-learned materials are already integrated in the learners' knowledge base, as was true for the related pairs. On the other hand, Rohwer et al.'s (1982) arguments would be strengthened considerably by more direct assessment of strategy use and probes tapping subjects' intentional use of strategies versus automatic activation of knowledge. See Waters (1982) for conclusions consistent with Rohwer et al. (1982) that were supported by more direct measures of process.

Mapping occurrences of knowledge activation versus strategic activity will be a prominent research activity in the next few years, with such work critical to the understanding of alternative routes to proficient performance and population differences in information processing. For instance, when related materials are presented in a blocked fashion, performance differences between younger and older normals and younger and older learning disabled children are smaller than when related materials are separated, and hence, semantic overlap is not so obvious. In the latter case, older children and normal children fare better (Ceci, 1984). This pattern of results is due to two factors: (1) There is automatic activation of and processing by the knowledge base in the blocked situation; activation that occurs for both younger and older, normal and disabled children. (2) The separated situation requires true strategic activity for use of the knowledge base to occur; activity that is more likely with older and normal children. We expect that the search for knowledge base × strategy × population interactions will uncover many other interesting relationships.

Automatic Coding of Some Meaningful Materials Prompts More General Strategy Use

As they automatically process highly related items in a categorical fashion, some children may realize that categorization is a good learning technique. Hence, they initiate categorization strategies even when materials are not highly related. Bjorklund, Ornstein, and their associates have evaluated this hypothesis, and suggested that automatic processing of highly associated materials can lead to strategic processing of nonassociated categorical materials.

Bjorklund and Jacobs (1985) had third graders, fifth graders, seventh graders, and ninth graders learn a list of 20 categorizable items. Within categories, some of the items were highly associated (e.g., lion-tiger, dog-cat). Others were not associated with other category members (e.g., cow is not highly associated with dog, cat, tiger, or lion). The 20 items were presented either in a random order, in a blocked fashion with interitem associations minimized (e.g., dog, lion, cow, tiger, cat), or in a blocked fashion, emphasizing interitem associations (e.g., dog, cat, cow, lion, tiger). When associative relations prompt categorical strategic processing, recall of highly associated items occurs first, followed by nonassociated category members. This pattern was most prevalent among seventh and ninth graders, with grade differences in this pattern most striking in the blocked condition emphasizing associations. Third and fifth graders apparently failed to use nonassociative categorical relations to mediate recall. Reaction time data and analyses of clustering provided additional support for this developmental interpretation. An adult sample was subsequently administered the same list of items. The adults tended to recall categorically without starting with an associated pair. Bjorklund and Jacobs (1985) concluded that adults used categorization even without associative prompting to do so.

Best and Ornstein (1984) also presented data consistent with the interpretation that processing of associatively-related categorizable materials can lead to more complete semantic processing of nonassociated categorizable materials. Third graders learned a list of items with obvious categorical interrelationships. After learning this list of highly related materials, the transfer of categorization to materials that did not contain obvious relationships was tested. Automatic categorization during processing of the first list induced use of categorization with materials that would ordinarily not be processed categorically by third graders.

Bjorklund and Jacobs (1985) and Best and Ornstein (1984) are initial tests of the intuitively appealing notion that "self-initiated" strategy use by children is sometimes stimulus driven (Ornstein, Baker-Ward, & Naus, in press; Ornstein & Naus, 1985). This hypothesis holds that there is a carry-over from processing of materials that "elicit" more sophisticated processing because of their compatibility with elements that are readily accessible in the knowledge base, to materials that are not so obviously consistent with prior knowledge. Such carry-over experiences presumably can have a long-term impact, and in fact, are believed to be critical in the development of strategy use (e.g., Bjorklund & Zeman, 1982). Ornstein and Bjorklund hypothesize that at some point, children will reflect on their carried-over "strategy" use, realize its significance, and consequently abstract its structure for use on future occasions; a process similar to reflective abstraction (Bjorklund, 1985; Piaget, 1971). This potential account of the "invention" of some strategies by children deserves serious research attention.

The necessity for emphasizing "potential" consciousness and control when defining strategies, as we did earlier in the chapter, is very apparent when considering Bjorklund and Jacobs (1985) and Best and Ornstein (1984). Even though strategic processing that is driven by the knowledge base probably does not qualify as consciously intentional or planful, it accomplishes cognitive purposes, can be reflected on, and probably could be controlled if the subject wanted to do so. Thus, we consider this type of processing strategic, following the logic that if it looks like a duck, waddles, and quacks, it's a duck!

Knowledge Enables Use of Particular Strategies

Knowledge provides grist for the strategy mill. For instance, when presented physics or mathematics problems, less-than-expert solvers often use a means-ends analysis (Larkin, 1979; Newell & Simon, 1972; Simon, 1979; Simon & Simon, 1978). The problem solver possesses knowledge of an end state and makes an initial approximation at a solution. The approximation and end state are compared with the difference between the two. Long-term memory is searched for an operation that would reduce the discrepancy between the approximation and the goal state. What is relevant here is that the means-end strategy can only be successful when the problem solver already knows some domain-specific knowledge. For the example, the person working the problem must know how the two end states differ in ways that are relevant to the problem, as well as legal operations that can be executed to reduce these differences. When the knowledge base is not developed well enough to carry out means-ends analyses, problem solvers may revert to less powerful strategies that do not depend as heavily on a rich knowledge base, such as working forward (Gagné, 1985, Chapter 5).

With children, however, the bulk of the research on knowledge possession as an enabling condition for strategy use has been carried out in the area of memory. Some examples concretize this point and the diversity of memory-task situations that have been used to uncover dependencies of strategy use on the knowledge base.

Ornstein and his associates have carried out a variety of experiments aimed at documenting that strategy application depends largely on the state of the knowledge base. Corsale and Ornstein (1980) presented third-grade children a list of 20 "unrelated" items, ones that did not fall into explicit taxonomic groupings, but that nonetheless could be put together in a number of ways to form meaningful groups. When told to "make groups of pictures so that you will be able to remember the pictures later," their sorting was essentially random. This was despite the fact that the children could sort hierarchically when explicitly instructed to "put things together that go together." Prompted by this finding, Corsale (1978) provided the same instruction to Grade 3 children, but varied whether children were given a list of highly salient categorizable examples to learn or a list composed of items with low categorical saliency. Third graders given the very salient materials sorted in a very organized fashion; third graders provided the low saliency list sorted randomly, even though they could sort the low saliency list when told to do so explicitly. Spontaneous strategy use in this study depended on the relationship of the studied materials to the knowledge base, with sophisticated strategy use occurring when materials activated (were consistent with) the knowledge base and production deficiencies occurring when materials did not link up with the knowledge base.

Enabling effects occur even when subjects are under strong instructional control to produce strategies. Tarkin, Myers, and Ornstein (in preparation) examined 8-year-olds' rehearsal of lists as a function of meaningfulness in the verbal learning sense (i.e., more meaningful items elicit more associations than do less meaningful materials). Rehearsal characteristics differed clearly as a function of meaningfulness. The most dramatic result was that rehearsal set size was larger for meaningful materials (i.e., items that children "know" more about) than for less meaningful items. Again, the knowledge base seemed to enable more sophisticated strategy use. See Ornstein and Naus (1985), Ornstein, Baker-Ward, and Naus (in press), and Zembar and Naus (1985a, 1985b) for summaries of other studies conducted by the North Carolina group that are relevant to the position that high knowledge enables high strategy use.

Rabinowitz (1984) provided additional data that nicely complemented Ornstein's findings. Second and fifth graders were presented one of two types of lists to learn for free recall. The lists were composed of 24 items from 6 categories, with category members either highly or moderately associated with the category. Subjects were given one of three learning instructions, either (1) no instruction, (2) repetition of individual items, or (3) grouping by categories to learn. The categorization instruction was made especially easy to execute because categorization subjects were given the list items blocked by category. Items were not blocked for repetition or no strategy subjects. In general, for both second and fifth graders, the categorization instruction produced a greater boost in performance relative to the repetition and no strategy conditions when the list contained highly associated items than when it was composed of moderately associated items. The potency of the categorization strategies varied with the learners' knowledge base—a more potent strategy when items were strongly linked to the category label in the knowledge base than when the item-category linkage is weaker.

This knowledge enabling relationship has been observed in other memory paradigms as well. Chi (1981) taught children to use a retrieval heuristic for recalling a set of names. The children applied the strategy easily to an overlearned, very concrete, highly familiar content (i.e., the names of their classmates), but had difficulty applying the strategy to another set of names, a list of unfamiliar people whose names had been learned as part of the experiment.

Pressley and Levin (1977b) observed a similar relationship between the knowledge base and strategy execution. Young grade-school children could quickly and easily apply an interactive imagery strategy to word pairs for which obvious relationships existed in their knowledge base (e.g., needle-balloon). When such relationships were not so well known, Grade 2 children applied the strategy much more slowly, although they could execute it given sufficient time.

Perhaps the most important recent direction in research on knowledge × strategy interactions is the study of differential strategy instructional effects during reading as a function of prior knowledge. This important new direction is a direct outgrowth of the general position that prior knowledge and prior schematized knowledge are important determinants of text comprehension and learning (e.g., Anderson, 1984; Mandler, 1983). Consistent with this position, many reading instructional programs aimed at children include components that activate relevant prior knowledge (e.g., Hansen & Pearson, 1983; Palincsar & Brown, 1984; Tharp, 1982). Nonetheless, empirical evaluations of schema activation strategies with children are only now appearing.

One was offered by Hasselhorn and Körkel (1986). Two types of Grade 6 children participated in the study; those who knew a lot about soccer (soccer experts) and those who knew relatively little (soccer novices). During the preinstructional phase, the children read a 350 word story about soccer twice. The story contained six inconsistencies. The main dependent variable of interest was the number of text errors that children could identify when asked to do so. Consistent with the earlier claim that the knowledge base is often automatically activated when a person encounters material that they know about, and consistent with voluminous data generated by schema theorists and researchers (e.g., Graesser, 1981; Mandler, 1983), the soccer experts detected more inconsistencies (about 30% of them) than did the soccer novices who spotted 15% of the problems in the text.

Half of the experts and half of the novices then received one form of reading instruction based largely on knowledge activation. They were told to activate their prior knowledge relevant to the text contents and to use this knowledge for text comprehension. The remaining subjects were taught to use multiple strategies to direct reading, a mixture of goal-specific, monitoring, and higher-order strategies. They were taught to try to get hints from the title about text content. They were instructed to stop after each paragraph and to check whether they understood everything or not. They underlined the most important sentences and were told to rethink content and summarize it. In addition, a four-step self-questioning strategy was taught for application when inconsistencies were encountered. Subjects were taught to ask themselves: (1) What is the problem at hand? (2) Which are the possible solutions for the problem that I can gather? (3) Which one will be the best to solve the problem adequately, and why is it the best one? (4) Is the problem at hand—after applying the solving procedure—now completely resolved? Finally, subjects were told to apply appropriate strategies before, during, and after reading.

Following training, subjects were once again presented the soccer passage with the task of identifying inconsistencies in the passage. The most relevant result was that knowledge activation training boosted the performance of experts from 30% to 63%, but had little impact on novices who spotted only 21% of the errors following training. Having the relevant knowledge base is an enabling condition for benefits due to the knowledge activation strategy. The multiple-strategy package elevated the performance of novices to 33%, slightly higher than the pretesting level of experts. Experts trained in multiple-strategy use also improved slightly from 30% at pretesting to 40% at posttesting. Thus, the multiple-strategies training approach was a better instructional option when prior knowledge was low, although use of multiple strategies never elevated the novices to the levels of experts who were prodded to make full use of their understanding of soccer. See Naus and Ornstein (in preparation) for another example of high knowledge about soccer leading to sophisticated strategic behavior in the learning of soccer content (Zembar & Naus, 1985a, describe this study in detail).

Closing Comments on Knowledge Effects

It is common to pit process analyses and knowledge-based conceptions of competent performance against one another (e.g., Glaser, 1984; Sternberg, 1985). Although such a dichotomy is defensible for some purposes (e.g., for organizing some of the research reviewed in this chapter), postulating strong boundaries between strategic process and knowledge does not make sense in light of what we know about high-level thinking skills. In fact, such distinctions seem arbitrary for several reasons: (1) Goal-specific strategies are exactly what the name implies—procedures that are appropriate for only certain tasks and domains (e.g., Glaser, 1984). For instance, there are few "general" memorization strategies that are applicable across tasks. Instead, there are procedures applicable for associative learning, list learning, and prose learning. Within these categories, additional distinctions are made. For instance, categorization strategies are appropriate for list learning, but only if the list categories are consistent with categories in the learners knowledge base. How can strategic operations that are only appropriate for certain portions of the knowledge base be completely disentangled from that knowledge base? (2) Even if one clings to the clear separability of knowledge and strategies, it is apparent from the data reviewed here that good thinking is a mixture of well articulated strategies and knowledge, and not due predominantly to knowledge or strategies alone (e.g., Chi, 1985; Rabinowitz & Chi, 1986; Rabinowitz & Glaser, 1986). Although strategy and knowledge effects can be studied profitably in isolation (as has been the case until recently), complete explanations of good thinking must interweave these factors.

AUTOMATICITY AND GOOD STRATEGY USE

The GSU possesses a complex network of strategies (both general and specific), knowledge about those strategies, and knowledge about the world. When confronted with a task that can be solved strategically (e.g., learning some history facts for a test), the general strategies of effort expenditure and paying attention are activated. Assuming the situation bears some resemblance to one encountered previously, specific strategy knowledge can be used to identify an appropriate goal-specific strategy, or more likely in the case of the types of complex tasks that humans encounter, a series of goal-specific strategies. These strategies are each matched to particular subgoals that form a sequence for accomplishing the task. Higher-order planning strategies arrange the goal-specific strategies matched to the order of the subgoals, mixing in monitoring as part of the higher-order routine. Strategy execution would be facilitated if the learner had good prior knowledge of history. If that knowledge were very complete, the learner might realize early on that use of the complicated strategy sequence was unnecessary. Alternatively, using an imagery-pegword strategy to learn important dates in the U.S. history might be facilitated by understanding the significance of the dates. For instance, constructing an image to mediate memorization of 1945 as the date of F. D. Roosevelt's death is facilitated by knowing what Roosevelt looked like, that he was president for most of World War II, and that 1945 was the last year of the war.

One possible reaction to this model is, "How could the mind possibly do all that, given the time constraints often put on strategy use?" After all, human beings have limited attention that can be applied to such problems (Kahneman, 1973).

The answer was briefly discussed earlier in the chapter, but can be expanded now that all the components have been reviewed. The good strategy user has automated many of the components, and thus, these components require little attention (e.g., Hess & Radke, 1981; Ackerman & Schneider, 1985). It is generally recognized that most of human performance is a mixture of automatic and controlled components (e.g., Sternberg, 1981), and that controlled components demand much more attentional capacity than automatic ones (e.g., Shriffin & Walter Schneider, 1977; Walter Schneider & Shriffin, 1977; Walter Schneider, Dumais, Shriffin, 1984). Although virtually all aspects of good strategy use could be carried out in a controlled fashion, many aspects are probably automatized through frequent practice. Regrettably, there has been far more attention to controlled deployment of strategies. This attention is largely due to the assumption that conscious, capacity-consuming intentionality is a necessary attribute of strategic behavior. As detailed earlier, we do not concur with this view, and note that study of automatic aspects of strategy use is growing in prominence (e.g., Pressley & Ahmad, 1986; Bjorklund & Jacobs, 1985; O'Sullivan & Pressley, 1984, adult data; Rohwer, Rabinowitz, & Dronkers, 1982). We suspect that really good strategy users probably recognize, with little effort, which strategies should be used in given situations. They sequence and monitor goal-specific strategies habitually with relevant prior knowledge activated almost effortlessly, often through associations with the new material (Bjorklund, 1985). Although speculative at this point, this portrait of practiced strategy use is consistent with how practiced behaviors are carried out in general (Schneider et al., 1984).

Two possible determinants of who becomes a good strategy user and who does not are: (1) individual differences in attentional capacity, and (2) individual differences in the facility for using available attentional resources. Although there is considerable debate about determinants of functional differences in working memory (e.g., Dempster, 1985), evidence is accumulating that good thinking is tied to working memory efficiency (e.g., Benton, Kraft, Glover, & Plake, 1984; Masson & Miller, 1983). We expect research to map out relationships between working memory capacities and good strategy use in the near future, especially given the likelihood of reciprocal causation here. Working memory differences probably underlie strategy use to some extent, but good strategy use in turn increases functional working memory (Dempster, 1985).

On the other hand, the machinery hypothesized here works in the absence of extensive automaticity, largely because the many components required in good strategy use are not executed simultaneously. Rather, components are usually executed sequentially. Thus, a person can consciously decide to get set to be strategic and explicitly eliminate distractions. After studying the task and its attributes, the strategy user elects relevant strategies and perhaps then thinks through how to map them onto the sequence of subgoals that the learner faces. The learner might then search world knowledge and activate knowledge relevant to the task (Levin & Pressley, 1981). The learner may consciously keep track of how learning is going, using monitoring skills, as the sequence is executed, and make a point of updating specific strategy knowledge when something important about a strategy is discovered during the task. As learning proceeds, the conscious strategy user might even make a point of taking note of newly acquired knowledge that should be stored.

One of the most tantalizing possibilities is that even children do this sequencing by taking their own attentional limitations into account. Guttentag's (1984) research supports this perspective. Guttentag first determined that use of a cumulative rehearsal strategy for list learning consumed attentional capacity in grade-school children. His subjects experienced more interference on a concurrent task (finger-tapping) when they cumulatively rehearsed than when they did not. Guttentag also found a negative correlation between spontaneous rehearsal and finger-tapping interference: The less interference, the greater the size of the set of items the subject rehearsed spontaneously. Guttentag interpreted this finding to mean that the "mental effort requirement of a strategy may be one factor affecting children's strategy selection. There may be a tendency for children to avoid using strategies which require a very large expenditure of mental effort on their part (p. 104)." An extrapolation of this argument is that the spontaneous use of more complex strategies by older children is a by-product of increasing functional working memory (e.g., Dempster, 1985). Notably, Guttentag's conclusions are consistent with other observations of greater strategy use by children when information processing requirements are reduced, and hence, when strategy use requires less effort (Waters & Andreassen, 1983). Because of dependencies between strategy use and automaticity, there is certainly motivation for a thorough study of these variables in interaction, with experiments like that of Guttentag constituting (1984) a good beginning.

THE CHALLENGE THAT THE GSU MODEL POSES FOR DEVELOPMENTAL PSYCHOLOGY

We have suggested that there is a developmental orderliness to strategy development, even if the details about the course of that development are not well worked out at this time. At one extreme are young children who possess only general action control tendencies and the beginnings of world knowledge. In contrast, mature learners are facile at appropriate deployment of higher-order, goal-specific, and monitoring strategies. They possess general strategic tendencies that facilitate the use of other strategies. Mature learners also thoroughly understand a wide range of strategies, recognize which aspects of the world they are knowledgable about, and sense how their personal world knowledge interacts with their use of strategies.

Thus, development consists of acquiring and automatizing the strategic components and learning to use them in concert with an ever-increasing and somewhat personal knowledge about the world. The challenge for developmental psychologists is to map development of both the components per se as well as age-related changes in component interactions. Meeting this challenge will be costly and time consuming, but one important byproduct that justifies the costs will be new and more effective ways to train strategic thinking in actual classroom settings (Pressley, 1986; Pressley & Levin, 1983a, 1983b).

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