

Opportunistic Planning: Being Reminded of Pending Goals

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Pending goals are intentions that are postponed by a planner because they do not fit into the current, ongoing activity. Recognizing later opportunities to achieve pending goals is an important cognitive ability because it allows one to defer work on a goal until one is in a better position to achieve it. This research focuses on when and how pending goals are recognized in everyday planning situations and offers a *predictive encoding* model of goal representation. Experiment 1 provides evidence that pending goals are stored as long-term memory elements that become associated, at the time of encoding, with features of the environment representing opportunities to achieve the goals, consistent with the predictive encoding model. Experiment 2 shows that these predictive inferences tend to be concrete (e.g., “use Vaseline to remove a stuck ring”), rather than more abstract (e.g., “use any lubricant”), which is nonoptimal for recognizing novel opportunities. However, as shown in Experiment 3, instructions to encode a potential plan with only abstract constraints can lead to recognition of a wider range of opportunities. These findings provide evidence for the predictive encoding model and suggest ways to facilitate the later recognition of opportunities for satisfying pending goals. © 1997 Academic Press

Planning—the ability to anticipate a series of actions intended to culminate in the achievement of a goal—requires the capacity to successfully postpone and resume the pursuit of goals. In everyday planning, it is often the case that many goals arise simultaneously. In order to plan for some of these goals, others must be postponed until more important goals have been achieved. Resources and constraints in the environment also contribute to the need to

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be able to postpone and resume pursuit of goals. If a required resource is not currently available, the plan to achieve a goal must be suspended until that resource becomes available. Successful planning, then, depends on learning how to prioritize goals, to postpone achievement of goals due to low priority or lack of available resources, and to resume pending goals when their priority increases or needed resources become available.

Miller, Galanter, and Pribram (1960) identified planning for everyday goals and actions as an important cognitive function. Their book, *Plans and the Structure of Behavior*, introduced key assumptions: that plans are organized as hierarchical sequences of operations and that these operations are stored in memory and then executed serially. Since then, few behavioral studies in cognitive psychology have investigated behavior in common-sense planning situations (i.e., situations in which it is relatively straightforward to generate a reasonable plan to achieve a goal). Instead, the focus has been on more difficult tasks where straightforward planning fails because an impasse is reached and problem solving is required to resolve the impasse (e.g., the “Tower of Hanoi” and “Missionaries and Cannibals” problems; c.f. Van Lehn, 1989). Exceptions include a study by Byrne (1977), in which participants with cooking experience talked aloud as they planned meals for dinner parties. The successful meal plans generated showed substantial reuse of earlier planning experiences in memory. Lichtenstein and Brewer (1980) demonstrated that knowledge about typical plans is organized schematically in memory, and Barsalou (1983) found not only that college student participants were competent at generating plans for novel goals (“Ways to Make Friends”), but that these “ad hoc” categories had features such as graded structures commonly associated with more well-established categories.

A classic study by Hayes-Roth and Hayes-Roth (1979) introduced a paradigm that engaged participants’ common-sense planning abilities. Think-aloud protocols were collected as participants planned a route to complete a set of errands within a specified time frame. The participants were presented with a list of 12 goals to achieve, such as “pick up clothes at the dry cleaners,” “see a movie at 1, 3, or 5 P.M.,” and “buy today’s newspaper at the newsstand.” The participants’ task was to construct a master plan for achieving these goals using a schematic map depicting neighborhood businesses where the goals could be achieved. The results provided evidence that people use multiple strategies for ordering goals. Participants ordered their goals on the basis of such strategies as “achieve most important goals first,” “achieve goals in order of proximity to one another,” and “achieve goals that have approaching deadlines.” Furthermore, participants shifted strategies opportunistically. For example, if one were pursuing the strategy “achieve most important goals first,” but passed a location in which a less important goal could be readily achieved, the “achieve goals in order of proximity” strategy might be adopted and the less important goal might be incorporated into the ongoing plan.

This paradigm captures an important aspect of planning behavior, namely, the problem of ordering a set of goals to be achieved. Most interestingly, while planning out a route following these initial strategies, participants often appeared to notice opportunities to achieve other goals. For example, a participant planning to proceed toward the bank to satisfy a high-priority goal then noticed that her planned route passed by the dry cleaning shop where she needed to pick up a cleaning order. These “opportunities” to group together plans that have similar requirements (being at a specific physical location) could result in more optimal, less effortful execution. Participants frequently mentioned noticing these congruences of plan requirements and modified their current planning so as to take advantage of them (e.g., by planning to stop at the dry cleaner on the way to the bank). Hayes-Roth and Hayes-Roth described this behavior as “opportunistic planning,” in which participants appeared to spontaneously take advantage of unforeseen opportunities to achieve their goals.

However, the opportunism observed in the Hayes-Roth and Hayes-Roth paradigm was somewhat limited since it involved altering only the intended order of plan execution. In addition, the participants’ task did not require remembering the goals to be achieved apart from the “world” where their plans would later be executed. In the task, a list of goals was provided throughout the experiment, so that participants could readily compare the goals to the actual locations of businesses on the town map. All of the information that is normally unavailable during planning (e.g., that the newsstand is next door to the bank) was displayed to participants throughout the task. Finally, the generation of plans was simplified such that the same basic plan was needed to achieve each goal, that is, to go to the location stated in the goal. Only a few of the goals could be satisfied by more than one plan, and even these were only slightly different (e.g., seeing a movie at either 1, 3, or 5 P.M.) or involved two potential locations for their satisfaction (viewing an apartment for rent in one of two buildings). Consequently, all available opportunities to achieve goals were accessible from the time that the participants first comprehended the goals, rather than after thoughtful deliberation or exposure to unexpected opportunities.

While the planner in this paradigm possessed location information normally available only during execution, everyday planning often involves a less omniscient planner. Typically, there is a planning phase, in which a sequence for execution may be generated, and then a “situated” phase, in which planning resumes in the face of the actual circumstances present at execution. For example, suppose the bank is closed for lunch, or the newsstand is out of today’s paper. Execution must again be “suspended” (Schank & Abelson, 1977) and the pending goal stored in memory to return to at a later time. A record of the need to resume pursuit of a suspended goal is available only from memory, and the new circumstances that will enable its satisfaction may not be foreseeable. For example, a newspaper carrier may cross one’s path

in the street, providing an easy opportunity to acquire today's paper. More generally, then, opportunistic planning requires retrieving a goal from memory at some future, unspecified point in time when circumstances are perceived that are conducive to satisfying a pending goal.

Thus, opportunistic planning may be defined as the problem of *recognizing* the relevance of a pending goal in memory given circumstances in the current environment (Birnbaum, 1986; Birnbaum & Collins, 1984). People may sometimes fail to take advantage of such opportunities, especially those not readily apparent from cues in the environment. For example, imagine that you need stamps to mail some bills. You might stop to buy milk at the grocery store on your way home from work, failing to recognize that you could probably buy the needed stamps there too. What available cues in the store environment (such as a "U.S. Post Office" sign above the service desk) would be needed in order to result in the recognition of this opportunity? The ability to create potential plans and postpone their execution, to recognize new circumstances as opportunities, and to usefully incorporate unforeseen circumstances "on the fly" is important for the efficient pursuit of multiple goals.

A MODEL OF OPPORTUNISM

What cognitive processes are involved when opportunities to satisfy pending goals are successfully recognized? Our model (Hammond, Converse, Marks, & Seifert, 1993; Hammond & Seifert, 1994; Seifert & Patalano, 1991; Seifert, Hammond, Johnson, Converse, McDougal, & Vanderstoep, 1994) proposes that plan-related inferences are best drawn at the time of initial planning, when the planner can devote his or her cognitive resources to the task. Then, the results of inferential processing can be "cached" in memory as prepared associations between pending goals and potential stimulus features. The recognition of pending goals is achieved by indexing the suspended goal in memory in terms of features of the environment that are related to its achievement. Later, these prepared memory indices are more likely to automatically, through associations, retrieve the goal from memory when the indices are observed in the environment. This "predictive encoding" model accounts for the recognition of later opportunities based upon planning inferences drawn at the time of the initial encoding of the suspended goal.

Optimally, based upon the planning connections drawn, the inferential connections stored in the memory representation during planning should include features of stimuli that are likely to be easily noticed in the later environment (Hammond et al., 1993). That way, matching a new stimulus to a suspended goal can take place as a consequence of the usual, ongoing perceptual processing that occurs while pursuing other goals in the environment. Instead of examining each new object and attempting to connect it to pending goals, recognition instead occurs through normal comprehension processes. Consider an example from "TRUCKER" (Marks, Hammond, &

Converse, 1989) a computer model of a parcel pickup and delivery task in which new orders are continually received. When TRUCKER receives a goal that it cannot immediately accomplish (because all of its trucks are busy), the goal is added to a list of pending goals to be executed at a later time. For example, a request to pick up a package at "the Sears Tower" in Chicago may be added into memory. How does this goal then get reactivated for pursuit at a later time? At the time of encoding, TRUCKER connects the goal with its internal representation of the Sears Tower. As a result, if a truck later passes the Sears Tower, its perceptual processing of the tower automatically activates the goal in memory so that it can now pursue the suspended goal by stopping at the Tower to pick up the package.

In order to recognize less obvious opportunities, the agent will need to *predict* the features that are critical to opportunities for a specific goal. Of course, the degree of inference performed in advance may vary, and individual agents will be more or less successful at anticipating features related to opportunities. If little inferential processing occurs, then the goal (e.g., get a newspaper) may be indexed in memory with straightforward features (like "newsstand" and "corner paper box"). If more inferences are drawn about other potential circumstances for achieving the goal ("people usually leave their copy after having coffee"), then other features ("coffee shop") can also be used to index the goal in memory. Recognition of opportunities, then, depends on the quality and generality of the indices generated at the time of encoding the suspended goal into memory, rather than on later inferential processes. As a result, the planner is freed from the need for complex inferential processing in order to recognize opportunities, which is particularly important when the planner is actively engaged in pursuing other goals when the opportunities arise (Seifert et al., 1994).

The predictive encoding model implies that not all opportunities will be recognized. Rather, only those opportunities that are anticipated and used to encode the goal into memory will result in retrieval when the matching stimuli occur in the environment. Of course, an agent can always create explicit plans later if no opportunities to achieve the goals arise in the meantime. However, every time a goal can be achieved by taking advantage of a nearby opportunity, the resulting savings can substantially reduce effort required from the planner. The predictive encoding model specifies how to elaborate at encoding so as to maximize the likelihood of recognizing useful opportunities while minimizing the cognitive effort required for recognition. Consequently, predictive encoding can be a very valuable ability when an agent's goals exceed the resources available for their pursuit.

In the following experiments, we examine the predictive encoding model through a planning task designed to tap participants' everyday knowledge of goal pursuit in a familiar domain. We created a paradigm that instantiates several important properties of opportunistic situations while providing con-

trolled measurement of recognition. Our goals were to determine how often unanticipated opportunities are recognized, when this recognition tends to occur, and what factors might promote the recall and pursuit of pending goals at opportune times.

OVERVIEW OF EXPERIMENTAL PARADIGM

The paradigm used in the experiments consists of a *goal study phase*, a *reminding phase*, and a *recall phase*. In the goal study phase, our college student participant reads a scenario in which he or she is asked to imagine being left alone in a friend's dormitory room for a short period of time. The scenario then presents a set of goals that the participant needs to achieve in the room, such as to "retrieve an elastic band from a high shelf." Ten goals are presented serially, and the participant is asked to make a mental note of the goals since he or she will be tested on them later. This phase establishes a set of pending goals in memory for the participant. Further, in some conditions, participants are exposed to plans for these goals (e.g., "if only you could find a chair to stand on, you might be able to retrieve the elastic band"), or they are asked to generate such plans, in order to manipulate the encoding of these suspended goals into memory.

In the next phase of the experiment, the reminding phase, the participant is presented with descriptions of a series of objects available in the dormitory room, such as a "roll of tape in a desk drawer," followed by a "jar of Vaseline in the medicine cabinet." The participant is asked to record next to each object any of the goals from the study phase that come to mind. The reminders are used as evidence for memory connections between the cue and the information brought to mind (cf. Gentner & Landers, 1985; Johnson & Seifert, 1992; Ross, 1987; Seifert, Abelson, & McKoon, 1984; and Wharton, Holyoak, Downing, & Lange, 1994, for reminding methodologies). The cue objects used could be matched with a plan for one of the study goals ("chair" can be used to stand on in order to reach the elastic on the high shelf) or were filler objects not likely to be useful ("comb"). By considering when and how frequently plans to achieve goals are retrieved in response to object cues, we can measure the recognition of opportunities to achieve pending goals and compare performance under different goal encoding conditions.

Finally, in the recall phase of the experiment, the participant is asked to free recall all of the goals from the first part of the experiment. This will determine whether the study goals were sufficiently memorable to allow comparisons of reminding results. If a participant does not notice opportunities to achieve some goals during the reminding phase but later recalls these goals, it is possible to rule out poor memory for the goal as an explanation for the failure to notice an opportunity. In Experiment 1, this paradigm allows us to test the predictions of the predictive encoding model of opportunism: Is retrieval of pending goals affected by differences in how goals are encoded?

EXPERIMENT 1A

We are specifically interested in the following three questions. First, is there a difference in reminding performance when pending goals are committed to memory versus when they are present on a list during the reminding task (as in Hayes-Roth & Hayes-Roth, 1979)? Second, is there any improvement in reminding performance when the plan to achieve a goal is anticipated (i.e., associated with the goal) at the time of encoding as predicted by the predictive encoding model? And third, does the degree of facilitation depend on the depth of encoding (Craik & Lockhart, 1972) of the goal-plan connection? Experiment 1a was designed to address these questions by manipulating the type of memory encoding experienced for the goals across participants.

In this study, participants were assigned to one of four conditions: No-Memory Control, No-Plan Control, Given Plan, and Guided Plan. In the two control conditions, no suggestion was given at the time of encoding regarding planning to achieve each goal. In the No-Memory Control condition, participants did not have to commit the study goals to memory at all; instead, a list of the goals was available to these participants throughout the experiment. In the No-Plan Control condition, participants had to read and remember the set of goals for later testing. In the two planning conditions, the Given Plan and Guided Plan, in addition to reading the goals, participants were asked to anticipate a means of achieving each presented goal at the time of encoding. For example, in the Given Plan condition, after reading about retrieving an elastic band from a high shelf, the participant might read, "If only you had a chair, you could stand on it to reach the elastic band." In this way, participants were encouraged to create a link at encoding between a goal and one specific plan for achieving it. According to the predictive encoding model, participants should notice a significantly greater number of opportunities in response to cue objects that were anticipated during encoding of the goal. Alternatively, there may be no difference in goal reminders for cues related to an anticipated plan (e.g., chair) versus an unanticipated plan (e.g., "broom"), since the inference could simply be made by participants at the time of exposure to the cue.

The Guided Plan condition differed from the Given Plan condition in the following way: Participants were presented with the same objects as in the Given Plan condition, but had to generate a plan that would allow them to use each specific object (one object per goal) to achieve the presented goal (e.g., "Please write down how you could use a chair to achieve the goal of retrieving an elastic band from a high shelf"). Because the latter required generating the information rather than simply reading it, the resulting memory associations may be stronger, due to either a generation effect (Slamecka & Graf, 1978) or simply a greater depth of processing (Craik & Lockhart, 1972). As a result, there may be a larger difference between the recognition of

anticipated versus unanticipated opportunities in the Guided Plan condition compared with the Given Plan condition. However, the benefits of elaborative inference may be evident only when participants are exposed to anticipated cues, as the predictive encoding model implies.

Method

Participants

Participants were 171 undergraduates (89 men and 82 women) at the University of Michigan who participated in partial fulfillment of introductory psychology course requirements.

Materials and Procedure

Participants were randomly assigned to one of four conditions (No-Memory Control, No-Plan Control, Given Plan, or Guided Plan). All participants were tested in groups of 10–15 in 50-min sessions. They spent approximately 10–15 min on the study phase of the task, 5–8 min on the reminding phase, and 2–3 min on the recall phase, each of which will be described below. The procedure was the same for all conditions except where noted.

Scenario. Participants were given test booklets to read and complete. The instructions asked participants to imagine themselves in the following scenario:

Imagine that you are visiting your best friend, Chris, in her dormitory room. After chatting with one another for a while, you both hear a knock at the door. A neighbor peeks her head in and summons Chris to attend a spur-of-the-moment hall meeting. Chris announces she'll be back soon and strolls down the hall to see what's up.

In the first few minutes that you are alone in Chris's room, you realize that this is a perfect opportunity for you to do some snooping around. There are all kinds of things that you'd like to know about your friend Chris! And, if you are careful to leave no sign that you've tampered with anything, she'll never find you out.

Additionally, participants were given a drawing of the dormitory room to help them imagine the described scene.

Goal study phase. Participants were then presented with a set of 10 goals related to the scenario. Except in the No-Memory Control condition, 1 goal was written on each of the subsequent 10 pages of the workbook. Instructions stated that participants should read and make a mental note of each goal since they would need to retrieve the goals from memory at a later time. In the No-Memory Control condition, all 10 goals were presented on a single workbook page, and the instructions did not indicate a need to make a mental note of the goals. In all conditions, each goal was a description of something that the participant needed to accomplish in the dorm room before the friend returned. An example follows:

You notice that Chris left her new college ring on her bureau. You try it on your finger and it gets stuck. Chris will kill you if she finds out that you were so careless with her new piece of jewelry. You need to get the ring off before Chris returns.

All goals were tasks that could be accomplished using objects found in a typical dormitory room (see Appendix A). For example, the above goal might be accomplished by rubbing soap around the ring and attempting to slide it off.

In the two Plan conditions, participants either were given or were asked to generate further information. In the Given Plan condition, participants received a specific suggested plan for achieving each goal. The suggested plan was stated as the last line of each goal description. For example, appended to the goal of removing a ring from one's finger might be the statement: "You think that if only you had some Vaseline, you might be able to grease your finger and

slide the ring off.” The suggested plan was specific in the sense that it included mention of a particular object (such as “Vaseline”) that could be used to instantiate the plan. In the Guided Plan condition, participants were given the same objects as in the Given Plan condition, but were not told how each object could be used to achieve its goal. Rather, for each object, participants were asked to “Please describe how you might use Vaseline to achieve your goal.” The objects used in these 2 conditions are shown in Appendix B.

Reminding phase. Following the goal study phase of the experiment, all participants were told to imagine that, as they continued inspecting the dorm room, they encountered numerous objects which might be useful in achieving their goals (see Appendix B for object cues). One object cue was described on each of the subsequent pages of the workbook. For example, an object description might be: “The only thing you find under the sink is a jar of Vaseline. If you could use the Vaseline in a plan to achieve any of your goals, record the plan(s) below.” Participants were instructed to read about each object and, if they believed the object could be used to achieve an earlier goal, to record their plan for using the object presented. Participants were tested with 10 goal-related objects and 5 filler objects presented in one of two random orders. In the No-Memory Control condition only, participants were instructed to remove from their workbooks the page containing the earlier list of goals and to refer to the list while completing this portion of the experiment.

The goal-related objects were selected from compilations of object-based plans generated by 15 pretest participants. Constraints placed on cue object selection were that: (1) the object was generated for that goal by at least $\frac{1}{3}$ of the participants and (2) the object appeared most relevant to achieving only 1 of the study goals. Two objects were selected to match each of the study goals, constituting 2 equivalent sets of cue stimuli. Each of the 2 objects used to achieve the same goal was a part of a different plan for achieving that goal (e.g., Vaseline and soap were not both selected for the goal of removing the stuck ring since both involve the plan of lubricating one’s finger). Objects generated with higher and lower frequency by pretest participants were divided equally among the 2 sets, and the same 5 filler objects were added to each set. The objects were presented in a single random order for all participants, and each of the 2 cue sets was given to $\frac{1}{2}$ of the participants in the experiment.

The goal-related objects from the reminding phase also served as goal study phase suggestions in the Given Plan and Guided Plan conditions previously described (as shown in Appendix B). In these conditions, $\frac{1}{2}$ of the planning suggestions given to a participant were drawn from the set of goal-related objects serving as the participant’s reminding cues. The other $\frac{1}{2}$ of the suggestions were drawn from the set not serving as reminding cues for that participant. Materials were counterbalanced so that each reminding cue matched a planning suggestion for approximately $\frac{1}{2}$ of the participants receiving that cue. For a given participant in the Given or Guided Plan conditions, 5 of the reminding cues matched the plans they had been given or had generated, 5 of the cues were relevant to goals for which they had prepared other plans, and 5 were filler cues.

Recall phase. Finally, participants (excluding the No-Memory Control) were asked to recall as many goals as they could from the first part of the experiment. They were instructed to write only enough about each goal so that the experimenter would know which of the goals they were referring to.

Results

Goal Study Results

In the Guided Plan condition only, participants were asked to generate plans for using a presented object to achieve the stated goal. An independent coder reviewed these plans and verified that exactly one plan was generated

by each participant on each trial. All of the generated plans were consistent with those given to participants in the Given Plan condition.

Reminding Results

Reminding data were scored by counting a response as an instance of a reminding whenever it uniquely identified one of the earlier goals. Participants tended to describe the goals accurately and almost verbatim. The majority of the responses could be unambiguously identified as one of the study goals, and those that could not fell into one of two categories and were scored as "Other." A few participants reported goals not presented as target goals yet plausible in the stated scenario. For example, in response to the filler cue comb, one participant wrote, "I would use it to comb my hair since it must be messed up by now and I wouldn't want my friend to know that I had been doing anything." The second set of responses appeared to be confused or combined target goals; for example, "I would use it [student directory] to look up the number of the guy she's interested in dating" (a combination of Goals 2 and 6 in Appendix A). Of 2128 responses, 132 (6%) fell into the category of Other and were excluded from the analyses.

Two types of reminding scores were computed for each participant: the percentage of target reminders and the mean number of nontarget reminders per cue. For participants in the two planning conditions, the percentage of target reminders was further divided into two scores: the percentage generated in response to anticipated cues (those considered at the time of goal encoding) versus the percentage generated in response to unanticipated cues. Similarly, the mean number of nontarget reminders was further broken down by cue type (anticipated, unanticipated, and filler) in the two planning conditions. An example of a nontarget reminding in response to an anticipated cue would be to write the goal "retrieve elastic band" in response to the cue "hair dryer," when hair dryer had been associated during the goal study phase with another goal. This example would be scored as a nontarget reminding if written in response to an unanticipated cue (if hair dryer had not been associated with any goal during study). An increase across conditions in the percentage of target reminders generated without a corresponding increase in the mean number of nontarget reminders would indicate increased recognition of opportunities to achieve pending goals (it is the ability to discriminate good cue-goal matches from poor ones). An increase in both would indicate an increase in responses generated, but not necessarily an increase in the ability to recognize opportunities.

First, is there a difference in reminding performance in the No-Plan Control condition compared to the matching of goals to cues in the No-Memory Control condition? As indicated in Fig. 1, a mean of 89% of all target reminders were generated in the No-Memory Control condition (where the list of goals was always displayed), compared with 74% in the No-Plan

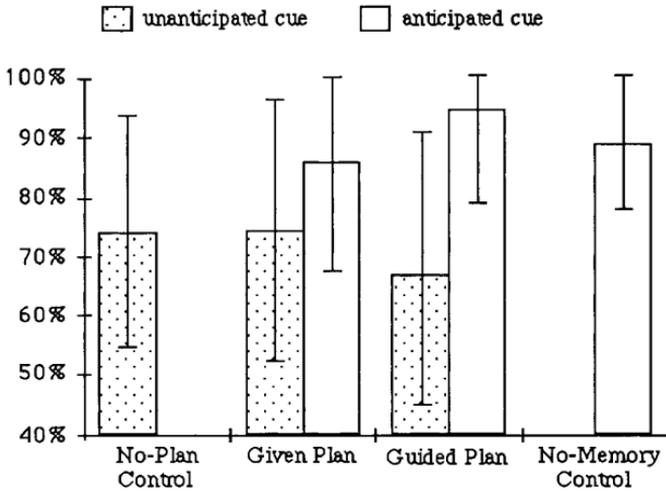


FIG. 1. Percentage of target goal reminders in response to unanticipated versus anticipated cues for each study condition in Experiment 1a.

Control condition, $F(1,72) = 13.67$, $p < .001$. As indicated in the first two lines of Table 1, a mean of 0.18 nontarget reminders were generated in the No-Memory Control condition while 0.31 were generated in the No-Plan Control condition, $F(1,72) = 6.05$, $p < .016$. Overall, participants' performance decreased in the No-Plan compared with the No-Memory condition, suggesting that opportunity recognition is impaired when goals must be kept in memory compared to matching the goals to the cues. These results suggest that memory processes do affect opportunism, so that the results in Hayes-Roth and Hayes-Roth (1979) (where the goal list was also provided throughout the experiment) may overestimate opportunistic behavior compared to situations where the pending goals are available only from memory.

In the No-Memory Control condition, participants generated a mean of approximately 9 out of 10 target reminders, and 0.18 nontarget reminders. This serves as a check on the quality of the materials. Recall that the intention was to choose object cues for which there is general agreement as to whether or not the objects can be used to achieve the intended goals. The high performance of participants in this nonmemory condition, in which both the objects and the goals were always available to participants, suggests that there was agreement as to the relevance of each object cue. In general, nontarget reminders included less plausible responses, such as: "I would throw the shoe at the elastic on the shelf to try to knock it down," "I would wedge the paper clip under the ring to try to remove it," and "I would use the masking tape to try to dry the shirt."

Next, is there significant improvement in reminding performance in re-

TABLE 1
Mean Number of Nontarget Reminders as a Function of Cue Type
and Study Condition in Experiment 1a

Study condition	Cue type			
	Unanticipated	Anticipated	Goal available	Filler
No-Memory Control ($N = 31$)	—	—	0.18 (.20)	0.44 (.38)
No-Plan Control ($N = 43$)	0.31 (.30)	—	—	0.44 (.30)
Given Plan ($N = 60$)	0.36 (.36)	0.26 (.31)	—	0.48 (.39)
Guided Plan ($N = 37$)	0.26 (.26)	0.10 (.17)	—	0.38 (.30)

Note. Values in parentheses in all tables refer to standard deviations.

sponse to the anticipated versus unanticipated object cues in the two planning conditions? Compare the responses to anticipated versus unanticipated cues across the two planning conditions, as presented in Fig. 1 and in the last two lines of Table 1. For target reminders, there is a main effect of cue type, $F(1,96) = 57.27$, $p < .001$, with more target reminders being generated in response to anticipated (89%) versus unanticipated (71%) cues. This means that a participant who, for example, associated Vaseline with the goal of removing a stuck ring (Goal 1) and “chewing gum” with the goal of rehang-ing the fallen poster (Goal 9) in the study phase of the experiment was more likely to be reminded of the stuck ring upon seeing Vaseline than to be reminded of the poster upon seeing “masking tape.” There is also a main effect of cue type for nontarget reminders, $F(1,96) = 8.49$, $p = .004$, with fewer reminders being generated in response to anticipated (0.20) versus unanticipated (0.32) cues. This suggests that not only were participants more likely to recognize an opportunity when a cue had been anticipated, but they were also less likely to generate a nontarget response for that cue.

A main effect of planning condition on target reminders was expected due to the benefits of self-generation in encoding; namely, Guided Plan participants should perform better than Given Plan participants. However, no main effect of planning condition was observed, $F(1,96) = 1.39$, $p = .710$. For nontarget reminders, however, Guided Plan showed fewer intrusions, $F(1,96) = 4.46$, $p = .037$.

In accord with the predictive encoding model, there was a significant interaction between cue type and planning condition. The effect of cue type is greater in the Guided Plan condition compared with the Given Plan condition for anticipated cues, suggesting that stronger memory associations were created in the Guided Plan condition. In the Guided Plan condition, 28% more target reminders were generated in response to anticipated cues versus unanticipated cues, while only 12% more reminders were generated in the Given

Plan condition, $F(1,96) = 9.09$, $p = .003$. As expected, no significant interaction was found for nontarget reminders, $F(1,96) = 0.23$, $p = .588$.

Should the target-reminding interaction be attributed to an increase in anticipated-cue reminders in the Guided Plan condition, to a decrease in unanticipated-cue reminders in the Guided Plan condition, or to both? It was expected that participants in the Given, Guided, and No-Plan Control conditions would generate the same percentage of target reminders in response to unanticipated cues, as the model gives no indication that responses to unanticipated cues should be affected by prior planning context. Though the Guided Plan participants generated somewhat fewer target reminders in response to unanticipated cues than did participants in the Given Plan and No-Plan Control conditions, no simple effect of condition on unanticipated-cue reminders was found ($F(2,137) = 1.46$, $p = .236$), indicating that responses to these cues changed little across the conditions. However, as expected, a simple effect of condition on anticipated-cue reminders was found between Given and Guided Plan conditions, $F(1,95) = 5.64$, $p = .020$, indicating that responses to these cues increased with deeper encoding. The analyses suggest, then, that the interaction is predominantly due to an increase in anticipated-cue reminders.

Free-Recall Results

Free-recall data were scored for the No-Plan Control, the Given Plan, and the Guided Plan conditions by counting a response as an instance of recall whenever it uniquely identified one of the earlier goals. Participants tended to describe goals accurately, as they did in the reminding phase of the experiment, using wording similar to that used by the experimenter to present the goals. However, as in the reminding phase of the experiment, occasional confusions of goal elements were apparent in the participants' descriptions of a goal. Out of 1156 recall responses, 31 (3%) did not uniquely identify one of the earlier goals. The latter were not considered in the following analyses.

Overall, participants showed little difficulty in recalling the majority of goals. On average, 8.3 goals out of 10 were recalled by each participant. Table 2 summarizes the recall results for each cue type and study condition. No significant differences in recall were found (F 's < 1).

Discussion

The results demonstrate that the association of goals and plans at encoding facilitates the retrieval of pending goals as specified in the Predictive Encoding model. However, a striking finding not anticipated in the model is the high overall rate of reminding for unanticipated cues, which averages around 70% across conditions. One might expect that unanticipated cues would result in relatively low target reminding rates, as well as few nontarget reminders in

TABLE 2
 Percentage of Goals Recalled as a Function of Cue Type
 and Study Condition in Experiment 1a

Study condition	Cue type	
	Unanticipated	Anticipated
No-Plan Control ($N = 43$)	80% (20)	—
Given Plan ($N = 60$)	83% (19)	85% (19)
Guided Plan ($N = 37$)	85% (19)	86% (15)

response to all cues. However, a considerable number of reminders, both target and nontarget, were produced in response to unanticipated cues and fillers.

There are several reasons why this experimental paradigm might lead to a high base rate of reminding even for unanticipated cues. First, making the inferential connection between cues and goals may require variable degrees of inferential processing. For example, some connections may be readily available from the cue object based on experiences prior to the experimental context (e.g., a tack can be used to rehang a poster) or may have been stereotypical or obvious enough to require little inference (e.g., a key can be used to open a lock). Predictive encoding would provide the greatest advantage when unanticipated cues are difficult to match to pending goals at test time. Second, in this study, subjects were given unlimited time to consider the cue at test time, which may allow them to generate the inference at test time. In other settings, time demands and competing activities may limit inferential capacity at test time, presumably resulting in a lower base rate for unanticipated cues and increasing the relative utility of predictive encoding.

Another reason for a high base rate of reminding is that the goals and objects, though perhaps unusual, were selected because of their utility and plausibility in everyday life. Consequently, the domain familiarity or the informality of the tasks may lead to more competent problem-solving performance than typically seen in studies using abstract or unfamiliar content (e.g., Cheng & Holyoak, 1985). In any case, this high base rate of reminding should make it more difficult to detect any effects of predictive encoding. However, despite this, predictive encoding still shows reliable improvement in reminding rates for the anticipated cue condition. For these reasons, the paradigm used here probably underestimates the utility of predictive encoding for resolving infrequently encountered goals and for taking advantage of nonobvious opportunities to achieve routine goals.

The ability to systematically compare the goals to the test cue would also increase the rate of reminding for the unanticipated cues. Because the reminding phase immediately followed the goal study phase, it is possible that

participants may have kept many of the goals in mind while completing the reminding task. This would be especially easy to do because participants did not have any other tasks to which they needed to devote their attention. In a follow-up experiment, an intervening task was inserted before the reminding phase to allow the studied goals to presumably become less accessible in memory. When reminding performance depends upon memory alone, predictive encoding should have an even greater impact. The question of whether the phenomena observed in Experiment 1a depend upon the ready availability of the goals in memory was addressed through a replication with a delayed reminding phase.

EXPERIMENT 1B

In Experiment 1b, all participants were assigned to a single condition, the Given Plan Delay condition. This condition was identical to the Given Plan condition of Experiment 1a with the exception that a 20-min distractor task was inserted between the study and the reminding phases of the experiment. As in the Given Plan condition of Experiment 1a, the hypothesis was that participants would notice more opportunities in response to anticipated cues versus unanticipated cues. The motivation for this experiment was to discern whether or not the findings of Experiment 1a could be generalized to situations involving a longer delay period. This is important if we wish to generalize the findings to everyday experience, in which there is often considerable delay between the acquisition of a goal and the presence of an unforeseen opportunity.

Method

Participants

Participants were 25 undergraduates (12 men and 13 women) at the University of Michigan who participated in partial fulfillment of introductory psychology course requirements.

Materials and Procedure

Participants were tested in groups of four to eight in 90-min sessions. The procedure was identical to the Given Plan condition of Experiment 1a with the following exception: Upon completing the study phase of the experiment, each participant was given a distractor task. The task required solving a series of complex word problems. Each participant worked on the task for 20 min. The distractor task was then taken away and replaced with a booklet containing the reminding and recall phases of the experiment. This will be referred to as the Given Plan Delay condition.

Results

Reminding Results

In the reminding phase of the experiment, participants in all conditions recorded goals that came to mind upon seeing each object cue. Reminding

data were scored as in Experiment 1a. Of 297 reminders, 10 (3.4%) fell into the category of Other; the remaining 287 were coded as referring to one of the 10 goals.

As in Experiment 1a, a greater percentage of target goals was generated in response to anticipated (98%; $SD = 7\%$) compared with unanticipated (75%; $SD = 21\%$) cues, $t(24) = 5.53$, $p < .001$. Anticipated cues also led to a decrease in the mean number of nontarget reminders generated for each cue. A mean of 0.19 ($SD = 0.20$) nontarget reminders were generated in response to each unanticipated cue versus a mean of 0.05 ($SD = 0.11$) overall reminding for each anticipated cue, $t(24) = 2.06$, $p < .05$. A mean of 0.31 ($SD = 0.36$) unintended reminders were generated in response to each filler item.

A comparison of target reminding results across Experiments 1a and 1b also showed a main effect of cue type, $F(1,83) = 36.60$, $p < .001$, with anticipated cues leading to a greater percentage of reminders than unanticipated cues. Furthermore, there was a marginally significant main effect of time delay, $F(1,83) = 3.57$, $p = .062$, such that an increase in time delay leads to an increase in target reminders. And, finally, a marginally significant interaction between cue type and time delay was found, $F(1,83) = 3.35$, $p = .071$, revealing that while reminders in response to unanticipated cues do not change over short periods of time (74% with no delay vs 75% with a delay), reminders in response to anticipated cues increased (from 87 to 97%) with a time delay.

Free-Recall Results

Free-recall data were scored as in Experiment 1a. All recall responses uniquely identified one of the earlier goals. Overall, participants showed little difficulty in recalling the majority of goals. On average, 8.04 goals out of 10 were recalled by each participant. Goals associated with anticipated cues were no better recalled ($M = 81\%$; $SD = 23\%$) than those associated with unanticipated cues ($M = 80\%$; $SD = 24\%$), $t(24) = 0.16$, $p = .877$.

Discussion

The main findings of Experiments 1a and 1b are as follows. First, Experiment 1a showed a higher percentage of target reminders in the No-Memory Control condition compared with the No-Plan Control condition, showing that recognizing opportunities is a memory phenomenon. Second, Experiment 1a found a higher percentage of target reminders in response to the anticipated versus unanticipated object cues in the two planning conditions (Given Plan and Guided Plan). Third, Experiment 1a showed an increase in the differential effect of anticipation in the Guided Plan compared with the Given Plan condition, presumably due to the enhanced depth of processing required by self-generation (Slamecka & Graf, 1978). And, fourth, Experiment 1b showed that the effects of anticipation generalize to situations in which a

delay occurs between the study and the reminding phases of the experiment, even though the goals are less available in memory. These results are consistent with the predictive encoding model, in which the ability to recognize the relevance of a pending goal in memory depends upon the preparation of inferential connections.

These differences in observed reminders result from manipulations of the type of encoding experienced when initially learning about and encoding the pending goals. When goals are encoded in memory in terms of a later opportunity, participants are approximately 12% more likely to recognize an opportunity. This interpretation is supported by the fact that participants did not generate more target reminders in response to anticipated objects simply because they generated more reminders overall in response to these objects; instead, overall reminders for anticipated and unanticipated objects were about equal. In addition, participants recalled an equal number of goals associated with anticipated versus unanticipated objects in the final free recall test. This rules out the possibility that participants recognized more anticipated opportunities because they simply had better memory for the goals associated with these opportunities.

This initial evidence in support of the predictive encoding model raises further questions regarding how people encode goals in memory, when and how reminders occur, and how strategies might be developed to facilitate appropriate reminders when opportunities arise. Most importantly, does predictive encoding provide memory access to goals only when an opportunity occurs that is identical to the one anticipated? Clearly, if the preparation at encoding facilitates recognizing only that single opportunity, the gain from predictive encoding is somewhat limited. This question of how generally one benefits from predictive encoding is examined in two further studies. In addressing this question, we will also provide some evidence regarding the representation of goals and plans in memory, and the ways in which these knowledge structures can be readily accessed.

EXPERIMENT 2

Experiment 1 established that preparing for a specific opportunity will increase the likelihood of recognizing that opportunity when it arises. However, such preparation may also provide only limited benefits to the planner; for example, the object intended for executing a plan may turn out to be unavailable, while a substitute object may fill the same need. Optimally, the predictive encoding that takes place initially should prepare one for any opportunity that might serve to allow the execution of the anticipated plan. In Experiment 1, the test objects were always either identical to the anticipated plan or involved a different plan altogether, so any evidence for more general application of the prepared plans could not be observed.

Experiment 2 was designed to test whether people can take advantage of

abstract plans to recognize novel opportunities. In this experiment, the reminding cues were either identical to, related to the same plan as, or related to a different plan from the object presented at encoding. For example, if the object presented at encoding for the goal of retrieving the elastic band was broom, then broom (identical object), “hockey stick” (same abstract plan—extend reach—but different object), or chair (different abstract plan—raise height) was presented at test time. If participants automatically encode abstract plans from concrete objects presented at encoding, they should recall more goals with same-plan cue objects compared with different-plan cues, since the same plan was anticipated at encoding (though with a different object). If participants only show benefits from predictive encoding when the specific object is again presented, they should recognize the same number of opportunities in response to hockey stick and chair since neither was specifically anticipated.

Method

Participants

Participants were 52 undergraduates (24 men and 28 women) at the University of Michigan who participated in partial fulfillment of introductory psychology course requirements.

Materials and Procedure

Participants were tested in groups of 15–20 in 50-min sessions. The procedure was identical to the Guided Condition of Experiment 1 with the following exceptions. First, 2 new goals were added to the materials in order to increase the number of goals to 12. The added goals were as follows:

Goal 11: You want to buy Chris a long coat for her birthday but you do not know what length coat to get. Thus it would help to know exactly how tall Chris is.

Goal 12: You love the color of Chris’s hair and want to have your hair dyed to the same color. But, in order to do this, you need to take something to your hair salon that indicates exactly what color Chris’s hair is.

Four cues were generated as a means of achieving each of the new goals: two cues were related to one abstract plan and two to another. So, for example, the materials generated for the goal of determining Chris’s height (Goal 12) were as follows:

Plan 1: find height on document
Cues: “medical records” or “driver’s license”

Plan 2: measure height from clothing
Cues: “pair of jeans” or “pajamas”

Similarly, two new cues (to be added to the two existing cues from Experiment 1) were generated for each of the 10 original goals, half associated with each of the two abstract plans identified for each goal, and new filler cues were added. (See Appendix C for a list of the materials used.)

Test booklets were constructed such that each participant saw, during the goal study phase,

only one of the sets of cue objects in the Given Plan condition. During the reminding phase, participants were presented with 16 cues, such that 4 cues fell into each of the following categories:

Filler cues: These were irrelevant cues, as in Experiment 1. Example: Shown “baseball” at test.

Identical cues: These cues were identical to the objects studied during the goal study phase. Example: Shown “jeans” at study and jeans at test.

Same-plan cues: These cues were based on the same abstract plan as objects studied during the goal study phase. Example: Shown jeans at study pajamas at test.

Different-plan cues: These cues were based on a different plan than the objects studied during the goal study phase. Example: Shown jeans at study, driver’s license at test.

Materials were counterbalanced so that each object studied could later appear with an identical, a same-plan, or a different-plan cue for different participants. One set of filler items was used across all participants, and cues were presented in a single random order for all participants.

Results

Goal Study Coding

In the goal study phase of the experiment, participants were given objects and asked to generate plans for using suggested objects to achieve the stated goals (as in the Guided Plan condition in Experiment 1a). An independent coder reviewed all goals in this phase of this condition. For each goal, exactly one plan was found to have been generated by each participant. All plans were consistent with those intended by the experimenter.

Reminding Results

In the reminding phase of the experiment, participants recorded goals that came to mind upon seeing each object cue. Reminding data were scored as in Experiment 1. Of 603 reminders, 22 (4%) fell into the category of Other and were excluded from further analysis.

Participants reported reminders on 98% ($SD = 8\%$) of trials in response to identical cues, a mean of 75% ($SD = 21\%$) in response to same-plan cues, and a mean of 63% ($SD = 22\%$) in response to different-plan cues. The reminding rates for each of the cue types is significantly different from the others (identical vs same-plan contrast: $F(1,51) = 39.89, p < .001$; same- vs different-plan contrast: $F(1,51) = 17.00, p < .001$) in the predicted direction. No significant difference was found in nontarget reminders for identical ($M = 0.56; SD = 0.39$), same-plan ($M = 0.66; SD = 0.50$), and different-plan ($M = 0.63; SD = 0.40$) cues, $F(2,50) = 2.18, p > .120$. Participants generated a mean of 0.15 ($SD = 0.21$) responses to filler items.

It is possible that the increase in same-plan reminders as compared with

different-plan reminders is due not to the functional similarity between study and reminding phase objects, but to some overall perceived similarity (e.g., same-plan objects “snow” and “ice cubes” may be perceived as highly similar, while different-plan objects snow and “margarine” are not). Post hoc analyses were performed to test this hypothesis. Similarity ratings were collected for each object pairing (consisting of a study object and its matched reminding object) used in the experiment. Twelve undergraduate and graduate students at the University of Michigan were asked to rate each of the 24 pairs of objects on a scale from 1 to 5 where 1 = highly similar and 5 = not very similar at all. Participants reported a mean similarity rating of 2.88 ($SD = 0.96$). When these similarity ratings were correlated with mean reminders, a Pearson r of -0.32 ($N = 24$; $p = .124$) was found. When mean similarity ratings were rounded to the nearest whole number (e.g., .50–1.49 = 1, 1.50–2.49 = 2, etc.), the mean number of reminders for each rating number was as follows: 1 = 0.90 ($N = 1$; $SD = 0$), 2 = 0.83 ($N = 6$; $SD = .14$), 3 = 0.74 ($N = 12$; $SD = .19$), 4 = 0.66 ($N = 3$, $SD = .41$), and 5 = 0.45 ($N = 2$; $SD = .63$). A Spearman rank-order correlation is significant for these values, $r_s = 1.00$ ($N = 24$; $p < .01$). Overall, the results suggest that perceptual similarity may account for some of the variation in reminders in response to different same-plan object pairs.

Free-Recall Results

Free-recall data were scored as in Experiment 1. Out of 513 recall responses, 10 (2%) did not uniquely identify one of the earlier goals and were not considered in the following analyses. Overall, participants showed little difficulty in recalling the majority of goals. On average, 9.70 goals out of 12 were recalled by each participant. The results show that goals that had been associated with identical cues were more available in memory ($M = 87%$; $SD = 19%$) than those that had been associated with same-plan ($M = 78%$, $SD = 19%$) and different-plan ($M = 77%$, $SD = 20%$) cues combined, $F(2,50) = 9.97$, $p = .003$. This contrasts with Experiment 1, in which no differences were found in free recall. Since the identical-plan condition approached a perfect reminding rate, this free-recall difference could be accounted for by increased activation from access during the reminding phase.

Discussion

In Experiment 2, participants did not always encode plans at an abstract level, as evidenced by the higher reminding rate for identical compared to same-plan cue objects. To some degree, reminding behavior in this experiment was nonoptimal in that the retrieval of goals did not always occur when later opportunities to achieve them arose. However, reminders were more likely to occur in the context of same-plan compared to different-plan cue objects. This shows that the benefits of predictive encoding extend beyond the specific

object present during planning to unanticipated objects only abstractly related to the anticipated plan. Participants were sometimes able to recognize opportunities based on abstract plan category despite the literal conflict between specific preparation at encoding and the test object. This suggests that a general advantage may result from predictive encoding, in that novel objects useful in the same abstract plan category as the anticipated object do result in more reminders than cues from different plans. Thus, it appears that the preparation of specific plans at encoding led to reliably better recognition of similar opportunities involving the same abstract plan.

The advantage for same-plan over different-plan objects may, in part, be explained by some overall perceived similarity (which may include perceptual, thematic, and functional aspects of similarity) between study and reminding objects. This is suggested by a decrease in mean reminding rate across same-plan object pairs grouped into five categories based on perceived similarity. However, the relatively low correlation between overall perceived similarity and rate of reminding for same-plan object pairs suggests that this alone does not account for the difference. The fact that even object pairs rated as "not very similar at all" resulted in significant numbers of reminders suggests that the plan-relevant features of the objects are serving as cues to the goals. Of course, objects that are selected to have functional features in common that are relevant to a particular plan are likely to have greater overall similarity than objects that are selected to have no plan features in common. It might be possible to empirically separate the effect of overall perceived similarity from that of plan-relevant feature cueing by using different-plan object pairs with high overall similarity but with no plan-relevant features in common (e.g., pairing a yardstick at study with a 6-in. ruler at reminding for retrieving an object from the high shelf).

Based on Experiment 2, it appears that preparing a specific plan in advance will only sometimes result in the recognition of related opportunities through reminding. However, a maximal strategy of associating a goal at encoding with *every* object that might be used in a plan to achieve the goal would require considerable cognitive effort. In many plans, any number of objects might be used for successful execution of the plan; for example, in order to retrieve the elastic band, one could swipe it down from the shelf with a broom, or substitute a hockey stick, curtain rod, umbrella, or any long, rigid object. It would require substantial effort to first generate and then rehearse the association between the pending goal and each of these potential opportunities. Even then, if a novel or an unexpected object, such as a piece of aluminum piping, appears in the environment, the opportunity to use it might be missed because it was not specifically anticipated at encoding. In the final experiment, an alternative approach of attempting to predict only the *type* of object needed is explored.

EXPERIMENT 3

Ideally, one would like to encode a goal in such a way as to minimize the amount of cognitive effort expended at encoding, while maximizing the

likelihood of recognizing any opportunity that might later arise. One possibility is to encode a goal in terms of a plan for its achievement, but without going so far as to specify the specific objects that could be used in the plan. For example, at the time of encoding, one might associate the goal of retrieving an elastic band from a high shelf with the plan of “using a long, rigid object to swipe down the elastic band,” rather than with the plan of “using a broom to swipe down the elastic band.” Notice that the former plan is more abstract than the latter in that it describes a means of obtaining the elastic band (i.e., extend reach to swipe it down), without specifying which object should be used to execute the plan.

Rehearsing a more abstract plan at encoding would require less effort because there are fewer abstract plans than more concrete, object-specified versions to be associated with any goal. In addition, it may not be necessary to associate a goal with specific objects at encoding in order to increase the likelihood of recognizing those objects as opportunities to achieve the goal. With the preparation of plans using specific objects, one may successfully recognize a broom as an opportunity to “use a long, rigid object to swipe down the elastic band from the shelf,” as shown in Experiments 1 and 2. But with more general preparation, one may increase the likelihood of recognizing any one of a large number of opportunities simply by associating the goal with an abstract plan (e.g., “extend reach with a long and rigid object”). Then, even if an unusual or unfamiliar object appears in the environment (e.g., a ceiling light bulb changer), the object may be recognized as fitting the requirements for application of the abstract plan in memory. Thus, predictive encoding of abstract plans rather than object-specific plans could result in considerable improvement in opportunity recognition with little additional cognitive effort.

To test this hypothesis, Experiment 3 involved participants encoding an abstract plan, rather than a more specific one, at the time of encoding the goal. So, for example, in the Given Plan condition, instead of receiving the suggestion that a broom could be used to reach the elastic and swipe it off the high shelf, participants received the suggestion that “you could use a long object to swipe the elastic down from the high shelf.” In a Generate Plan condition, participants were simply asked to generate abstract plans for achieving each goal. If participants in these two planning conditions recognize a greater number of opportunities in response to cue objects that can be used in anticipated plans (versus unanticipated plans), we will have evidence that participants can take advantage of abstract plans presented at encoding as a means of recognizing later opportunities to achieve goals.

Method

Participants

Participants were 101 undergraduates (48 men and 53 women) at the University of Michigan who participated in partial fulfillment of introductory psychology course requirements.

Materials and Procedure

Participants were randomly assigned to one of three conditions (No-Plan Control, Given Plan, or Generate Plan) and were tested in groups of 15–20 in 50-min sessions. The procedure was identical to that of Experiment 1 with the following exceptions. First, two modifications were made in the materials: Masking tape, a reminder to rehang a fallen poster (Goal 9), was replaced with “thumb tacks”; and the “hot air popcorn popper” used for drying a wet shirt (Goal 5), was replaced with “curling iron.” These changes were made to increase the differences among the objects relevant to each potential abstract plan. Second, the two planning conditions were altered to avoid mentioning any specific objects. For example, in the Given Plan condition, abstract plans included “using a long, rigid object to swipe down the elastic band,” and “reaching the elastic band by standing on a sturdy object.” Concrete, object-based plans could be derived from each abstract plan by generating objects that can be used in each abstract plan. For example, “standing on a chair,” “standing on a stack of books,” and “standing on a step ladder” are all concrete instantiations of the abstract plan of “reaching the elastic band by standing on a sturdy object.”

The plans in the Given Plan condition used in Experiment 3 were more abstract versions of the plans used in Experiment 1 (see Appendix B for the abstract plans used); the difference between the two sets was only in whether or not a specific object was suggested as a means of instantiating the plan. Recall that, in Experiment 1, participants in the Guided Plan condition were given an object for which they were to generate a plan to use the object to achieve the goal. This requires participants to encode the generated plan in terms of a specific object. To avoid this, in Experiment 3, a Generate Plan condition replaces the Guided Plan condition. The Generate Plan condition for Experiment 3 was created by simply instructing participants to generate abstract plans in response to each goal with the following instructions:

When you create your plans, keep in mind that we are not interested in what specific objects you would use to resolve each situation. Rather, we are interested in the kinds of approaches you would take. So, for example, suppose you need to get past a locked door, you might write the general plans:

“Break down the door.”—GOOD
 “Pick the lock on the door.”—GOOD

You need not, however, write the more specific:

“Use a sledgehammer to break down the door.”—TOO SPECIFIC
 . . . since you could use any one of a number of objects to break down the door, a sledgehammer being only one possibility.

Participants in this condition were instructed to record plans in the order that they came to mind during the goal study phase and to generate only realistic plans.

Results

Plan Generation Results

Because the participants, rather than the experimenter, determined which plans were anticipated in the Generate Plan condition, the plans generated by participants were scored to determine which reminding observations fell into anticipated versus unanticipated categories. A coding scheme for categorizing plans at an intermediate level of abstraction, consistent with the categories used to describe plans in the Given Plan condition, was used successfully to

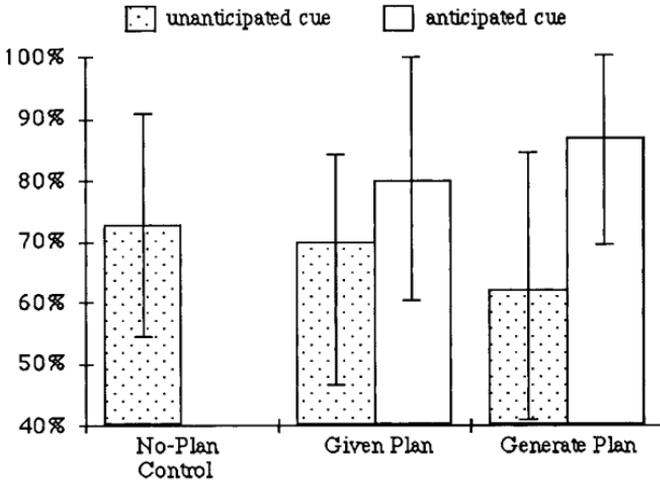


FIG. 2. Percentage of target goal reminders in response to unanticipated versus anticipated cues for each study condition in Experiment 3.

code all responses. For example, a participant's plan for removing a ring from one's finger (Goal 1) was coded under one of the following abstract plan categories: "lubricate finger," "reduce width of finger," or "wedge object under ring." On average, 5.30 ($SD = 1.30$) coding categories were needed for each plan, with a range of 4 to 8. Participants generated an average of 2.00 ($SD = 0.51$) plans for each goal. An average of 54% of participants generated each plan for which a related target cue appeared later in the reminding task. For each participant, an average of 5.50 ($SD = 1.50$) plans were related to later reminding cues, with a range of 2–8.

Reminding Results

In the reminding phase of the experiment, participants in all three conditions recorded goals that came to mind upon seeing each object cue. Reminding data were scored as in Experiment 1. Of 1256 reminders, 77 (6%) fell into the category of Other; the remaining responses were coded as instances of one of the 10 goals.

In a 2×2 ANOVA of the Given Plan and Generate Plan conditions, a significant improvement in reminding performance occurred in response to anticipated versus unanticipated cues in the two planning conditions, as illustrated in Fig. 2. There was a main effect of cue type, $F(1,69) = 27.65$, $p < .001$, with more target reminders being generated in response to anticipated (82%) than to unanticipated (65%) cues. There was no difference in the number of nontarget reminders generated across the two cue conditions, $F(1,68) = 0.93$, $p = .339$, as presented in Table 3. Unlike Experiment 1a, no other effects approached

TABLE 3
Mean Number of Nontarget Reminders as a Function of Cue Type
and Study Condition in Experiment 3

Study condition	Cue type		
	Unanticipated	Anticipated	Filler
No-Plan Control ($N = 31$)	0.22 (.22)	—	0.43 (.31)
Given Plan ($N = 50$)	0.26 (.30)	0.26 (.32)	0.42 (.37)
Generate Plan ($N = 20$)	0.22 (.33)	0.14 (.15)	0.45 (.31)

statistical significance, including the main effect of plan condition, and the interaction between plan condition and cue type, F 's < 1 .

As in Experiment 1a, despite the statistically nonsignificant results, the mean percentage of reminders in response to unanticipated cues tended to decrease across planning conditions (from No-Plan Control to Generate Plan). To further evaluate this trend, the unanticipated-cue reminding data from the three planning conditions of Experiments 1a and 3 were combined. Analysis of the combined data revealed a marginally significant main effect of planning condition on percentage target reminders generated in response to unanticipated cues across the No-Plan Control (74%), Given Plan (72%), and Guided/Generate Plan (65%) conditions, $F(2,235) = 2.79$, $p = .064$. No main effect of experiment was found, $F(1,236) = 1.46$, $p = .228$.

Free-Recall Results

Free-recall data were scored as in Experiment 1. Out of 776 recall responses, 26 (3%) did not uniquely identify one of the earlier goals and were not considered in the following analyses. Overall, participants showed little difficulty in recalling the majority of goals. On average, 7.80 goals out of 10 were recalled by each participant. Table 4 summarizes the recall results for each cue type and planning condition. There were no significant differences.

TABLE 4
Percentage of Goals Recalled as a Function of Cue Type
and Study Condition in Experiment 3

Study condition	Cue type	
	Unanticipated	Anticipated
No-Plan Control ($N = 31$)	83% (19)	—
Given Plan ($N = 50$)	75% (24)	79% (22)
Generate Plan ($N = 20$)	74% (23)	83% (18)

Discussion

Experiment 3 showed a greater number of reminders in response to anticipated versus unanticipated cues even when the encoding was based on an abstract plan rather than a specific object. In addition, as in Experiment 1, the effect of predictive encoding was greater in the Generate Plan compared with the Given Plan condition. These effects of anticipation at the time of encoding occurred even though no differences were found in the number of goals recalled at the end of the experiment. The results suggest that predictive encoding of abstract plans leads to significant improvement in recognition of opportunities to use concrete, plan-related objects to achieve pending goals. In fact, despite the more general plan at encoding, the results of Experiment 3 replicate those of Experiment 1. In Experiment 1, the magnitude of the effect of anticipation was 12% in the Given Plan condition and 28% in the Guided Plan condition. In Experiment 3, the magnitude of the effect was 10% in the Given Plan condition and 25% in the Generate Plan condition. In both experiments, these differences emerged even though there were no differences in the number of nontarget reminders generated across cue or planning conditions, and there were no differences in the percentages of goals freely recalled by condition within each experiment.

The reminding rate for goals encoded with abstract plans in Experiment 3 was approximately 6% lower than for the concrete plans in Experiment 1a. However, the advantage for the abstract plan lies in an increased likelihood of recognizing any one of a wide range of concrete cues that might be used in the plan to achieve the goal, while encoding a concrete object increases the likelihood of recognizing that object and, to a lesser degree, similar objects. In a highly predictable world, it might make sense to encode a suspended goal by associating it with a specific anticipated cue (e.g., when you are near a particular mailbox). However, in other circumstances, the ability to recognize a range of opportunities to achieve goals may be desired, such as when in an uncertain environment, or when a specific object with desired attributes cannot be identified in advance (e.g., "I need something long, rigid, and lightweight to help me retrieve the elastic band on the high shelf"). In such cases, these experiments suggest that encoding an abstract plan at the time of suspension can be successful for recognizing a broader range of opportunities.

These findings are important in that they provide evidence that encoding abstract plans facilitates reminding nearly as well as encoding the specific concrete objects that will later appear as potential opportunities. This is particularly striking given that participants in Experiment 1, but not in Experiment 3, could be aided by lexical priming and recency effects. Consider, for example, a participant presented with broom during the study phase of Experiment 1: When later presented with broom during the reminding phase, the partici-

pant might have used the recency of having been exposed to this word as a cue to its usefulness in achieving a goal. This could not, however, have been the case in Experiment 3, in which concrete objects were presented for the first time during the reminding phase.

A striking trend (though only marginally statistically significant in a combined analysis of Experiments 1a and 3) was that anticipating either a concrete or an abstract plan at encoding decreased recognition (by means of 18% in Experiment 1a and 16% in Experiment 3) of objects related to unanticipated plans (compared with a baseline condition in which no planning was done at encoding). One explanation is that a potential strengthening of the association between a goal and one plan leads to a weakening of the association between the goal and other potential plans, leading to an interference or "fan" effect (Anderson & Bower, 1973). In order for this phenomenon to occur here, direct associations would have to already exist in memory between the goal and all unanticipated plans, so that these associations could then be weakened. But, Barsalou (1983) showed that goal-derived categories are not well established in memory, suggesting that an interference account may be implausible. In Experiment 3's Generate Plan condition, when participants had the opportunity to generate all possible plans to achieve a goal, they generated only about half of the objects that would later appear, suggesting that these plans were not directly associated with the goal.

Another possible explanation for decreased recognition from unanticipated cues is that the unanticipated baseline conditions are inflated. In the No-Plan and Guided Plan conditions of Experiment 1a, participants had more time at encoding to spontaneously associate several plans with goals. As a result, participants might have recognized a greater number of "unanticipated" opportunities because many of them might actually have been anticipated by the participants. This is unlikely given that, again, even when the Generate Plan participants had the opportunity to record all possible plans, they rarely generated more than half of those that would later appear. A third possibility is that participants in the different conditions varied in the effort they were willing to devote to making inferences in the reminding phase. In the planning conditions, anticipated cues facilitated relatively effortless retrieval of the appropriate goals. When goals did not come to mind as quickly for the unanticipated cues, participants in planning conditions may have been quicker to doubt the usefulness of these objects. However, when no cues were anticipated, as in the No-Plan Control conditions of Experiments 1a and 3, participants may have worked harder during the reminding phase to generate ways to use each cue to achieve an earlier goal. A low motivation to work hard to find a reminding may provide a more accurate estimate of baseline performance in everyday life, since people presumably do not think about how they might use each object they encounter in a plan to achieve a pending goal.

The results of Experiment 3 suggest that recognition of plan-consistent

opportunities is facilitated when abstract plans to achieve goals are generated at the time of encoding. Facilitation occurs to a greater extent than when the goal is encoded without consideration of how it might be specifically achieved and to the same extent as when the goal is encoded in terms of the concrete object that will later serve as an opportunity. Note that this facilitation occurs even in the Generate Plan condition, in which participants generated an average of 5.30 abstract plans per goal. This provides some evidence that the effect is not reduced when more than one plan is associated with each goal at encoding. In sum, these results suggest that the abstract plan level may be the optimal level for encoding goals in order to maximize later recognition of a wide variety of opportunities to achieve these goals.

GENERAL DISCUSSION

How should a pending goal be encoded into memory in order to increase its likelihood of coming to mind at opportune times? Experiment 1a showed that encoding a goal in terms of a specific object that can be used to achieve the goal increases the likelihood of recognizing an opportunity. As seen in Experiment 2, encoding at the specific object level sometimes facilitates retrieval even when a novel cue object later appears, but many objects would have to be associated with the goal at encoding in order to maximize recognition of new opportunities. Experiment 3 showed that associating the same goal with abstract plan information also facilitates retrieval of the goal in response to novel specific object opportunities. Encoding at the abstract plan level appears to facilitate reminding in response to a range of cue objects (i.e., those that can be used to instantiate the encoded plan). The experiments described here provide evidence in favor of the predictive encoding model, which states that opportunities to achieve goals must be anticipated at the time of initial goal encoding in order to maximize recognition of nonobvious opportunities. These results confirm that, at the time of encoding, effort spent on generating abstract plans for achieving a goal will increase the likelihood of recognizing a later opportunity.

One limitation of the planning paradigm used in these studies is that only minimal information is provided in both the goal study and the retrieval phases of the experiments. Do people automatically monitor this information when they process the physical world? The problem of constraining plan generation and, later, of identifying important features in the test environment may prove much more difficult when one has to select information from within a background context. For example, during the reminding phase, participants could focus on the presented object to determine if it could be used to achieve an earlier goal. It is rarely the case that one perceives objects in the world with little else in mind but determining whether or not the object might be used in a plan to achieve a pending goal. With many such objects simultaneously available in the environment, the cost of searching for plans from unanticipated cues would be prohibitive. Thus, the unlimited processing

time at recall in this experimental paradigm may overestimate the occurrence of unanticipated goal reminders and consequently underestimate the value of predictive encoding.

Differences in the degree of association between goals, plans, and objects in memory are also not considered here, though they may play an important role in accounting for which opportunities are noticed. For example, suppose one were to encode the goal to “rehang the poster” in terms of finding a “sticky” substance. One can speculate that the concept tape might be highly associated with the concept of sticky, while the concept of chewing gum might be less associated with sticky and more associated with “chewable,” “flavorful,” etc. As a result, some objects might serve as better retrieval cues than others, even if both have a property that could be used to achieve the goal. Similarly, as mentioned earlier, goals “suggest” some plans through prior experience, such as using tape to hang posters and a chair to reach a height. The “built-in” functions from experience have been shown to interfere with novel uses of objects (as in Maier’s (1931) theory of functional fixedness), and affordances of objects affect the quality of design (Norman, 1988). The novelty of both the abstract plan type generated and the specific objects incorporated into the plan may also affect recognition of opportunity.

Finally, these studies do not address the processes involved in generating novel plans. The predictive encoding model suggests that, without preparation, people rarely recognize objects that could be used in truly novel plans to achieve pending goals. However, it suggests that people do recognize the relevance of novel objects for use in anticipated abstract plans. For example, imagine that one has thought about retrieving an elastic band from a high shelf by swiping it down, but has only contemplated using a yard stick or an umbrella in the plan. Later, upon encountering a novel object (e.g., a light bulb changer), the person might still recognize that she could use this object in her plan because it fits the functional requirements. The predictive encoding model can account for this recognition of novel opportunities at cue presentation, but makes no claims about the likelihood that someone will or will not generate a novel plan or object to associate with a goal at the time of encoding. The generation of plans at encoding may be the point at which individual differences in creativity have the largest impact (Cronbach, 1970).

Our findings on the representation of pending goals, such as the use of abstract features to link plans to specific objects, parallel results from “ad hoc” categorization studies. Barsalou (1983) found that ad hoc categories such as “Ways To Make Friends” and “Places To Look For Antique Desks” are not well established in memory, compared with common categories such as animals or furniture. But while goals and plans may not be already existing in memory, these associations can be inferred as they are needed. The present studies also suggest that such inferences, once made at encoding, can facilitate

retrieval of goal categories from category instances outside of the context in which the association was made. This work also introduces the notion of levels of abstraction within an ad hoc category, just as such levels exist in common categories (e.g., fruit, apples, Macintosh apples). Future research might consider whether or not this facilitation persists a considerable time after the goal has been associated with the cue. Experiment 1b suggests that facilitation increases over a 20-min time period, but different changes might take place over considerably longer periods.

The reported experiments also demonstrate that at least some basic principles of associative memory do apply to the representation and retrieval of pending goals. For example, generation effects as described by Slamecka and Graf (1978) appear to explain the enhanced memory observed in the Guided and Generate plan conditions in which participants more actively participated in the inferential processing. Levels of processing (Craik & Lockhart, 1972) may similarly play a role in the recognition performance observed. Indeed, the basic notion in the predictive encoding model—that associates at encoding determine the circumstances for retrieval—is an old idea in theories of associative memory. Tulving and Thomson (1973) used the term “encoding specificity” to refer to the finding that lexical items associated with specific cues at the time of encoding are more likely to be retrieved in the presence of those same cues. The present work extends this general phenomenon to more complex knowledge structures. Specifically, it illustrates that the context in which a goal is learned strongly influences when it will later come to mind. But, in addition, the predictive encoding model prescribes *which* associations should be formed in order to facilitate goal retrieval at opportune times. Namely, one should anticipate the circumstances needed for successful plan execution and describe those circumstances in the form of features that are easily noticed when processing the environment during normal perception. Further, these features are best described in abstract functional form, rather than as a concrete instance of a potential opportunity. As a consequence, this research has practical significance for improving planning skills in that it demonstrates that principles of associative memory can be utilized to increase the efficiency of goal achievement.

Given these common processes, how might memory for pending goals differ from associative memory more generally? Some evidence is provided by other research on prospective memory—memory for things to be done in the future—which focuses on pending goals that must be achieved at particular points in time (e.g., remembering to take medication at certain times of day or to make phone calls to an experimenter (Moscovitch, 1982; Wilkins & Baddeley, 1978)). These goals are sometimes termed “time-based,” in contrast to the resource-based goals that are the focus of the present studies. One line of research on time-based goals examines how people monitor time while waiting for the appropriate moment to achieve a single goal; for example,

how often one looks at a clock while waiting to take a cake out of the oven (Ceci & Bronfenbrenner, 1985). Another line of research investigates the strategies people use in order to help themselves remember to achieve time-based goals at appropriate times, such as how people use notes to themselves or reminders on key chains as memory aids (Meecham & Leiman, 1982). External aids appear to improve performance over strict reliance on internal monitoring processes, especially when a long time period intervenes between goal acquisition and appropriate execution time.

Other prospective memory studies present an external cue at the time a goal is to be achieved (e.g., "Circle the word 'house' each time you see it" (as in Brandimonte & Passolunghi, 1994; Einstein & McDaniel, 1990)) or explicitly manipulate external cue availability. A study by Loftus (1971) varied the specificity of the retrieval cues presented. Participants were asked to record some personal information in a workbook after "finishing the last survey question" or after "finishing the question about the Black Panthers," which was the last question in the workbook. With the specific cue, participants were more likely to remember to write the requested information. Loftus concluded that retention of intentions is not different than retention of other kinds of materials with respect to the influence of a retrieval cue, but that little is known about the exact nature and efficiency of retrieval cues. The present work addresses this issue by examining the nature of cues for resource-based goals when the future availability of needed resources (e.g., masking tape or a step stool) can be anticipated.

Another study, by Goschke and Kuhl (1993), asked participants to act out a script (e.g., "Setting The Table") after performing an intervening lexical decision task for approximately 15 min. Participants were told that the experimenter would interrupt them after 15 min or were told to switch tasks on their own at the appropriate time. Response times on the lexical decision task indicated heightened activation of script-related words, but only for participants who were told that they would have to switch tasks on their own, indicating that the intention was active in memory only for these participants. Goschke and Kuhl noted that this can be detrimental, because heightened activation appears to be related to frequency of unwanted goal intrusions during engagement in other activities. Their work suggests that, to the extent it is possible to provide external goal retrieval cues for oneself, one should do so in order to increase the amount of cognitive resources available for intervening tasks. Our predictive encoding model suggests a means for maximizing the utility of external retrieval cues for opportunistic retrieval of resource-based goals.

Many factors may affect the occurrence and the functionality of predictive encoding during planning. The uncertainty or predictability of the environment, the importance and priorities of goals, the demand for efficiency or limitations on resources, and the domain theory of possible plans may all impact the value of attempting to anticipate opportunities. In addition, there

may be significant individual differences in how frequently and successfully planners adopt this process. Other basic questions about planning, such as how one decides to pursue or postpone particular goals, how multiple plan operations are interleaved, when and how ongoing plans are interrupted, and even how success in goal pursuit is recognized, are necessary for a complete theory of opportunistic planning. But the power of opportunism in responding to a dynamic environment, and the potential for more creative solutions to pending problems, suggests its importance to cognition. In fact, successful planning experiences may also influence what people learn about their environment by teaching them, in effect, “what to notice.” Insightful answers to these questions and the development of new experimental paradigms for testing them serve as “pending goals” for psychological research on planning.

APPENDIX A: STUDY PHASE GOALS FOR ALL EXPERIMENTS

Goal 1: First, you notice that Chris left her new college ring on her bureau. You try it on your left index finger and it gets stuck. Chris will kill you if she finds out that you were so careless with her new piece of jewelry. You need to get the ring off before Chris returns.

Goal 2: You suddenly remember that as a joke you’ve been wanting to send a forged note from Chris to a guy she’s interested in dating. To do this, you need to see a copy of Chris’s signature (so that you can forge it accurately on the note). Now would be a perfect time to view the signature. You need to find a copy of it before Chris returns.

Goal 3: You go to put your hair in a ponytail with Chris’s favorite elastic ponytail holder (she bought it in Paris over Spring Break). The ponytail holder snaps out of your hand and flies across the room. It lands atop her bookshelf, too high for you to reach. You cannot stand on the furniture to reach it because dorm furniture is very unstable (and you don’t want to break anything!). But you do need to retrieve the elastic band before Chris returns.

Goal 4: When you then try to open Chris’s top file cabinet drawer you find out that, mysteriously, the drawer is locked. Now you are really curious to know what is inside! You need to get inside the drawer before Chris returns.

Goal 5: You left on the floor a full glass of water that you had been sipping. When you walk back across the room, you accidentally trip over the glass, pouring water onto a shirt Chris laid out to wear tonight. Chris has been talking all day about wearing this new shirt tonight and would be very upset to find it wet. You need to dry the shirt quickly, before Chris returns.

Goal 6: You want to call Chris’s brother so that you can collect some embarrassing childhood stories about Chris, but all you know is that the brother’s name is Carl Jacobs and that he just moved to a New England town called Milford. You need to find Carl’s phone number before Chris returns.

Goal 7: Next, you clumsily drop the tab to your soda can down the drain in the sink. Though you can see the piece of metal resting just inches away, you are unable to reach it. You don’t want to wash it down the sink because the dorm sinks clog very easily. So you need to get the can tab out of the drain before Chris returns.

Goal 8: You lean over Chris’s bed to see if there is anything interesting between the bed and the wall. In the process, you manage to leave scuff marks high up on the white wall next to the bed. Though the marks are faint, they are in a very unusual and conspicuous location. You need to make the wall white again before Chris returns.

Goal 9: When you open Chris’s window to get some fresh air, a cold breeze blows her poster off the wall (it had been hanging over her bed). You are not sure how the poster had previously been attached to the wall, but you do know that you need to reattach it before Chris returns.

Goal 10: Finally, you remember that Chris claims that she is going to Florida the week after the semester ends. But you don't believe her, since she's always kidding around with you. Before Chris returns, you need to find out if she is really planning this trip.

APPENDIX B: MATERIAL SETS FROM EXPERIMENTS 1 AND 3

For each goal listed below, two complete sets of materials were created. The first line below (in italics) corresponds to the abstract plans (used in Experiment 3 only) associated with each set. The second line corresponds to the concrete objects associated with each set. The concrete objects were used in the planning conditions for encoding during the goal study phase. The objects were also used as test cues during the reminding phase for all conditions.

Goal	Materials Set A	Materials Set B
1	<i>lubricate finger</i> jar of Vaseline	<i>cool and shrink finger</i> bin of ice cubes
2	<i>sign of legal obligation</i> canceled checks	<i>sign of ownership</i> two textbooks
3	<i>height extension</i> set of encyclopedias	<i>arm extension</i> broom
4	<i>unlock</i> small key	<i>pick lock</i> paper clip
5	<i>blow air</i> hair dryer	<i>apply heat</i> hot air popcorn popper (Experiment 1)/ curling iron (Experiment 3)
6	<i>find personal record</i> address book	<i>find official record</i> phone bills
7	<i>grasp</i> tweezers	<i>attract</i> magnet
8	<i>cover up</i> box of white chalk	<i>erase</i> damp rag
9	<i>adhere</i> bag of gum balls	<i>use sharp object</i> roll of masking tape (Experiment 1)/ thumb tacks (Experiment 3)
10	<i>find daily organizers</i> appointment calendar	<i>find travel materials</i> travel tickets

Filler object cues: bottle opener, directory, box of tea bags, shoe, comb

APPENDIX C: MATERIAL SETS FROM EXPERIMENT 2

Goal	Plan	Materials Set A	Materials Set B
1	lubricate finger cool and shrink finger	jar of Vaseline bin of ice cubes	tub of margarine snow
2	find documents find receipts	apartment lease canceled checks	insurance papers credit card receipts
3	arm extension height extension	broom encyclopedia stack	umbrella trash can
4	pick lock force open	small key screwdriver	nail file bottle opener
5	blow air apply heat	hair dryer curling iron	fan radiator
6	find in book of numbers find among notes and lists	address book phone list on wall	phone directory old phone messages
7	grasp hook	tweezers paper clip	clothes pin pipe cleaner
9	erase cover up	damp rag white chalk	old sock white-out
9	adhere use sharp object	chewed gum thumb tack	Band-aid nail
10	find daily organizers find travel materials	wall calendar hotel reservations	appointment calendar plane ticket
11	find documented height estimate from clothing	driver's license pair of jeans	medical records pair of pajamas
12	find photograph find hair sample	photo album hair brush	yearbook pillow

Filler object cues: watch, plant, cup, baseball

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