Postclassification Category Use: The Effects of Learning to Use Categories After Learning to Classify

Brian H. Ross
University of Illinois at Urbana-Champaign

The use of category knowledge can affect category representations, including classification knowledge, even if people learn to classify before learning to use the categories. In 5 experiments, subjects first learned to classify spy messages and then learned a category use that required simple problem solving (applying a formula to decode a message). The number relations that were important for the decoding were later used as an additional basis of classification. This effect of category use occurred even when the classification was not provided during use learning, if the category representation was incidentally available. This incidental activation of the category representation is common in real-world situations and can occur by additional processing (Experiment 2) or by extended classification learning (Experiments 3–5). The discussion focuses on the conditions necessary for obtaining this effect and the generality of the findings.

From their experiences in the world, people acquire new concepts and build up representations of these concepts, such as knowledge about how to classify new items. These representations may change as people learn more about the concept. The goal in this study was to investigate one aspect of this issue—how learning to use an already learned classification can affect the conceptual representation, including knowledge available to classify later instances.

The focus of the vast majority of work on category learning has been on classification, that is how people learn to assign new instances to categories (e.g., Kruschke, 1992; Lamberts, 1994; Medin & Schaffer, 1978; Nosofsky, 1988; Rosch, 1978; see Medin & Smith, 1984; Ross & Spalding, 1994; Smith & Medin, 1981, for reviews). Although classification is a crucial function of categories, it is not the only one. When people classify an instance, it allows them to access the relevant knowledge about the category and to use it to accomplish their goals. The diagnosis (classification) of a particular mechanical or medical difficulty is often made because people want to consider how best to treat this difficulty. The classification of a mathematical problem allows people to bring to bear relevant knowledge about the category, such as the equations that are useful for solving it. Thus, learning new categories involves both learning to classify and learning to make use of the category.

Much of the research on using categories has examined how people use established categories to make inductions or predictions (e.g., Anderson, 1991; Gelman & Markman, 1986; Heit, 1992; Malt, Ross, & Murphy, 1995; Murphy & Ross, 1994; Osherson, Smith, Wilkie, Lopez, & Shafir, 1990; Ross & Murphy, 1996). However, some recent work has shown that interactions with instances and the use of categories during learning can affect later classification. Ross (1996b) found that if people who learned to classify equations also solved each equation, they were more likely to classify later equations on the basis of the mathematical structure than were people who did not solve the equations. Ross (1997, Experiments 1–5) had people learn to diagnose “patients” (sets of symptoms) with fictitious diseases and then, for each patient, to decide what drug treatment should be given. The drug treatment depended on the disease (as it often does in life), so it can be viewed as a use (or prediction) from the category. Feedback was given after the classification and after the use of the category. The symptoms that were predictive of the treatments came to be viewed as more central to the disease than other symptoms that were not predictive of the treatments (though, in fact, both types of symptoms were equally predictive of the disease and were presented equally often). Thus, learning to use categories while learning to classify can affect the classification. Those features relevant to the use may come to be viewed as more relevant for the classification. Experiments 6 and 7 in that article examined problem-solving tasks in which subjects learned to classify an equation or message and then to use the classification to apply a formula. Here, too, information learned from the use (applying the formula)

Brian H. Ross, Department of Psychology and the Beckman Institute for Advanced Science and Technology, University of Illinois at Urbana-Champaign.

This work was partially supported by Grant NSF SBR 97-20304 from the National Science Foundation. Research for this article was conducted at the Beckman Institute for Advanced Science and Technology. I thank Gregory Murphy for a number of discussions and comments on the article; Lawrence Barsalou, Gary Dell, Susan Gelman, Douglas Medin, Colleen Seifert, and Edward Smith, for discussions of this research; and Arthur Markman, Robert Nosofsky, and three anonymous reviewers for comments on earlier versions. I also thank Amy Anderson, Corinna Crawford, Amanda Lorenz, Amanda Schulze, and Holly Trytten for their help in conducting the experiments.

Correspondence concerning this article should be addressed to Brian H. Ross, Beckman Institute for Advanced Science and Technology, University of Illinois at Urbana-Champaign, 405 North Mathews Avenue, Urbana, Illinois 61801. Electronic mail may be sent to bross@s.psych.uiuc.edu.
affected the classification. This effect of using categories on the category representation, including knowledge for classification, was called the category use effect (see Ross, 1996a, for an overview and a review of the relevant literature). The category use effect indicates that when one is learning to classify and learning to use the categories, the reliance on features for classification is a joint function of their diagnosticity for classification and their relevance to the category use.

The exact explanation for the category use effect in these studies is still under investigation, but at least two possibilities are likely: changes in feature weighting and adding new features or relations to provide a deeper understanding. First, the simplest explanation for the disease experiment effects is that the use led to greater weighting of the features that were relevant for the use. Second, for the problem-solving tasks, it appears that the use of the category led subjects to incorporate some additional features and relations into the category representation. For example, when solving the simple equations in Experiment 6, subjects learned that different categories had different solution methods. The solution method used was incorporated into the category representation and seemed to provide a better explanation for the category than the more available superficial feature predictors, such as number of parentheses.

This effect of category use on classification has not generally been considered by theories of classification, and how they might be extended has not been tested (see Ross, 1997, for a discussion). However, these findings are just a beginning toward understanding classification in the broader context of how we use categories. The effect has been demonstrated under one learning paradigm, but much remains to be learned about its generality and the conditions under which category use may influence classification. The experiments in this article extend the generality in two important ways. First, I examined a different, but common, learning situation in which people learn the classification before learning to use the category. Second, after this effect had been established, the experiments then investigated how such learning may proceed when the learning of the use does not require an explicit classification. That is, in many cases, we may be trying to accomplish goals (e.g., making predictions, solving problems) in which the categories of the entities involved are not always explicitly considered. If the classification is more incidental to the goal, does the learning of the use still affect later classification? I now turn to a fuller explanation of each of these issues.

Postclassification

In a previous study (Ross, 1997), I examined one standard learning situation, in which the classification and use were learned on each trial, which I will call interleaved. For example, after classifying an item, such as deciding which disease a patient had, subjects then had to make use of the classification, such as determining what drug treatment should be given to this classified patient. This type of learning situation is a common one when people are learning about a new principle in a domain by the use of examples.

In this article, I examine a very different but also common learning situation, which I will call postclassification—people first learn to classify and only then learn the use of the category. Such a learning situation may come about in at least two ways. First, people learning a domain may learn some initial classifications and then, as they learn more about the domain and the categories, learn to use the categories to accomplish some goals. Experience in some domains may well begin with classification experience. Second, people may learn categories and how to use them, but later learn a new use. In addition, such a paradigm may be especially helpful for understanding the category use effect because it affords a separation (conceptual and temporal) between the classification learning and various ways of learning the use.

Why might the category use affect classification performance even when the classification is learned before the category use is introduced? That is, by the end of classification learning, subjects have presumably developed a means of classifying instances, so why should learning to use the category to do some other task influence this classification scheme? Although this question is addressed further in the General Discussion, I give a brief outline of an answer here. If one thinks of the knowledge about a concept that is used to classify instances as isolated from other knowledge about the concept, then there is no reason to believe that later use will influence the knowledge available for an already learned classification. If, however, one thinks of classification as potentially involving all sorts of knowledge about a concept, then learning further information about a concept (such as how the category is used) may well influence the classification. The means by which learning a category use has an effect in the postclassification situation may be very much like the ones in the interleaved situation that was mentioned earlier. In some cases, as one learns to use a category, some features of the category items may be seen as especially important for the use, which may in turn influence their weight in the classification, even though their actual diagnosticity for classification is unchanged. These effects on feature weights may happen in a variety of domains. One might learn to classify a type of object, say an oak, by its leaves but later learn much about its shape or size (perhaps in deciding about its role in landscaping). These latter attributes could be used in classifying new oak trees, especially if the leaf information was not available (perhaps because the observer is at a distance or under poor viewing conditions). In other cases, the use may lead to adding new features or relations that help to provide a deeper understanding of the category, with the features and relations highlighted by this understanding becoming more important in the representation, including the knowledge available for later classification.

This deeper understanding may be especially important in problem-solving domains. Suppose that, following classification learning of different mathematical problem types, people learned to solve one type of problem by applying a formula to a number of examples and that this problem solving led them to understand what was common to all members of the problem category. Those commonalities
may be part of what influences later classifications, even if they had not been learned during classification learning. For example, one can learn to classify many word problems on the basis of key words in the verbal description of the problem (e.g., Chi, Feltovich, & Glaser, 1981). Suppose one has learned to classify permutation problems in this way. As one applies the formula and understands why it works, the importance of the ordered assignment (i.e., that particular objects are assigned to, or "lined up" with, particular other objects) may become clear. This knowledge can then be used for classifying other word problems, especially when the key words are not present. In addition, it provides protection against being fooled by key words in misleading situations.

The point is that if one views classification as potentially using any knowledge about the concept, then there is reason to believe that even postclassification use might affect the knowledge available for later classification. In some cases, this use may lead to a change in feature weights for classification. In other cases, as one gets a richer conceptual representation, it can change many category-related judgments, including classification. Any additional features learned from the use may be important in classification when they provide a better prediction of the category than the originally learned features do (or people believe that they do) or when they are available in situations when the original features may not be. The generality of this idea is discussed following the presentation of the experiments.

**Prior Evidence**

Some results on real-world expertise are consistent with the idea that learning to use previously learned categories may well influence later classifications. Extensive experience in a domain often leads people to classify objects at a more specific level (e.g., Gibson, 1969; Tanaka & Taylor, 1991), though it may also lead them to see more commonalities (Murphy & Wright, 1984). Medin, Lynch, Coley, and Atran (1997) found that the classification sortings of trees by some experts, landscapes, were greatly influenced by the landscape uses of the different trees (e.g., ornamental, shade). Lopez, Atran, Coley, Medin, and Smith (1997) showed that the sortings of mammals by Itzaj-Mayan Amerindians were affected by various ecological considerations (see also Boster & Johnson, 1989; Malt, 1995). In many of these biological domains, it seems likely that much classification experience preceded learning the category use (such as landscaping or fishing for particular types of fish).

In problem-solving domains, experts often use more abstract features of problems to classify problems than do novices (e.g., Chi et al., 1981), features that they have presumably learned by considerable problem-solving experience in the domain. That is, the classification knowledge initially depends upon superficial aspects of the problem (e.g., "inclined plane"), but with greater use of the categories, the person learns deeper knowledge about the underlying principles (e.g., Newton's Second Law) that can be used for classification. Although these results all indicate that experience in using categories may influence later classifications, they do not show that simply learning to use already learned categories will influence classification. Not only do experts have much experience using categories, they also have much additional formal and informal training about the categories, as well as more experience classifying in the domain. In addition, it is not clear how much of the classification learning precedes the learning to use the categories in the different domains. Thus, this work on expertise is suggestive, but not conclusive, in showing that learning to use categories after having learned to classify may affect the knowledge available for later classifications.

Other work has shown that experience with category members in a nonclassification task may later affect the categories formed and the classifications (e.g., Billman & Heit, 1988; Billman & Knutson, 1996; Lassaline & Murphy, 1996; Ward & Becker, 1992). In addition, the well-known work on ad hoc and goal-derived categories by Barsalou (1983, 1985, 1991) also shows how the goals one has in mind may affect the classifications of items. However, none of this work has examined postclassification learning of the nonclassification use.

Yamauchi and Markman (1998; Markman, Yamauchi, & Makin, 1997) have some relevant findings on the effects of learning a nonclassification category use as part of a project on examining different ways in which categories might be learned. They found that a classification-learning task led to a focus on the diagnostic features (those useful for distinguishing the categories), whereas an inference or feature-prediction learning task led to a focus on the commonalities among exemplars in each category and the family resemblance structure of the categories. The authors argued that the category representation reflects the uses of the category. Although the work did show an effect of different category uses, it was not designed to examine how using the category might affect previously learned classifications.

**Other Postclassification Experiments**

Ross (in press) has reported a series of experiments examining this postclassification paradigm with the disease-treatment materials from Ross (1997). The classification of symptom sets into disease categories is a task that has often been used in studying classification (e.g., Gluck & Bower, 1988; Medin & Edelson, 1988). Following the learning of this classification, subjects learned to make an additional decision about which fictitious drug treatment should be given. The classification of diseases involved four perfectly predictive symptoms for each disease. The decision about treatments involved two of these symptoms, which were called relevant-use symptoms. That is, any of four symptoms were equally (and perfectly) predictive of a disease, but two of these symptoms, the relevant-use symptoms, also each perfectly predicted one of the two treatments for that disease. The other two symptoms, irrelevant-use symptoms, were perfectly predictive of the disease classification, but they did not predict the treatment (i.e., they occurred equally often with each of the two treatments for that disease). The critical tests were later disease classifications. If the treatment decisions that were learned after disease-classification learning did not affect the knowledge used for disease...
classifications, then there should be no differences in later classifications for the relevant-use and irrelevant-use symptoms. If, however, the relevant-use symptoms also came to be viewed as more central to the disease, then they should be more readily classified than the irrelevant-use symptoms. In this case, the use would affect the feature weights for the relevant-use symptoms so that they would appear to be more diagnostic for the classification than the irrelevant-use symptoms (even though they were not). Such a difference in classification performance is not predicted by most current theories of classification. I use the term postclassification category use effect to refer to cases in which a use learned after a classification has been learned has effects on later category judgments.

These experiments showed that often there were effects of learning the treatment on later classification. This postclassification category use effect occurred with both classification tests and generation tests ("If a patient had Disease A, what symptoms would the patient be likely to have?"") and occurred whether the subject continued classifying during the treatment learning or was simply given the disease of each patient during treatment learning. The only situation that did not lead to a postclassification category use effect was when the treatment learning made no reference at all back to the disease-classification learning. One interpretation is that the category use effects require the category representation to be activated during the learning of the use. That is, if a subject has to respond with Treatment 1 for a particular Disease A patient, this response will not affect the representation of Disease A if the learner does not realize that this is a Disease A patient. Thus, requiring a classification or providing a classification during learning of treatments leads to this postclassification category use effect, but having the treatment learning occur without having the subject activate the disease category does not lead to the effect. The current experiments extend this work both by examining effects that depend on new relations among features (not just feature weights) and by investigating other circumstances that might lead to such activation of the category during the learning of the use, as elaborated in the next section.

In sum, understanding the effects of category use in the postclassification paradigm is important both because it is a common learning situation and because it may provide insight to effects of category use in other learning situations. People's conceptual representations allow them to not just classify, but also to perform a variety of goal-related tasks. A central issue is to understand how different category uses affect these representations. Categories and their uses are crucial in a wide variety of domains, so such an understanding will have implications in many research areas.

Incidental Classification

In the previous work that showed a category use effect, with both the interleaved paradigm (Ross, 1997) and the postclassification paradigm (Ross, in press), the classification was always required or provided during the learning of the use. The current experiments investigated whether it is necessary for subjects even to be given the classification, or whether subjects' incidental classifications might be sufficient to lead to a postclassification category use effect. In many learning situations, classifications may not be required or given but may still be made incidentally (sometimes even automatically for superordinates and other context-independent features; e.g., Barsalou, 1982; Barsalou & Ross, 1986). Are such incidental classifications sufficient for leading to a postclassification category use effect? If so, the effect's generality is much greater because many learning situations in which explicit classifications are not required or given may still lead learners to make their own classifications.

By incidental, I mean that the classification is not required for the activity (i.e., the use). For instance, in problem-solving situations classification is often crucial but the goal is to solve the problem, not to classify it. When people are solving a problem for which they do not have a well-learned solution, they often learn much from the problem solving. However, for such knowledge to be useful for solving later problems, this knowledge needs to be accessed when solving problems for which it is appropriate. Thus, if the solver has activated the appropriate problem category during the solution, the knowledge may be represented with this category and available for use in solving later similar problems. This problem classification is incidental during the learning because it is not required to solve the problem, but clearly it may be crucial for solving later problems of this type. The incidental classification does not occur only with active problem solving. As another example, part of our ability to learn from observation requires that we understand the type of object or situation being acted upon. Again, if one is to make use of this knowledge, it must be stored with the representation of the appropriate category. The point is that humans often learn by doing and by observing, and our ability to make use of this learning depends upon being able to access what we have learned at the appropriate time. These incidental classifications are common but are not usually examined in category research.

The Current Experiments

The five experiments reported here had two goals. One goal was to establish whether there is a postclassification category use effect in a very different type of situation (from Ross, in press). The second goal was to investigate whether the incidental classification may be sufficient to lead to such an effect. In these experiments, category learning consists of both learning to classify and then learning to use the category to do some additional problem-solving task. That is, there is a classification-learning phase followed by a category use learning phase.

Pertaining to the first goal, this work extends the disease-treatment experiments described earlier in three important ways. First, unlike the earlier experiments, these experiments did not require the subjects to learn further distinctions within the category, but rather required a problem-solving use of the categories. The prediction about treatments could be viewed as another classification in which the learners are assigning patients to the (sub)category of people
to be given each treatment (e.g., Disease A patients who need Treatment 1). The category use effect does occur with other types of uses (see Ross, 1997), but it is important to establish this for postclassification category use as well. Although I think that subclassifications can be viewed as a type of category use, it was not clear that the observed postclassification effects of learning subcategories would also be true for problem-solving category uses.

Second, because the disease classifications and treatment decisions could be made on the basis of the same symptoms (the relevant-use symptoms), it is possible that the postclassification category use effect is restricted to such situations. In the current experiments, different features were involved in the classification and the use. Thus, any effect cannot be due to getting a single set of features to accomplish both tasks.

Third, in the disease-treatment experiments, the category use effect led to a change in feature weighting of the relevant-use symptoms. In the current experiments, the use led to incorporating into the category representation a new relation among the features.

Pertaining to the second goal, Experiments 2–5 examined cases in which no classification was required or provided during the learning of the use. As mentioned, in problem solving, problem classification is helpful but it is not the goal—the goal is to solve the problem. In such cases, one often gets feedback about the correctness of the answer, not the correctness of the classification. The earlier experiments using disease-treatment materials suggested that when the classification of the patient was not required or provided during treatment learning, then there was no effect of the treatment learning on later classifications (i.e., no postclassification category use effect). Experiments 2–5 in the present study explored whether there is an effect in cases in which the learners might be able to classify the items even when no classification is required or provided, as in many real-world situations.

Experiment 1

Experiment 1 provides an examination of the basic postclassification category use effect with this new set of materials and problem-solving category use—does learning to use a category following classification learning affect the category representation, including knowledge available for subsequent classifications? The materials and general procedure were as in Ross (1997, Experiment 7), which showed a strong influence of the use on classification when the learning of the classification and use were interleaved. Will a similar effect be found when subjects learn the classification first?

In these experiments, subjects were told that they were clerks in an intelligence-gathering operation. Spies would send them coded messages consisting of letters and numbers. Their job was to determine which spy sent the message (classification) based on the letters. After they learned to classify spies well, the decoding task was introduced. For each message they were told which spy sent it and then had to apply the appropriate decoding formula on the numbers (each spy had a different decoding formula). The decoding of the messages led them to make use of different relations among the numbers (products and quotients). The critical issue was whether these relations were incorporated into the category representation as reflected in their availability for later classification, even though subjects had already learned to classify. Note that this could not have been due to a change in feature weights, but rather involved learning a new relation among the features.

Two aspects of this design are particularly important, as described in Ross (1997). First, the classification and use were based on different parts of the message, and subjects were explicitly told this information. The main issue is whether the knowledge they gained from the use was added to their category representation and was available for later classification. To examine this question, I made the critical test items ones in which the original classification information was not available. If subjects added the information from the use to their category representation and it was available for classification, then subjects would classify these test items in a manner consistent with the use. Such partial tests not only provide clear tests of the hypothesis, but they are also common in real-world situations in which one must classify on the basis of partial information (see the General Discussion for elaboration). Second, as I explain in more detail in the Method section, both critical relations among the numbers were true of all the coded messages. However, different uses (decoding formulas) made explicit one relation for members of one category and another relation for members of the other category. Thus, if different relations were incorporated into the category representations of different spies, this difference had to be a function of the use.

Method

Subjects. The subjects were 16 University of Illinois undergraduates who participated as part of a class assignment or for pay. The sessions lasted 30–45 min.

Materials. The study and test materials were coded messages from fictitious spies, as in Ross (1997, Experiment 7). The study codes were each two letters followed by six numbers. There were two spies, Spy A and Spy B. Spy A messages all began with PD or DP, whereas Spy B messages all began with SF or FS. (The category use effect was found by Ross [1997] with this simple classification, though also with a more difficult spy-classification scheme.) Depending on the spy, subjects then had to apply one of the decoding formulas given in Table 1. For example, if the coded message was FS342526 for Spy B, then the decoding formula (sixth + second/fifth + fourth + third) would lead to (6 + 4/2 + 5 + 2 = 15). The six-number sequences for all messages had the following two constraints, one of which would be computed in each application of a decoding formula. First, the sixth number times the third number was always equal to 12 (e.g., FS342526 has 6 × 2). Second, the quotient of the second and fifth numbers was always equal to 2 (e.g., FS342526 has 4/2). Table 1 gives some examples. Note that all study and decoding items had both of these constraints, but each decoding formula made explicit a different constraint (i.e., that the product was 12 or the quotient was 2). There were eight study items for each spy, divided into two sets of four. The study materials consisted of two blocks of eight codes.
Table 1  
Sample Materials for Experiment 1

<table>
<thead>
<tr>
<th>Decoding formula*</th>
<th>Spy A: 2nd + (6th × 3rd) + 1st + 5th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spy B: 6th + (2nd/5th) + 4th + 3rd</td>
<td></td>
</tr>
<tr>
<td>Sample study coded messages</td>
<td>6th × 3rd</td>
</tr>
<tr>
<td>Spy A: DP763434</td>
<td>12</td>
</tr>
<tr>
<td>Spy B: FS624113</td>
<td>12</td>
</tr>
<tr>
<td>Test condition</td>
<td>Sample messages</td>
</tr>
<tr>
<td>Consistentb</td>
<td>SP462336</td>
</tr>
<tr>
<td>Conflictc</td>
<td>SP253824</td>
</tr>
<tr>
<td>No-letterd</td>
<td>8272126</td>
</tr>
</tbody>
</table>

*These refer to the position of the number in the message. bConsistent means that the coded message is just as in study, so that the number relations are consistent with both spies, though the letters are consistent with just one spy (in this example, Spy B). cConflict means that the letters are each predictive of different spies. Only one of the number relations from study is present (in this example, the product of the 6th and 3rd number equaling 12, as predicted to be noticed for Spy A from study). dNo-letter means that the letters were not presented. Only one of the number relations from study is present (in this example, the product of the 6th and 3rd number equaling 12, as predicted to be noticed for Spy A from study).

There were 24 test items, which were divided into three types: consistent, conflict, and no-letters. The consistent tests had letters and numbers that were generated exactly as for the study items and were included to ensure that subjects still remembered how to classify on the basis of the letters. The other test items incorporated only one of the number relation constraints (i.e., the product was 12 or the quotient was 2) and provided the critical test of the hypothesis that the decoding had led to additional knowledge being available for later classification. In the conflict items, the code included one letter that was predictive of each spy (e.g., FF), so that subjects could not rely on the letters to classify the item. In the no-letter tests, dashed lines were included instead of letters (subjects were told that the letters had been lost as a result of garbled transmission). Examples of these tests are given in Table 1.

All study and test codes were handwritten on a 5-in. × 7-in. (12.7-cm × 17.8-cm) index card.

Design. All subjects received the same coded messages and made the same classifications. As a counterbalancing variable, half the subjects used each decoding formula for Spy A and the other for Spy B. If the relations among the numbers had been learned from using the decoding formulas and incorporated into the category representations, then conflict and no-letter classification test responses should have been a function of the constraint among the numbers (i.e., whether the product was 12 or the quotient was 2). All the study messages had both these constraints, so the prediction was a claim about how the use led subjects to learn some aspect of the item relative to other aspects.

Procedure. The study phase consisted of two parts: learning to classify messages and learning to decode messages. All subjects were told that they should think of themselves as being clerks in an intelligence-gathering operation and that their job was to determine which spy had sent the coded message. They were told that the letters in the message could be used to determine which spy had sent it. For each study trial, the subject was handed a code, classified it as to which spy sent it, and was given feedback. This classification continued until the subject was correct on 7 of the 8 messages in a block after the 1st block. All subjects were able to classify at this criterion by the 2nd block.

The learning-to-decode procedure began after the subjects learned to classify the messages. For each message they were told which spy had sent it and then had to apply the appropriate decoding formula. They were told that the resulting number could be passed on to their supervisor for further decoding. The decoding formula for each spy was typed on a piece of paper that remained in front of the subject during the decoding phase. Then subjects applied the appropriate decoding formula by writing the parts and answer down on a piece of paper. When they had finished, the next item was presented. Both blocks of eight messages were decoded.

For each test trial, the subject was handed a code and had to determine which spy had sent it. They were told that some codes might have missing or incorrect letters as a result of garbled transmission.

Results and Discussion

The classification (spy) criterion of 7 of 8 messages correct was met by all subjects by the 2nd block (the minimum required). The mean proportions correct for the 1st and 2nd blocks were .90 and .98, suggesting that the letters-to-spy information had been learned well. After this, subjects decoded 16 messages.

The consistent tests, in which the letters and numbers were exactly as in the study phase, led to correct classification .73 of the time, which differs from chance responding of .50, t(15) = 2.91, p < .05.1 The main question of interest is how subjects classified the codes when the letters were not informative, either because they conflicted or were missing. The scoring for these tests was in terms of whether the classifications were what would be predicted if subjects were using the number relations (i.e., the product of 12 or quotient of 2). For example, if the decoding formula for Spy B always led to calculating a quotient of 2 for the second and fifth numbers, then the prediction would be that conflict and no-letter test items with this number relation would be classified as Spy B messages. If the decoding had not led subjects to notice the number relations and how those relations corresponded to the spy categories, and then to incorporate this information into their category representations, then subjects would have no basis for responding when the letters were not informative. As a result, one would expect performance near .50. However, in both the conflict and no-letter tests, the classifications were clearly influenced

---

1 The consistent test performance of .73 is considerably lower than the final study classification performance of .98. Some of that difference may be due to the delay between the classification learning and test (because the classification was given during the use learning). However, much of it may be due to some subjects who applied what they had learned about the numbers even to the consistent tests. For example, some subjects classified on the basis of one number relation (e.g., "If the second number divided by the fifth number is equal to 2, then it is Spy B."). This would misclassify half of the consistent test items by classifying all of them as Spy B because both number relations were true in the consistent test items.
by the relations among the numbers. For the conflict trials, .68 of the classifications were as predicted by the number relations, t(15) = 2.36, p < .05. For the no-letter tests, .68 of the classifications were again based on the number relations, t(15) = 2.42, p < .05.² Note that this effect of use occurred even though the numbers were separate from the predictive-classification letter cues, and the subjects were told at the beginning of the experiment that the letters would indicate which spy had sent the message. Despite this instruction, in some cases the number relations appeared to have a strong influence even when the letters were informative. Six of the 15 subjects had scores on the conflict and no-letter tests that were equal or higher than on the consistent tests (1 subject had all tests correct).

This experiment shows the basic postclassification category use effect. This effect has also been shown with the disease-treatment materials, but the current experiment provides a replication with a very different set of materials, in which the classification and use parts were clearly separated and the subjects were informed of this separation. Even so, those number relations that were relevant to each category's decoding scheme were available later for classifying items into that category, indicating that they were incorporated into the category representation. In addition, the task required incorporating new relations among the features, not just feature weights. Most important, this effect occurred even though the number relations were not predictive of the spy classification during classification or decoding learning. In addition, unlike the Ross (in press) studies, the problem-solving use cannot be interpreted as a type of subclassification.

Experiment 2

Experiment 1 (as well as the experiments in Ross, in press) showed that requiring or providing a classification during the learning of the use leads to a postclassification category use effect. The goal in the remaining experiments was to investigate the possibility that the effect may also come about from incidental classification during the learning of the use. As mentioned in the introduction, there may be many cases in which no explicit classification is required, but in which people do classify the object, situation, problem, or person. Thus, finding an effect with incidental classification greatly increases the generality of the effect. To test this possibility that incidental classifications may lead to a postclassification category use effect, I contrasted two conditions—one in which no incidental classification was likely and the other in which it was. For this first condition, I used a separate condition, in which the use was learned without any reference to the categories. That is, following classification learning, subjects were given the appropriate decoding formula to each message and learned to apply the formulas, but no mention was made of the spies. When this condition was used in Ross (in press) with the disease-treatment materials, subjects did not usually make any connection between the category and the use. The classification was made difficult enough in Experiment 2 that people would be unlikely to classify a message during decoding unless they were forced to examine the classification-relevant portion of the message. For the other condition, there could be no explicit reference to the classification, but a simple manipulation was needed to increase the probability that such classifications would be made incidentally. In this experiment, subjects in this incidental condition had to write the codes down (including the letters) and read them aloud before decoding. If attending to the letters allows learners to classify the codes and such incidental classifications are sufficient to lead to a postclassification category use effect, then there should be such an effect in the incidental condition.

Method

Subjects. The subjects were 36 University of Illinois undergraduates who participated as part of a class assignment or for pay. The sessions lasted 30–50 min.

Materials. The study and test materials were coded messages from fictitious spies, as in Experiment 1, but with a few changes to make the classification more difficult and less likely to be made in the course of decoding (to make sure the separate condition did not incidentally classify as well). The order of the numbers and letters was switched, so there were six numbers followed by two letters. There were two spies, Spy A and Spy B. Spy A messages all ended with a pair of letters chosen from the three letters P, D, and N (so PD, PN, DP, DN, ND, or NP), whereas Spy B messages all ended with pairs of letters from S, F, and K. As in Experiment 1, all study items had both number relations. There were 16 classification study items for each spy, leading to 4 blocks of 8 codes, plus 8 separate codes for each spy that were used for decoding. Examples of Spy A codes were 122816PD and 544323NP, and examples of Spy B codes were 162236FS and 683664SK. To make the classification and decoding seem more distinct, I used different colored cards (white and light green) for the two phases.

There were 24 test items, 8 consistent tests and 16 no-letter tests (as described in Experiment 1), presented on pink cards. Conflict tests were omitted to allow an increase in the number of observations for no-letter tests. All study and test codes were handwritten on 5 in. × 7 in. (12.7-cm × 17.8-cm) index cards.

Design. The design was exactly as in Experiment 1, except for a between-subjects manipulation of the connection made between the spy classification and the decoding at the time of learning the decoding. Subjects in the separate condition learned the use (decoding) with no explicit connection made to the classification. The prediction was that the number relations used in the decoding would not be incorporated into the category representations, and so would not be used in responding on the no-letter tests. In the incidental condition, no classification was required or given (as in Experiment 1), but the subjects were required to write the classification letters and read them aloud. This manipulation was made to increase the probability of an incidental classification of the message. If such a classification were made during the decoding, the prediction was that the incidental-condition subjects would incorporate the number relations into their category represen-

² The proportions also include 1 subject who saw that the relations among the numbers were predictive of the spies but during the classification test reversed all the Spy A and Spy B judgments for the conflict and no-letter tests. If this subject's scores (of 0 of 8 correct for these types of tests) are reversed (to 8 of 8 correct for each), then the proportions were .74 and .74.
tations during decoding and then later respond to the no-letter tests on the basis of these number relations.

Procedure. The study phase consisted of two parts: learning to classify messages and learning to decode messages. The classification of spies procedure was the same as in Experiment 1, except that at least three learning blocks were required.

The learning-to-decode procedure began after the subjects learned to classify the spy. The spy story was changed from Experiment 1 to separate the classification and decoding. In this experiment, subjects were told that the agency computer used a complicated formula for generating the numbers, and that it needed to be checked to ensure that the code had not been tampered with. The job of the apprentice (i.e., the subject) was to apply a supplied formula to each code and then pass the resulting number to the experimenter. For each message they were given a sheet with the formula to be used, and they applied this decoding formula. In the separate condition, subjects applied the decoding formula by writing down the six numbers and then plugging them into the provided formula. In the incidental condition, subjects first wrote down the six numbers and the two letters and then read them aloud (they were told that the writing and reading of the codes were agency rules to ensure that they were working on the correct coded message). This manipulation forced them to consider the classification letters during their decoding. When they had finished, the next item was presented. Both blocks of eight messages were decoded.

For each test trial, the subject was handed a code and had to determine which spy had sent it. They were told that some codes might have missing letters as a result of garbled transmission.

Results and Discussion

The classification (spy) criterion of 7 of 8 correct was met by most subjects by the 3rd block (3 blocks were required), but 8 subjects did not (5 in the incidental condition and 3 in the separate condition), requiring 4 to 6 total blocks.\(^3\) The mean proportions correct for the 1st, 2nd, and 3rd blocks were .74, .83, and .84, respectively, in the incidental condition, and .72, .80, and .85, respectively, in the separate condition.

The consistent tests, in which the letters and numbers were exactly as in the study phase, led to correct classification .79 of the time in the incidental condition, which differs from chance responding of .50, \(r(17) = 3.60, p < .01\), and .80 of the time in the separate condition, \(r(17) = 4.47, p < .01\). The difference between those two conditions was not significant, \(r(34) = -0.07\).

The performance on the no-letter tests is of most interest. Did subjects make use of the number relations when the letters were not informative? It appears that they did for the incidental condition but not for the separate condition. In the incidental condition, .69 of the no-letter tests were classified consistently with the number relation, \(r(17) = 3.26, p < .01\), but only .48 in the separate condition, \(r(17) = -0.45\). This difference of .69 versus .48 between the two conditions was statistically significant, \(r(34) = 2.84, p < .01\). Thus, the incidental-condition subjects showed a greater influence of the number relations on their classifications than did subjects in the separate condition.

This experiment shows that incidental classification is sufficient for obtaining a postclassification category use effect—it is not necessary to continue classification training or provide the classifications during the learning of the use. In the incidental condition, subjects simply wrote the code and read it aloud to ensure that the letters were attended to. This simple processing was sufficient for allowing the use to affect the knowledge available for later classifications. This finding greatly increases the generality of the effect because incidental classifications are often made when an item is encountered, even if no explicit classification is required or given.

Experiment 3

Experiment 2 showed that additional processing of the code was sufficient for producing a postclassification category use effect, presumably because the additional processing led to an incidental classification. A stronger test of this idea would be to promote such incidental classifications the way they often are assumed to arise in real-world situations—from extended classification experience. That is, with more classification experience, people will be more likely to classify problems, objects, and situations even if there is no explicit requirement to do so.

This incidental classification from experience is probably most obvious with objects—in many cases we automatically classify an object we encounter, such as a chair, tree, and so forth. In addition, there is evidence that when presented with a word of an object, certain important information, such as the immediate superordinate category, appears to be activated—such as “flower” when presented with *tulip* (e.g., Barsalou & Ross, 1986). However, it is also likely that extensive experience classifying other items, such as problems or situations, will also lead to quick classification of the items (e.g., Chi et al., 1981). In many cases, these classifications may be made explicitly (e.g., “this is a permutations problem”), but in other cases the classification may be more incidental. As mentioned in the introduction, we often learn by doing and by observing, and both types of learning can benefit from having the appropriate categories incidentally activated. The main point is that extensive experience in a domain often leads to the automatic classification of domain items when they are encountered, and having the category representation activated allows knowledge gained about the item to be stored with, or related to, the category representation.

The goal in the remaining experiments was to test the idea that extended classification experience leads to a postclassification category use effect even when no explicit connection is made between the use and the category. In these experiments, subjects were given much greater experience in learning the classification. The hypothesis was that if they learn the classification so well that they incidentally classify items during the decoding phase, then there would be a postclassification category use effect. Because the item’s presentation would activate the category representation—even though it was not required for what the subject

\(^3\) An experimenter error led to 5 subjects’ having only two classification blocks instead of three. Omitting these subjects does not change the results.
had to do), the learning of the use would lead to changes in
the representation that could affect later category judgments,
such as classification. Note that the hypothesis was that
greater experience in classification before learning the
category use would lead to a greater effect of the category
use on later classification. That is, the more people learn to
classify before learning the use, the more influence the use
will have on later classifications. To test this hypothesis, I
had subjects learn the 'spies and decoding just as in the
separate condition of Experiment 2 (in which no category
use effect was found) except that they did not begin the
decoding until they had much greater experience in classify-
ing the spies (4 additional blocks after they had 7 of 8 correct
[which was the learning criterion in Experiment 2], but at
least 6 blocks). I call this manipulation the extended
condition. The prediction was that subjects in the extended
condition would show a postclassification category use
effect.

Method

Subjects. The subjects were 20 University of Illinois under-
graduates who participated as part of a class assignment or for pay.
The sessions lasted 30–50 min.

Materials. The study and test materials were exactly as in
Experiment 2.

Design. The design was exactly as in the separate condition of
Experiment 2, except that the extended condition subjects in this
experiment continued their classification (spy) learning for 4 more
blocks after reaching the classification learning criterion of 7 out of
8 correct. If the subject reached this criterion on the 1st block,
learning was continued for 5 more blocks so that all subjects had at
least 6 blocks (48 trials) of classification. (Note that in Experiment
2, subjects had at least 3 blocks.) The idea behind this manipulation
is that the extended classification learning will lead to incidental
classifications during decoding learning. The hypothesis was that
such incidental classifications would be sufficient for leading to a
postclassification category use effect because they activated the
category representation. Thus, the prediction for this experiment
was that subjects in the extended condition would respond to the
no-letter tests on the basis of the number relation used in the
decoding, whereas subjects in the separate condition would not.

Procedure. The study and test procedures were exactly as in
Experiment 2 except for the extended classification learning.

Results and Discussion

The classification (spy) criterion of 7 of 8 correct was met
by 19 of the 20 subjects by the second block, so they had 6
blocks (48 trials) total. One of the subjects required 5 blocks
to reach the criterion, so this subject had 9 blocks of
classification learning. The mean proportions correct for the
1st to 6th blocks were .77, .73, .91, .97, .99, and 1.00. Thus,
it appears that subjects in this extended condition knew the
classification very well.

As further evidence of this high level of learning, the
consistent tests, in which the letters and numbers were
exactly as in the study phase, led to correct classification .96
of the time, which differs significantly from chance respond-
ing. \( r(19) = 34.38, p < .01 \).

As before, the performance on the no-letter tests is of
most interest. Did the extended classification learning lead
to a postclassification category use effect when the letters
used for initial spy classification were not available? In the
extended condition, .61 of the no-letter tests were classified
consistently with the number relation, \( r(19) = 2.20, p < .05 \).

Although the overall data showed a statistically signifi-
cant effect on the no-letter test, the effect was not large.
Based on postexperiment questions, the data were separated
into subjects who claimed they did notice something about
the relationship between the spies and the decoding during
the decoding phase (\( n = 7 \); these also included partial
relationships, such as about one spy only) and subjects who
did not (\( n = 12 \); 1 subject's answer was unclear, and the data
were not included). Split in this way, subjects who noticed a
relation were correct on .79 of the no-letter tests, compared to
.50 for the subjects who did not notice, \( r(17) = 3.29, p < .01 \).
Thus, it seems that the extended condition did lead to
about a third of the subjects' noticing the relation between
spies and the decoding formulas, and those subjects showed
a strong postclassification category use effect. (One of the
subjects who noticed was confused about the two categories
by the no-letter tests and misassigned the items; if those data
are reversed, then the subjects who noticed were correct on
.86 of the no-letter tests.)

This experiment shows that greater experience in classifi-
cation can lead to a postclassification category use effect—it
is not necessary to have a nonclassification task during the
use to draw attention to the relation between the categories
and their uses. If learners have enough experience in
classification so that they classify items during use without
being required to, then the use affects their later classifica-
tions. In many real-world situations, people with experience
in a domain may incidentally classify the domain items.

Experiment 4

Experiment 4 replicated Experiment 3 with two changes.
First, although there was a statistically significant effect, the
proportion of subjects who noticed this relation in Experi-
ment 3 was only about one third. In debriefings, it appeared
that many subjects did not even look at the letters during
decoding because the letters were not involved in the
decoding and were to the right of the numbers. To increase
the probability that all subjects look at the letters, I put the
letters to the left of the numbers, as in Experiment 1. Second,
Experiment 3 contained no separate condition for direct
comparison. This control was necessary here because of the
change in the position of the letters from the earlier
experiments (in case this change was sufficient to lead to a
postclassification category use effect without extended
classification learning). The predictions were that subjects in
the extended condition would show a postclassification
category use effect, subjects in the separate condition would
not, and there would be a significant difference between the
conditions.
Method

Subjects. The subjects were 44 University of Illinois undergraduates who participated as part of a class assignment or for pay, with 22 each in the extended and separate conditions. Seven additional subjects were excluded as described below. The sessions lasted 30–50 min.

Materials. The study and test materials were exactly as in Experiment 3, except that the letters were now to the left of the numbers rather than to the right.

Design. The design included the separate condition as in Experiment 2 contrasted with the extended condition as in Experiment 3.

Procedure. The study and test procedures were exactly as in Experiment 3 (extended condition) and Experiment 2 (separate condition). However, the learning criterion was changed to be 8 out of 8 for the separate condition, and 4 additional blocks after 8 out of 8 for the extended condition. This minor change was made to promote even better classification learning. In addition, to avoid including subjects who may have forgotten the classification by the time of the test, I included only the data from subjects who had at least 6 correct on the 8 consistent tests. This led to excluding 1 subject in the extended condition and 6 in the separate condition.

Results and Discussion

The classification (spy) criterion of 8 of 8 correct in the separate condition required a mean of 2.8 blocks, with the range from 1–5 blocks (the numbers of subjects meeting the criterion for each of Blocks 1–5 were 1, 11, 4, 3, and 3, respectively). In the extended condition, the 8 of 8 criterion was met in a mean of 2.0 blocks, with the range from 1–4 blocks (7, 11, 2, and 2 subjects, respectively), although these subjects continued for 4 additional blocks.

It is clear that both groups learned the classification well, with proportions correct on the consistent tests of .95 for the separate condition and .99 for the extended condition. Because of the very small variances, this difference was significant, t(42) = 2.05, p < .05.

The performance on the no-letter tests showed a small nonsignificant difference from chance responding in the extended condition, .55, t(21) = 0.71; no effect in the separate condition, .47, t(21) = -0.77; and a nonsignificant difference between the conditions, t(42) = 1.01.

Although the overall data showed only a little evidence of the extended-condition effect found in Experiment 3, a further analysis suggested that such an effect may be hidden by 6 subjects (4 in the extended condition and 2 in the separate condition) who reported noticing the relation between the spies category and the decoding but then reversed the categories at the time of test. When those 6 subjects were omitted, then the extended condition showed a significant effect, .64, t(17) = 2.57, p < .05; the separate condition did not, .52, t(19) = .50; and the difference between the conditions was statistically significant, t(36) = 2.04, p < .05.

Retrospective verbal reports are subject to a number of interpretation problems (see Ericsson & Simon, 1993), so a second follow-up analysis did not rely on the verbal reports. Instead, I simply reversed the data of all subjects who scored below chance on the no-letter tests (so scores below 8 were subtracted from 16). This scoring ignores the subjects' reports and really focuses on how different from chance the responding was. It can also be viewed as a measure of how consistently subjects assigned codes with the same number relations to the same categories. Thus, a subject who discriminated the two categories perfectly at test on the basis of the number relations would score a 16, regardless of whether the test items were assigned to the correct spy category. This scoring clearly increases the overall proportion "correct," .74 and .63 for the extended and separate conditions, respectively, but still shows a significant difference between the conditions, t(42) = 2.31, p < .05.

Finally, I examined the number of subjects who both claimed to have noticed a relation between the spies and the decoding and provided specific enough information that could be used for classification. In the extended condition, 13 of 22 subjects noticed (.59), whereas 5 of 22 in the separate condition did (.23), χ²(1, N = 44) = 6.02, p < .05. Thus, the extended classification learning led to a higher proportion of subjects noticing the relation between the spy classification and the decoding use.

This experiment provides further support for the idea that incidental classification can lead to a postclassification category use effect. The extended classification learning led to more subjects noticing the spy-decoding relation and to a higher classification performance on the no-letter test (when subjects who reversed category assignments were excluded or all subjects were given the benefit of the category assignment that would lead to their higher performance). When combined with the findings of Experiment 3 (in which reversed-category assignments were not a problem), these results show that extended classification can affect the knowledge available for subsequent classifications.

Experiment 5

This final experiment provided another test of the hypothesis that extended classification learning leads to a postclassification category use effect. Because of the significance of this result for the real-world generality of the postclassification category use effect, it is important to replicate this effect without the interpretation problems caused by the few subjects in Experiment 4 who reversed category assignments. To avoid the reversed-category assignment problem, in this experiment I gave the subjects feedback on the first four tests (which included two consistent tests and two no-letter tests, one of each category). This feedback allowed the subjects to get the category assignment correct for the no-letter tests if they had noticed that the decoding use related to a spy category. The prediction, again, was that the extended condition would show more of a postclassification category use effect than the separate condition.

Method

Subjects. The subjects were 40 University of Illinois undergraduates who participated as part of a class assignment or for pay, with 20 each in the extended and separate conditions. In addition, 4 additional subjects who did not meet the consistent test criterion of 6 correct were excluded from the separate condition. The sessions lasted 30–50 min.
Materials. The study and test materials were exactly as in Experiment 4.

Design. The design was exactly as in Experiment 4.

Procedure. The study and test procedures were exactly as in Experiment 4, except that feedback was provided for the first four test items. These 4 tests were separated from the other 20 tests and used for all subjects. There were 2 each from the consistent and no-letter tests, and for each type of tests, 1 was from Spy A and 1 from Spy B. The order of the 4 tests was randomized for each subject, and they were immediately followed by the other 20 tests without feedback.

Results and Discussion

The classification (spy) criterion of 8 of 8 correct in the separate condition required a mean of 2.9 blocks, with the range from 1–8 blocks (the numbers of subjects for each of Blocks 1–8 were 2, 11, 2, 2, 1, 1, 0, and 1, respectively). In the extended condition, the 8 of 8 criterion was met in a mean of 2.1 blocks, with the range from 1–4 blocks (2, 15, 2, and 1 subject[s], respectively), though subjects continued for 4 additional blocks of classification training.

It is clear that again both groups learned the classification well, with proportions correct on the consistent tests of .97 for the extended condition and .94 for the separate condition, a nonsignificant difference, \( t(38) = 1.27 \). If one only includes the six tests for which no feedback was given, the difference of .99 versus .94 is significant, \( t(42) = 2.14, p < .05 \). Thus, it does seem that the four extra study blocks led to a small improvement in classification performance, though obviously there are ceiling effects with many of the subjects’ classifying all the items correctly (19 of 20 subjects in the extended condition and 14 of 20 in the separate condition).

The performance on the no-letter tests showed a large effect in the extended condition, .79, which differed from chance responding of .50, \( t(19) = 6.29, p < .01 \); no effect in the separate condition, .52, \( t(19) = 0.71 \); and a significant difference between the conditions, \( t(38) = 4.78, p < .01 \). If one includes only the 14 tests for which there is no feedback, the proportions and results are very similar: .80 for the extended condition, \( t(19) = 5.80, p < .01 \); .53 for the separate condition, \( t(19) = 0.80 \); and a significant difference between the conditions, \( t(38) = 4.36, p < .01 \).

The number of subjects who both claimed to have noticed a relation between the spies and the decoding and provided enough specific information to allow accurate classification showed a larger difference than in the previous experiment, with 14 of 20, .70, noticing in the extended condition, and only 1 of 20, .05, in the separate condition, \( \chi^2(1, N = 40) = 18.03, p < .01 \). Thus, the extended-classification learning again led to a higher proportion of subjects’ noticing the relation between the spies and the decoding use.

This experiment provides strong support for the hypothesis that extended classification learning leads to more people noticing the relation between the classification and the use, and also leads to a postclassification category use effect.

General Discussion

The present experiments show that even when the classification is already learned, learning to use a category can affect the category representation, including knowledge available to classify later instances. In addition, the current research extends these findings to cases in which the classification is incidental during the learning of the use.

Experiment 1 showed the basic postclassification category use effect: Providing the classification (of spy) during the learning of use (decoding) led subjects both to incorporate the number relations important to use into their category representations and to rely upon these relations for making later classifications. This effect occurred even though the number relations were not predictive of the classification. Experiment 2 began an examination of situations in which no classification was required or provided during learning of the use. In this case, additional processing of the message (to increase the probability of an incidental classification) led to an effect on later classifications, compared with a case in which incidental classification was less likely. Experiments 3, 4, and 5 investigated a situation that mirrors many real-world learning situations. If subjects had extensive classification experience in a domain (thus, again, increasing the probability of an incidental classification), then they were more likely to show a postclassification category use effect. The discussion focuses on an interpretation of the effect with incidental classifications, the generality of the effect, and the relation of this work to people’s understanding of categories.

Postclassification Category Use Effect and Incidental Classification

The category use effect suggests that an understanding of classification learning may not be separable from other types of learning. That is, classification learning is not simply a function of feedback about classification, but may be affected by nonclassification knowledge as well. Ross (1997) showed this effect with the interleaved learning paradigm, in which the classification is learned along with the use. With this interleaved learning paradigm, one might object that the effect on classification learning occurs only because feedback about the use can be directly incorporated into the classification or because people are trying to learn a rule that allows them to both classify and use.

The experiments reported here (and in Ross, in press) indicate that there is a category use effect even when the use is learned after the classification, suggesting that neither of these objections is correct. Learning to use a category to make a further prediction or to solve a problem appears to feed back and influence the representation (including knowledge available for later classifications) even when the learning of the use occurs after the learning of the classification. Thus, it is not necessary that the learning of classification and use be interleaved.

To gain a better understanding of how an effect comes about, it is useful to examine the conditions when the effect occurs and the conditions when it does not. Experiment 1
(and Ross, in press) established that there is a postclassification category use effect if a classification is provided during the learning of the use. The later experiments extend this result to show that one may get an effect even if the classification is not provided, as long as the subjects incidentally classify the item. However, the separate conditions of Experiments 2, 4, and 5 indicate that this effect may not occur if the classification is not provided and subjects do not incidentally classify the item on their own. Together, these results suggest that the postclassification category use effect depends upon having the category representation activated during the learning of the use. When the representation is activated, then knowledge about the use is incorporated into the representation and is available for later category-related judgments, such as classification.

To elaborate, consider the incidental and extended conditions. My claim is that when decoding the message, the subjects have activated the appropriate category representation (e.g., Spy A). The information gained from a decoding (such as the product of the two numbers being 12) is stored as having occurred with an item from this category. With repeated occurrences of such relations, this regularity is stored as part of the category representation (i.e., Spy A messages have the product of the sixth and third number equaling 12). In the separate condition, however, the category representation is not activated during the decoding. Subjects do often notice the number relations (that is, that the quotient was 2 or the product was 12), but they do not notice that each relation occurs for a particular spy. Thus, in this condition, the category representations are not affected by the decoding learning and there is no postclassification category use effect.

A major result of the current experiments is that this activation does not need to rely upon requiring or providing this classification during the learning of use. If subjects have extensive enough classification experience in the domain so that they classify presented items (whether required or not), then the postclassification category use effect occurs. In many real-world situations, we may incidentally (and automatically) classify a variety of objects. These classifications may affect not only our actions in the situations, but also what we learn from these situations. These incidental classifications are common, but are not generally considered in classification studies.

**Generality and the Relation to Real-World Category Learning**

The current experiments differ from the usual category learning experiments (as well as real-world situations) in a number of ways, so it is important to consider the generality of these findings and claims. For ease of exposition, I separate the discussion into the generality of the paradigm, the task-specific aspects, the type of category, and the relation between classification and use.

**Paradigm.** The primary claim for the importance of examining category use effects is that category learning outside the laboratory often includes learning to make use of the categories as well. However, there is no clear consensus on how adults learn categories outside the laboratory (there is work on how children may learn some types of categories, such as word meanings; e.g., Woodward & Markman, 1998). Most researchers, I think, would agree that we rarely learn categories by seeing and classifying hundreds of instances one after another, which is a common laboratory procedure. The focus on classification learning springs, at least partially, from the belief that classification may operate separately from the processes that rely upon the classification (e.g., inference, problem solving, explanation). Ross (1997) showed that even with the usual classification paradigm, if the use learning is interleaved, then it can affect subsequent classifications. The interleaved learning situation is one that I think often occurs when learning a new category—the classification and use are learned together.

Sometimes, however, learning may be more like the postclassification situation—people initially learn to classify items and only later learn a use, perhaps in developing expertise within the area (or perhaps people add a new use to the categories). The current results (and Ross, in press) extend the findings of the category use effect to postclassification. Thus, the category use effect is not limited to the interleaved learning procedure.

I do not know of any work that examines the relative proportions of different category learning situations in real-world settings. However, given that these category use effects have been shown (a) when the classification and use learning are interleaved and (b) when the classification learning precedes the use learning (postclassification), it seems plausible that such effects are likely in either pure case or in the possible mixtures of these two situations (e.g., in Ross, in press, Experiments 1 and 2, the classification task continued during the learning of the use and the same effect was found).

**Task-specific aspects.** The present experiments all used the same general task and tests, so it is important to consider the generality of the results and their relation to real-world situations. The spy code procedure clearly has a number of differences from real-world situations, but it does capture some aspects of problem-solving situations. In the experiments, different procedures were applied for different categories, and each procedure required an application of a general formula to a specific item. Most important, the knowledge learned from the use was not simply the weighting of features, but rather the learning of a relation among the features. In addition, a number of other experiments have shown a postclassification with a very different set of materials and procedures, classifying patients into fictitious diseases and then deciding on drug treatments (Ross, in press). Both of these tasks, plus another problem-solving task with equations, have shown category use effects in the interleaved paradigm (Ross, 1997). In the disease task, unlike the spy task, the classification and the use were both quite difficult. Thus, although there have not been a large number of tasks investigated, there does not seem to be any reason to believe that the effects depend on the particulars of the spy task.

A second issue of task generality concerns the tests. The main critical tests in the experiments were no-letter tests in
which the letter information was not available, so the only information that subjects could use for classification (if they knew it) was the relation among the numbers. The reason for choosing this type of test was to most clearly address the main experimental question: Did learning the use affect the category representation including the knowledge available for classification? Even though there was no letter information provided, if subjects had not learned the number relations and how these relations varied for the spy categories, then they could not have performed above chance on these tests.

An alternative type of test, suggested by a reviewer, would be to contrast the original classification information (the letters) with the number relations and then to see if subjects still chose the category on the basis of the number relations. I have used conflict tests in other domains both with the disease studies in postclassification (Ross, in press) and in the interleaved paradigm with the equation materials (Ross, 1997, Experiment 6). In the current experiments, however, I wanted to provide a very strong test of the effect of use on classification, so the method included a number of aspects that make such conflict tests less useful. First, the types of features required for the original classification (letters) were different than the ones required for the use (numbers). Second, the instructions explicitly told subjects that the letters should be used for classification. Third, the number relations were not at all predictive of the categories during the learning of the classifications or the learning of the use; that is, both number relations occurred in every item during these phases. These aspects of the method, along with the fact that the letters are quickly available at tests whereas the number relations need to be computed, led me to choose the no-letter tests over these conflict tests.

In addition to design considerations, I think the no-letter tests are similar to many real-life situations, especially compared with conflict tests. People often have to classify an item on the basis of only partial information, because of poor viewing conditions (e.g., occlusion, brief duration) or because we are presented with only a partial description (e.g., conversation). As one example, we may learn to classify animals on the basis of shape, but if we hear an animal at night we may need to classify it on the basis of sound. The main point is that in many real-life situations we must classify objects without having all the features and relations available. In sum, the choice of no-letter tests allows a clear test of the predictions and relates to a number of real-life situations of interest.

Types of categories. The current experiments examined problem-solving categories (and Ross, in press, investigated diagnosis categories), so the question as to whether such effects occur with object categories is still open. The work of Medin et al. (1997) with landscapers suggests that the category representation of trees can be influenced by their uses in landscaping, such as for shade or for ornament (also see Boster & Johnson, 1989; Malt, 1995). Although that work did not examine classification, the use did affect a standard measure of category representation, sorting. Other research with object materials also suggests that the category representation may be a function of not just the distinctive features but also of the various uses (e.g., Lassaline & Murphy, 1996; Markman et al., 1997), so that other category-related judgments might well be affected.

The relation of classification and use. Although these experiments investigate whether the use of the category might change the category representation learned from classification, it is important to realize that often the use may lead to a representation that is very similar to that learned during classification. That is, in some categories the aspects used to classify may also be important in the uses of the category, so the two tasks will tend to reinforce each other. Even in these cases, there may be some effect on the classification, perhaps speeding up the classification learning, especially if it is difficult. For example, in many real-world stimuli there may be a very large number of potentially relevant features that could make the classification learning difficult. Category use, even if it required the same features as the classification, might facilitate classification learning if learners used the heuristic that features involved in the use are more likely to be relevant for the classification than are features not involved in the use. In addition to the feature-weight change, category use could promote new features or relations that had also been important for the classification.

Category Use and Understanding

The present study emphasizes how category use may affect the information represented and available for later classification, but in some cases the effects of using categories may be even more pervasive. A central concern in the study of categories is to understand why we have the categories we do and what makes them cohere as categories. Classification-based theories often focus on the featural similarities among category members, but there are many arguments as to why featural similarity is not a sufficient explanation (e.g., Goldstone, 1994; Murphy & Medin, 1985). Rather, people often have an understanding of categories that goes beyond the featural similarities of the instances and includes a deeper underlying similarity. This knowledge may be involved in making inferences about category members (e.g., Will this new instance fly?) and even in classifying members (Is this new instance a bird?).

If categories cohere by these underlying similarities, then a critical issue is how people learn such underlying similarities (e.g., Gelman, Coley, & Gottfried, 1994; Ross & Spalding, 1994). It may help to consider a particular type of category use, problem solving, to make this idea clearer. In the learning of many problem-solving domains, determining the type of problem is often the main obstacle to solving it. There are large differences in problem classification between novices and experts, with novices classifying on the basis of superficial features rather than the deeper ones often used by experts (e.g., Chi et al., 1981). In solving problems, one may need to figure out how the procedure (e.g., formula) for this problem type applies to the current problem. In this application, there is much opportunity to see what features and relations are important in the solution and why (e.g., self-explanations as examined in Chi, Bassok, Lewis, Rei-
mann, & Glaser, 1989). Thus, the use of the problem category may highlight some of the important aspects of the problem and lead one to reweight the importance of features, see relations among features, add new features, or even reinterpret what some of the features arc.

The point is that as the category is used, the learners may come to understand why these instances are members of the same category. That is, they may begin to understand the underlying commonalities of the category members, which might not be learned by classification alone. The use often requires a consideration of the structural relations among the features for the members of a category, rather than a focus on how to distinguish members of this category from other categories. The argument is not that category use always provides a deeper understanding than classification, but rather that it sometimes does. Even when it does not, it provides an additional source of information that might be used to help understand the underlying basis of the category. Learning the underlying similarities requires going beyond the superficial features, and that may require some additional information source, such as background knowledge or category use.

Conclusions

Category learning consists of learning to classify and learning to make use of these classifications, but most work has focused on classification learning. Earlier work showed that learning to use the category can affect subsequent classification. The experiments reported here extend this finding to show that this category use effect even occurs when the use is learned after classification has been learned. This postclassification category use effect occurs when the classification is provided during the learning of the use (Experiment 1), or when it is incidentally activated as a result of additional processing (Experiment 2) or extended classification learning (Experiments 3, 4, and 5). Learning to use categories is an integral part of the study of categories and affects the category representation, including knowledge available for use in subsequent classifications.

References


Received June 30, 1997
Revision received December 2, 1998
Accepted December 2, 1998