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When Shoes Become Hammers: Goal-Derived Categorization Training Enhances Problem-Solving Performance

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Problem-solving theories have not examined how solvers navigate their knowledge to interpret problem situations or to plan strategies toward goals. In this article, the author argues that success in problem solving depends on the solver's ability to construct *goal-derived* categories, namely categories that are formed ad hoc to serve goals during the instantiation of problem frames. Experiment 1 ($N = 140$) showed improved problem-solving performance after training to construct goal-derived categories. Experiment 2 ($N = 80$) demonstrated that effects of training in category construction can be obtained without participants being explicitly informed regarding the relevance of training to problem solving. These studies suggest that problem solving is a dynamic expression of goal-directed cognition and provide evidence for the involvement of categorization in problem-solving processes.

Keywords: problem solving, categorization, goal-derived categories, ad hoc categories, insight problems

Problem solving refers to a situation in which the solver develops and implements plans with the intention of moving from a problem state to a goal state within a range of constraints. Some problem-solving situations are *well-defined*, wherein both the goal to be achieved and the path to be followed for the solution are obvious (e.g., solving the equation $125 \times 5 = ?$). In contrast, other problem-solving situations are *ill-defined*, wherein both the goal and the steps necessary for its completion are ambiguous, and the solution possibilities appear infinite (e.g., how to attach a candle on the wall with a book of matches and a box of tacks). Theories of problem solving have examined a variety of strategies by which individuals reach solutions to different problems. Such theories approach solvers' success with a problem either as the result of special thinking processes (e.g., Knoblich, Ohlsson, & Raney, 2001; Knoblich, Ohlsson, Raney, Haider, & Rhenius, 1999; Metcalfe, 1986a, 1986b; Metcalfe & Wiebe, 1987; Ohlsson, 1984, 1992) or as the product of ordinary cognitive processes like comprehension and memory (e.g., Chronicle, MacGregor, & Ormerod, 2004; Chronicle, Ormerod, & MacGregor, 2001; MacGregor, Ormerod, & Chronicle, 2001; Perkins, 1981; Simon, 1986; Weisberg, 1986, 1995b; Weisberg & Alba, 1981). In general, solvers achieve the solution to most well-defined problems through the use of exhaustive algorithmic or heuristic methods (see Newell & Simon, 1972). However, certain ill-defined problems (i.e., insight problems) can also be solved through a leap of insight. Specifically, *insight* in problem solving refers to an abrupt and unanticipated change in the solution path that leads the solver to immediate success with a problem (e.g., Weisberg, 1995b).

Despite their focus on the construction of effective solution strategies for goal achievement, current problem-solving theories have not adequately examined how the solver's knowledge and experience is implicated in the formation and implementation of those strategies. In particular, there has not been a systematic account proposed that reflects the flexibility by which the solver determines how knowledge is relevant to the achievement of those goals. No theory, thus far, has examined how the access to prior and, importantly, relevant knowledge is attained. This article argues that the processes by which solvers create an interface between their knowledge and the information provided in any problem-solving situation when constructing plans for action involve numerous categorizations of the elements of a problem, the effectiveness of which is directly implicated in and critical for problem-solving success.

The manner in which individuals' knowledge is structured and the ways in which it is influenced by a given context have been the focus of numerous theoretical and empirical investigations on the processes of categorization and concept formation (Barsalou, 1982, 1989; Blessing & Ross, 1996; Murphy & Ross, 1994; Pazzani, 1991; Roth & Shoben, 1983). Specifically, a *category* is defined as the set of entities or examples in experience that are selected by a concept (Medin, Ross, & Markman, 2005), whereas a *concept* refers to the specific information established in working memory that is used to represent a category (or a category exemplar) on a particular occasion (Barsalou, 1987). Barsalou (1991) further proposed the dichotomization of conceptual processes into two mechanisms. First, people form taxonomic categories by learning specific, idiosyncratically interpreted exemplars from

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their personal experiences (e.g., fruit, clothes). Second, in the presence of an impromptu goal, people construct goal-derived categories through the effortful, top–down, and dynamic process of conceptual combination (e.g., Ramey, in press; Wisniewski, 1997; Wisniewski & Love, 1998). These goal-derived categories may be either (a) well-established, because of previous experience, or (b) ad hoc, namely constructed "on the spot" from a combination of elements from well-established or taxonomic categories. Such categories are created spontaneously in specialized contexts and are typically used to achieve specific goals (e.g., things to sell at a garage sale). Particularly, in the presence of a goal, people retrieve from memory relevant knowledge about the situation in the form of *frames* (i.e., schemata; see also Markman, 1999; Murphy & Ross, 1999; Rumelhart & Ortony, 1977). The activated frame has attributes or aspects that have to be instantiated for the realization of specific plans by means of either taxonomic or goal-derived categorizations (well-established for familiar goals and ad hoc for novel goals); these categorizations satisfy various optimizations and constraints and are subject to constant modifications so as to best achieve the given goal (Barsalou, 1991).

Perhaps surprisingly, despite the focus of numerous studies within the categorization literature on goal-oriented cognition, these processes are typically not examined in conjunction with problem solving, even though the latter is an area that characteristically focuses on the cognitive strategies that individuals use when achieving intended goals (for an exception, see Barsalou, 1983). Similarly, within the problem-solving literature, the processes of categorization and concept acquisition are rarely discussed (e.g., Keane, 1989; Robertson, 2001; see also Maltzman, Brooks, Bogartz, & Summers, 1958). This article is, thus, the first attempt to examine problem solving as a process of frame instantiation in which solvers, faced with a goal, employ their knowledge to instantiate relevant properties of various problem elements and dynamically organize those elements in goal-derived categories dependent on a set of optimizations and constraints so as to satisfy the given goal (see also Chrysikou, in press).

However, contrary to the realization of well-defined novel goals as presented in the frame-instantiation model (e.g., planning a vacation; Barsalou, 1991, 1992), for which the impromptu construction of goal-derived categorizations occurs immediately and spontaneously, in most problem-solving situations the goal is not as well specified or unambiguous. Specifically with reference to insight problems, the solver, being in a state of uncertainty regarding how to reach the effective solution, is likely to form solution strategies based on primary categorizations of the problem's elements (e.g., in the Candle problem [see Experiment 1] a box of tacks is perceived exclusively as a container for the tacks; Murphy & Ross, 1994). However, reaching the solution to such problems typically involves the construction of goal-derived, secondary concepts. For example, the effective way to solve the Candle problem involves categorizing the box holding the tacks as something on which to stand a candle upright. As a result, when referring to ill-defined situations and, particularly, to insight problems, the generation of ad hoc categorizations—which are critical for the achievement of the correct solution—does not appear to occur with the effortlessness and spontaneity that may be observed in well-defined tasks.

Consequently, it has been hypothesized that if the construction of goal-derived and, particularly, ad hoc categorizations are critical for problem solving but difficult to execute, then training in goal-derived concept generation may enhance participants' instantiations of problem frames and, ultimately, improve their performance on insight problems. The two studies presented in this article investigated this possibility. Experiment 1 examined the effects of training participants to construct goal-derived categories by means of a categorization task on their subsequent insight problem-solving performance. In this experiment, participants were explicitly instructed as to the relevance of the training to problem solving. The necessity of the participants using explicit instructions regarding the relevance of the training originated from previous work on analogical transfer in problem solving, according to which solvers are unlikely to detect underlying similarities between two problems unless the problem structure is identical (e.g., Bassok, 1990; Gentner, 1983) or they are explicitly instructed to search for analogies (Dunbar, 2001; Gick & Holyoak, 1983; Holyoak, 1984; Spencer & Weisberg, 1986). Experiment 2 examined whether any enhancing effects of training in category construction are strong enough to be obtained without participants being explicitly informed regarding the relevance of the training to problem solving.

EXPERIMENT 1

The aim of the experiment was to provide evidence for the hypothesis that participants who received training to consider secondary (i.e., goal-derived) categories of items in addition to primary (i.e., taxonomic) categories of items would exhibit better performance on insight problem solving. Furthermore, this study aimed to examine whether goal-derived categorization training would be beneficial to problem-solving performance as a general cognitive strategy or whether training with problem-specific items would be required for the occurrence of potential enhancing effects. The goal of the experiment was, therefore, to investigate whether participants who would encounter critical items (i.e., those playing an important role in the solution to the problems) in the categorization task would show improved problem-solving performance relative to both nontrained and simple categorization task participants. A final aim of Experiment 1 was to explore whether the use of a different type of creative-thinking training that is not related to categorization would have positive effects on problem solving similar to those obtained with the use of the alternative categorization training. That is, this experiment aimed to examine whether creative thinking in general or categorization specifically would improve problem-solving performance.

Method

Participants

A total of 140 Temple University undergraduates (45 men, 95 women; mean age = 19.06 years) were recruited to participate in this study as partial fulfillment of an introductory psychology course. All participants were native English speakers.

Materials

Pre-Problem-Solving Measures

There were four pre-problem-solving measures. A brief description of each measure follows (for details, see Chrysikou, in press):

The Alternative Categories Task (ACT). The ACT, inspired by Barsalou's (1983) categorization studies, is a variation of the Unusual Uses Test (Christensen & Guilford, 1958). The test is presented in the form of a seven-page questionnaire and requires participants to consider 12 common items (e.g., shoe, fork). Each item on the test belongs in a common category, which is stated (e.g., for "shoe" the common category is "item used as footwear"). Participants are to list as many as six other categories to which each of the items might also belong (e.g., a shoe could also be something to pound a nail into the wall). The duration of the task is approximately 15 min.

The Alternative Categories With Critical Items Task (ACT-C). The ACT-C is a variation of the ACT that includes items of key importance for the solution to the seven insight problems used in this study that followed the pre-problem-solving phase (e.g., "box," which is an item of key importance for the Candle problem).

The Embedded Figures Test (EFT). The EFT (Witkin, Oltman, Raskin, & Karp, 1971) is assumed to draw on the concept of field dependence, namely how an individual's judgment is influenced by context. The EFT is a 25-item assessment contained in a 32-page booklet; the duration of the assessment is approximately 15 min. The participant's task on each trial is to locate a previously seen simple figure within a larger complex figure that has been so organized as to obscure or embed the sought-after simple figure (Witkin et al., 1971). As a result, scores on the EFT reflect extent of competence at perceptual (or field) disembedding. Competence on the EFT has been correlated significantly with better performance on insight problem solving (see Schooler & Melcher, 1995). As a result, the concept of field dependence is considered a reliable predictor of success in problem solving to the extent that insight problem solving requires ignoring the implicit context of the problem and seeking out an alternative perspective.

The Word Association (WA) test. The WA test (Christensen & Guilford, 1958) includes 100 stimulus words presented in two pages. These words are presented in two columns and are numbered 1–100. After reading each word, participants are asked to write the very first word that comes to their mind on the blank space beside the stimulus word. On the basis of previous findings (Chrysikou & Weisberg, 2004), the WA test does not seem to influence subsequent problem-solving performance; thus, it can be used reliably as a control pre-problem-solving task. In addition, the WA test occupies the same amount of time as the ACT, ACT-C, and EFT. As a result, any potential levels of fatigue when entering the problem-solving phase were expected to be equivalent across all participants.

Insight Problem-Solving Measures

Seven insight problems were used (see Chrysikou, in press): the Charlie problem (Weisberg, 1995b), the Fake Coin problem (Weisberg, 1995b), the Prisoner and Rope problem (Isaak & Just, 1995), the Candle problem (Isaak & Just, 1995), the Pyramid and Dollar Bill problem (Isaak & Just, 1995), the Two-String problem (Isaak & Just, 1995), and the Ten-Coin problem (Isaak & Just, 1995). As an example, the Candle problem (Isaak & Just, 1995) was stated as follows: "Your goal is to attach a candle to a wall so that it can burn upright. You have available a candle, a book of matches and a box of tacks. How would you solve the problem?"

Design and Procedure

Participants were randomly assigned to one of four experimental conditions: (a) ACT (n = 35), (b) ACT-C (n = 35), (c) EFT-Control A (n = 35), and (d) WA-Control B (n = 35). A power analysis based on the results of a pilot study (Chrysikou & Weisberg, 2004) indicated that, with moderate effect sizes, sample sizes of 35 participants per condition (N = 140) would provide a power of .80 to detect differences dependent on the experimental manipulation (Cohen, 1977). Each participant was tested individually, and all sessions were videotaped with the participant's consent. Participants were initially given a short questionnaire in which they were asked to provide demographic information and Scholastic Aptitude Test scores. Participants then received instructions regarding the experimental phase.

Pre-Problem-Solving Phase

On completion of the consent forms and introductory measures, two thirds of participants (i.e., 24 of the 35 participants per condition) received instructions for thinking aloud while performing the tasks. Specific guidelines concerning this process were given to the participants before the pre-problem-solving tasks began.

Verbal protocols have been widely used in problem-solving studies to provide a comprehensive record of participants' thinking processes while solving different types of problems. Concurrent verbalization has not been found unequivocally to influence negatively performance in problem-solving tasks (Ericsson & Simon, 1993; see also Bloom & Keil, 2001; Chrysikou & Weisberg, 2005; Dominowski, 1998; Reisberg, 2000; Taylor & Dionne, 2000). Nonetheless, to obtain some control regarding any potential influence of the verbalization procedure on participants' performance, in each condition one third of participants were not asked to think aloud. This strategy aimed to investigate any differences between participants who verbalized during the task (verbalization group) and those who did not verbalize during the task (nonverbalization group). The instructions for the verbalization group were modified from Perkins (1981) (p. 33) and can be found elsewhere (Chrysikou & Weisberg, 2005; Fleck & Weisberg, 2004). To ensure that participants read the instructions for the experimental tasks in their entirety, all participants were required to read the task instructions aloud.

After completing the introductory phase, participants were given instructions on the pre-problem-solving tasks. Participants in the ACT condition were given the Alternative Categories Test, participants in the ACT-C condition received the Alternative Categories Test including the key elements, whereas the EFT condition received the EFT, and the WA condition received the WA test. The order of presentation for the items included in the ACT and ACT-C tasks was randomized for each participant.

Problem-Solving Phase

After completing the pre-problem-solving phase, participants were asked to solve the seven insight problems. Each problem was presented individually, and the order of the problems was randomized. Problems were presented on paper, and each was numbered. No titles were presented for the problems to avoid possible influences of the titles on participants' interpretations of each problem.

For the ACT, ACT-C, and EFT groups, participants received specific task instructions regarding the relevance of the pre-problem-solving task. The instructions were as follows: "Keep in mind that the way of thinking that you employed during the task you just completed might be helpful for you when solving the problems." These instructions were given both at the beginning and at the end of the instructions to the problem-solving phase. In addition, previous results (Chrysikou & Weisberg, 2004) have indicated that the effectiveness of the instructions regarding the relevance of the pre-problem-solving task progressively diminishes from the first to the last problem in the problem-solving phase. Consequently, these instructions appeared as a reminder, right after each problem description, to ensure their effectiveness.

To obtain baseline measures regarding participants' performance on the insight problems after they had received a type of pretest, the experimenter gave participants in the WA condition neutral task instructions. These instructions were as follows: "Keep in mind that these problems are not very easy, so try to do your best and not become discouraged."

The time allocated for each problem was 8 min. While solving the problem, whenever participants felt that they had reached the correct solution, they asked the experimenter, "Is this answer correct?" The experimenter told the participant either that the answer was correct and proceeded to the next problem or that the answer was incorrect and that they should keep on working on the problem until either they reached the correct solution or the entire time had elapsed. After completing the test problems, participants were administered a short questionnaire intended to assess their familiarity with the experimental problems. Finally, participants were debriefed as to the purposes of the experiment, and they were asked not to reveal information regarding the study to their classmates. The duration of the experiment was approximately 90 min.

Results and Discussion

For Experiment 1, the type of task administered prior to the problem-solving phase (i.e., ACT, ACT-C, EFT, WA) composed the independent variable; performance on the seven insight problems, as measured by solution rates (i.e., solved, not solved), was the dependent variable. For each participant, data from problems that were identified as familiar were excluded from all analyses (6.4% of all problems across conditions). There were no differences among conditions regarding the number of problems excluded, $F(3, 24) = 0.92$, $p = .44$. A series of statistical analyses did not reveal any significant differences between the verbalization and nonverbalization groups (for details, see Chrysikou, in press); therefore, participants' scores were collapsed for an overall analysis, so as to maintain optimal power levels to detect differences among the four conditions.

Participants' performance (solution proportion) was averaged across all seven insight problems (for specific comparisons among conditions by problem separately, see Chrysikou, in press). An exploratory data analysis did not reveal any violations of the assumptions of homogeneity and normality of the data. To examine any significant differences in problem-solving performance among the four conditions, planned analysis of variance (ANOVA) contrast comparisons on solution rate percentages across the seven problems were performed. The comparisons between condition pairs were as follows: (a) ACT versus ACT-C, (b) ACT versus EFT, (c) ACT versus WA, (d) ACT-C versus EFT, (e) ACT-C versus WA, and (f) EFT versus WA. Given that the number of tests to be conducted would result in the inflation of the experimentwise error rate, a significance level of $\alpha = .05/6 = .008$ (Bonferroni correction) was used for all pairwise contrast comparisons.

According to the results of the contrast-based analysis, the ACT condition notably outperformed the EFT and WA conditions, $F(1, 136) = 27.01$, $p < .001$, and $F(1, 136) = 19.25$, $p < .001$, respectively (see Table 1). Similarly, the ACT-C condition outperformed the EFT and WA conditions, $F(1, 136) = 21.24$, $p < .001$, and $F(1, 136) = 14.42$, $p < .001$, respectively (see Table 1). In addition, the effectiveness of the training manipulation was not dependent on the specific inclusion of the key items in the ACT-C task, as the ACT and ACT-C conditions did not differ significantly from each other, $F(1, 136) = 0.35$, $p = .56$ (see Table 1). Finally, training with the EFT did not have any positive effects on problem-solving performance, as the EFT condition did not differ significantly relative to the WA condition, $F(1, 136) = 0.66$, $p = .42$ (see Table 1); for all pairwise contrasts, $MSE = 0.46$. It should be noted that for all significant comparisons, the measures of effect size were medium, ranging from $\omega^2 = .03$ to $\omega^2 = .04$.

Table 1
Solution Rate Proportions for Experiments 1 and 2

Condition	Proportion solution for Experiment 1		Proportion solution for Experiment 2	
	M	*SD*	*M*	*SD*
ACT	.57	.16	.58	.16
ACT-C	.54	.20	.61	.19
EFT	.34	.19	.41	.19
WA	.38	.18	.42	.21

Note. ACT = Alternative Categories Task; ACT-C = Alternative Categories With Critical Items; EFT = Embedded Figures Test; WA = Word Association test.

In conclusion, the results of the planned ANOVA contrast comparisons provide strong support for the experimental hypothesis. Experiment 1 showed that training to construct goal-derived categories by means of the ACT and ACT-C tasks significantly enhanced participants' solution rates on insight problem solving. Furthermore, this effect did not increase with specific training with the items that are crucial for the solution to the insight problems. This finding suggests that the observed improvement in problem-solving performance in the ACT and ACT-C conditions is due to the training in the process of goal-derived category construction and, therefore, is not item specific. Finally, the absence of any positive effects of pre-problem-solving training with the EFT (i.e., a creative thinking task that is not related to categorization) on problem-solving performance, along with the lack of significant differences between the EFT and WA conditions, suggests that the improved problem-solving performance in the ACT and ACT-C conditions cannot be attributed to a general training to "think flexibly," but rather to a specialized training in goal-derived category construction.

EXPERIMENT 2

Experiment 1 examined the effects of explicitly training participants by means of a categorization task to construct goal-derived categories on subsequent insight problem-solving performance. Experiment 2 was a follow-up investigation examining whether the positive effects of the categorization training on problem-solving performance obtained in Experiment 1 would also be observed when participants did not receive explicit instructions regarding the relevance of the pre-problem-solving task to the problem-solving phase. If the ACT and ACT-C training relative to the EFT and WA training enhanced problem-solving performance implicitly, that is, without participants being informed of the relevance of this training to problem solving, then the potential positive effect of the alternative categorization task on problem solving could override participants' tendency not to transfer spontaneously knowledge or strategies from one task to another (e.g., Dunbar, 2001; Gick & Holyoak, 1983) and, thus, was likely to be obtained in Experiment 2.

Method

Participants

A total of 80 Temple University undergraduates (18 men, 62 women; mean age = 20.53 years), who did not take part in Experiment 1, were recruited to participate in this study as partial fulfillment of an introductory psychology course. All participants were native English speakers.

Materials

The materials were the same as in Experiment 1.

Design and Procedure

Participants were randomly assigned to one of four experimental conditions: (a) ACT ($n = 20$), (b) ACT-C ($n = 20$), (c) EFT-Control A ($n = 20$), and (d) WA-Control B ($n = 20$). The design was the same to that of Experiment 1. As in Experiment 1, two thirds of participants ($n = 52$) received instructions for thinking aloud while performing the tasks, whereas one third of participants ($n = 28$) were not asked to think aloud. The pre-problem-solving, problem-solving, and debriefing procedures were the same as in Experiment 1. The only difference was that participants received the pre-problem-solving training tasks and directly proceeded to the problem-solving phase without being instructed to use the same type of thinking they used for the training task while solving the problems.

Results and Discussion

On the basis of the results of Experiment 1, participants in the ACT and ACT-C conditions were expected to exhibit higher solution rates, relative to participants in the EFT and WA conditions, which were not expected to differ from each other. In addition, participants' problem-solving performance between the ACT and ACT-C conditions should not have exhibited any significant differences. Scoring was the same as in Experiment 1. For each participant, data from problems that were identified as familiar were excluded from all analyses (8.6% of all problems across conditions). There were no differences among conditions regarding the number of problems excluded, $F(3, 24) = 0.50$, $p = .69$. Similar to Experiment 1, a series of statistical analyses did not reveal any general significant differences between the verbalization and nonverbalization groups (for details, see Chrysikou, in press). Participants' scores were, thus, collapsed for an overall analysis so as to maintain optimal power levels to detect differences among the four conditions.

Participants' performance (solution proportion) was averaged across all seven insight problems (for specific comparisons among conditions by problem separately, see Chrysikou, in press). To examine any significant differences in problem-solving performance among the four conditions, planned ANOVA contrast comparisons on solution rate percentages across the seven problems were performed. All assumptions of homogeneity and normality of the data were satisfied for this analysis. The comparisons were the same as in Experiment 1; a significance level of $\alpha = .05/6 = .008$ (Bonferroni correction) was used for all pairwise contrast tests.

According to the results of the ANOVA contrasts analysis, similar to the findings observed in Experiment 1, the ACT and ACT-C conditions showed significantly better overall problem-solving performance relative to the EFT and WA conditions, all Fs(1, 76) ranging from 6.86 to 10.82, $p < .001$ (see Table 1). The only exception was the comparison between the ACT and WA conditions for which the results were only marginally significant ($p = .01$, with $\alpha = .008$, Bonferroni correction). Relative to the first experiment, this difference is most probably attributed to the smaller sample size per cell (and, thus, lower power) for Experiment 2; nonetheless, the effect was in the expected direction, and the measure of effect size for this comparison was medium ($\omega^2 = .07$). Similar to Experiment 1, there were no significant differences observed between the ACT and ACT-C conditions, $F(1, 76) = 0.24$, $p = .63$ (see Table 1), or between the EFT and WA conditions, $F(1, 76) = 0.03$, $p = .85$ (see Table 1); for all pairwise contrasts, $MSE = 0.20$. For all significant comparisons the measures of effect size were medium, ranging from $\omega^2 = .06$ to $\omega^2 = .07$.

Overall, the results of Experiment 2 replicate the findings of Experiment 1 and provide further support for the effectiveness of the categorization training on problem-solving performance that was observed even when participants were not provided with additional instructions regarding the relevance of the pretask to problem solving. In fact, the findings from Experiment 2 suggest that the effects of training in alternative category construction on insight problem solving can be obtained implicitly and are strong enough to overcome participants' tendency to avoid transferring strategies from one task to another without additional explicit instructions.

GENERAL DISCUSSION

The studies presented in this article provide experimental evidence for the implication of goal-derived categorization in problem-solving processes. It was hypothesized that if such categorizations are critical for problem solving but do not occur spontaneously (at least to a sufficient extent for the solution to be reached), then training in goal-derived, ad hoc category construction should enhance participants' performance on typical ill-defined tasks. The studies presented in this article strongly support this hypothesis. According to the results of Experiment 1, participants in the ACT and ACT-C conditions exhibited significantly higher solution rates across all problems relative to participants in the EFT and WA conditions. Furthermore, this effect was not item specific, as participants in the ACT-C condition, who received specific training on the critical-for-the-solution items, did not show improved performance relative to participants in the simple categorization task (ACT) condition. In addition, it was shown that the observed effects were not attributed to a general training with tasks that have been associated with problem solving and creative thinking because participants in the EFT condition, who received an unrelated-to-categorization training in "flexible thinking," did not exhibit improved performance relative to the control (WA) condition. Experiment 2 replicated these findings and showed that the effects of the alternative categorization training could be obtained without participants receiving specific instructions regarding the relevance of the training to problem solving, contrary to what research on analogical transfer has suggested (e.g., Dunbar, 2001; Gentner, 1983; Spencer & Weisberg, 1986). Further analyses

(Chrysikou, 2005a; see also Chrysikou, 2005b) strongly supported the conclusion that categorization is a critical component of problem-solving processes with predictive supremacy relative to other factors typically regarded as fundamental in problem solving, such as gender and general intellectual ability.

The absence of differences between the ACT and ACT-C conditions, which was confirmed in both experiments, suggests that the categorization training facilitated the process of instantiation of frame attributes within the context of each problem during problem solving. That is, participants in the ACT-C condition encountered the critical items in the pre-problem-solving phase; however, the goal-derived categories that they generated for those items were not necessarily relevant to the problems they were subsequently asked to solve. Thus, participants in the ACT and ACT-C conditions benefited equally from the experimental manipulation in goal-derived category construction. Although the analysis of participants' concurrent verbalizations that were collected during Experiments 1 and 2 would go beyond the scope of the current article (for details, see Chrysikou, 2006), verbal protocols revealed that participants in the ACT and ACT-C conditions were more likely to construct and instantiate goal-derived categories regarding problem elements relative to participants in the EFT and WA conditions, which may have accounted for their enhanced problem-solving performance (for examples, see Chrysikou, 2006).

The present research is complementary to past and current theories of problem solving (e.g., Chronicle et al., 2001, 2004; Duncker, 1945; Hamel & Elshout, 2000; Jones, 2003; Simon, 1986, 1990; Weisberg, 1995a, 1995b), particularly by addressing the contribution of knowledge structures to problem solving through categorization processes (for a comprehensive framework, see Chrysikou in press, 2006). In addition, contrary to most previous problem-solving studies that have focused on one problem (for exceptions, see Ansburg & Dominowski, 2000; Fleck, 2005; Schooler & Melcher, 1995), the current experiments examined the effects of the categorization training in a variety of problems. Further studies examining the effectiveness of training with taxonomic versus ad hoc categories are expected to provide additional support for the critical role of goal-derived categorization in problem solving.

Aside from the significance of the current studies for problem solving research, this article may also have important implications for categorization theories. In particular, the transient nature of online class-inclusion processes remains largely unexplored in concept research (Murphy, 2002). That is, many traditional research paradigms in the field of concept acquisition use tasks involving isolated, de-contextualized categories as stimuli and typically require participants to perform some variation of a taxonomic organization task. However, the absence of more complex, ecologically valid tasks significantly reduces the generalizability of the findings as well as limits new knowledge regarding online categorization processes outside the laboratory. In addition, although most categorization tasks focus on participants' ease at establishing taxonomies, dynamic cognition focuses mostly on building and maintaining world models while establishing meaningful references with the world (Barsalou, 1993). Few studies (e.g., Barsalou, 1991; Barsalou & Hutchinson, 1987; Ross & Murphy, 1996) have examined how people use categories in realistic, everyday cognition tasks. In the light of these issues, the current findings examine categorization processes in a dynamic problem-solving task. As such, they provide support for Barsalou's (1991, 1992) theoretical accounts on frame instantiation processes as well as complement earlier findings on categorization.

In conclusion, the evidence presented in this article strongly suggests that the ways in which individuals employ their knowledge when planning strategies to achieve goals involve goal-derived and, particularly, ad hoc categorizations. The examination of problem solving through a model that is founded on higher order conceptualization processes may further encourage the possibility of advancing problem solving into the core of a mainstream theory of cognition.

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