Event Category Learning

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This research investigated the learning of event categories, in particular, categories of simple animated events, each involving a causal interaction between 2 characters. Four experiments examined whether correlations among attributes of events are easier to learn when they form part of a rich correlational structure than when they are independent of other correlations. Event attributes (e.g., state change, path of motion) were chosen to reflect distinctions made by verbs. Participants were presented with an unsupervised learning task and were then tested on whether the organization of correlations affected learning. Correlations forming part of a system of correlations were found to be better learned than isolated correlations. This finding of facilitation from correlational structure is explained in terms of a model that generates internal feedback to adjust the salience of attributes. These experiments also provide evidence regarding the role of object information in events, suggesting that this role is mediated by object category representations.

Events unfolding over time have regularity and structure just as do the enduring objects participating in those events. Adapting to a dynamic world requires not only knowledge of objects but also knowledge of the events in which those objects participate. Capturing this knowledge in event categories requires a highly complex representation because events can often be decomposed into a number of smaller yet meaningful spatial entities (i.e., objects) as well as temporal entities (i.e., subevents). Unlike object knowledge, this complex event knowledge must often be acquired in an unsupervised context because parents seldom label events for children while the events are occurring (Tomassello & Kruger, 1992). Both children and adults, however, manage to acquire scriptlike knowledge of "what happens" in particular situations (Nelson, 1986; Schank & Abelson, 1977), allowing them to anticipate future events on the basis of the present situation. How people are able to learn such event categories in the absence of supervision represents a serious challenge to models of concept learning, which are generally designed around the learning of object categories in a supervised context.

In the present experiments we explored the unsupervised learning of event categories. Our interest is in unsupervised learning because we believe that a primary goal of category learning is to capture predictive structure in the world. Good categories allow many inferences and not simply the prediction of a label. We believe that much natural category learning occurs in the absence of supervision, particularly when people are learning about events. Furthermore, because unsupervised learning tasks are less directive and provide fewer constraints as to what is to be learned, studying event category learning in an unsupervised context may be more likely to reveal learning biases that are unique to events.

Rather than studying complex extended events, we decided to focus on a much simpler event type, namely simple causal interactions between two objects (e.g., collisions). Causal interactions have been argued to be "prototypical" events (Slobin, 1981) and thus findings here may generalize to other event types. Causal interactions are also important in their own right, as indicated by studies of language and perception. For example, Slobin has noted that children consistently encode causal interactions in grammatical transitiv e sentences earlier than other event types. Michotte (1946/1963) has further demonstrated that adults perceive causality between projected figures even when they know there is no true contact. Human infants as young as 6 months of age have also been shown to perceive causality (Leslie & Keeble, 1987). To account for these results, Leslie (1988) has proposed that humans are born with a module responsible for the perception of causality, with the products of this module serving as the foundation for later causal reasoning. Thus, people may understand complex everyday events in terms of simple causal interactions.

Two Hypotheses for the Learning of Event Categories

In this research we contrasted two hypotheses as to how event categories are learned. One hypothesis is based on theories of object category structure and learning. According to this hypothesis, the same general principles should apply
when learning event categories as when learning object categories. The second hypothesis is derived from theories as to the structure of a certain type of event category, namely motion verb meanings. According to this hypothesis, event categories are structured quite differently from object categories, and thus different principles apply to their learning.

The first hypothesis assumes that although events may involve quite different attributes from objects, the same structural principles may apply when forming categories based on event attributes as when forming object categories. The specific claim whose applicability to event category learning we tested in this work is Rosch, Mervis, Gray, Johnson, and Boyes-Braem’s (1976) theory that “good” categories tend to form around rich correlational structure. Correlational structure refers to the co-occurrence of sets of properties in an environment. In an environment with rich correlational structure, some sets of properties are found together often, while others rarely or never co-occur. Thus, given one of those co-occurring properties, one can predict that the others will also be present. For example, beaks are often accompanied by wings because they are found together on birds, while beaks and fur rarely co-occur. On the basis of one’s category of birds, then, one can predict that when an object is known to have a beak, it will also have wings. Studies of natural object categories (e.g., Malt & Smith, 1984) have demonstrated that people are indeed sensitive to such correlations among properties.

Rosch et al.’s (1976) theory has implications not only for category structure but also for category learning mechanisms. That is, these learning mechanisms must be capable of detecting rich correlational structure when it is present in the environment. More specifically, Billman and Heit (1988) have proposed that people are biased to learn correlations forming part of a rich correlational structure and as a result are more likely to discover a correlation when the attributes participating in that correlation are related to further attributes. In support of this theory, Billman and Knutson (1996) demonstrated that people were more likely to discover a correlation between the values of two object attributes, such as the head and tail of a novel animal, when those attributes were related to further attributes such as body texture and the time of day in which the animal appeared.

There is also some evidence that the learning of event categories is facilitated by correlational structure, providing support for the hypothesis that event category learning proceeds similarly to object category learning. This evidence comes from work on verb learning. Although a detailed description of an event requires a complete sentence rather than just a verb, verb meanings in isolation may map onto schematic event categories. Verbs often convey information about the paths or the manners of motion of objects (Talmy, 1985). Moreover, verbs may also provide information about the identities of the objects carrying out those motions, such as through restrictions on the number and type of nouns allowed by a particular verb (e.g., to push requires two nouns, at least one of which must be able to play the role of agent). Thus, verb meanings may reflect simple, albeit highly schematic, event categories, and principles that apply to the acquisition of verb meanings may be relevant to the learning of event categories in general.

Evidence for facilitated learning of richly structured event categories comes from work on the acquisition of instrument verbs, such as to saw or to hammer. Such verbs seem to involve rich correlational structure, specifying not only the use of a particular instrument but also particular actions and results. For example, the verb to saw implies not only the use of a saw but also a sawing motion and the result of the affected object being cut. Huttenlocher, Smiley, and Charney (1983) have provided evidence for facilitated learning of instrument verbs. They demonstrated better comprehension in young children for “verbs that involve highly associated objects” (p. 82) than for verbs matched in complexity that do not implicate a particular object.

Behrend (1990) has also provided evidence for facilitated learning of instrument verbs. He found that when several different verbs could apply to an event, the first verbs used by both children and adults to describe the event were more often instrument verbs than verbs that describe the action or result of an event. This is surprising because instrument verbs are relatively infrequent in English. Behrend’s explanation for this finding was that instrument verbs convey more information than do other verb types. Although this explanation centers on communication, the use of these infrequent verbs by young children may also reflect facilitated learning of these verbs because of the rich correlational structure in their meanings.

The second hypothesis for the learning of event categories is that they are learned quite differently from object categories. This hypothesis is suggested by the observation that most verb meanings, unlike instrument verb meanings, are structured quite differently from object categories. In particular, Huttenlocher and Lui (1979; see also Graesser, Hopkinson, & Schmid, 1987) have proposed that verb meanings are organized in a matrix. A matrix organization is one in which different attributes vary independently of one another and thus form separate bases for organizing a domain. For example, path and manner of motion are independent organizing principles in the domain of motion events (Talmy, 1985), and thus more than one verb can apply to a given motion event. For example, an event in which someone runs into a building can be thought of as either running or entering.

This organization of verb meanings also has implications for correlational structure. Because there exist multiple ways of classifying the same event, each basis for classification tends to involve relatively few attributes, compared with the case in which a dominant organizing principle is present. For example, verbs such as entering convey little information beyond path because path varies independently of other attributes such as those involving manner of motion. Although path and manner may in fact each reflect a number of related types of information rather than being unitary attributes (e.g., the manner of motion of a creature may involve the motion of its limbs relative to its body, the way that the body as a whole moves along its path, etc.), the correlational structure found in such categories seems to be
relatively sparse compared with that associated with a category such as “bird.”

These differences in structure between nouns and verbs may have implications for the learning of object and event categories. For example, Gentner (1981) has argued that the richer correlational structure associated with object categories in part accounts for the faster learning of nouns than of verbs by most children. Gentner has proposed that noun meanings, which generally refer to object categories, tend to be associated with the highly intercorrelated attributes found within events, namely the objects participating in those events. Relational terms, such as verbs, are then associated with the remaining, relatively uncorrelated attributes. If this account is correct, people may expect relatively weak correlational structure when learning verb meanings and possibly when learning event categories in general. These expectations could trigger different learning strategies in the context of an event category learning task than in an object category learning task, resulting in little or no facilitation or possibly even overshadowing of event correlations forming part of a rich correlational structure.

Gentner’s (1981) theory suggests an alternative explanation for the finding of facilitated learning of instrument verbs. In particular, this facilitation may reflect the strong relation of these verbs to particular objects. Not only do instrument verbs such as to saw implicate the use of a particular object, they often share a common word stem with a noun (i.e., a saw). Because nouns are generally easier for children to learn, this tight linkage of instrument verbs to objects may help children learn what the verbs mean. Thus, it may not be necessary to appeal to correlational structure to account for the learning of instrument verbs.

A second difference between object and event categories also favors the hypothesis that event categories should not show facilitation from correlational structure. In particular, the fact that different information becomes available at different points in an event may make unsupervised event category learning more similar to supervised than to unsupervised object category learning. Even when no category labels are provided and the experimenter considers the task to be unsupervised, participants may consider the task to be one of predicting the outcome of an event on the basis of earlier predictor attributes. The eventual display of this information would then act as feedback regarding the participant’s predictions. Such temporal relations are similar to those found in supervised category learning, in which feedback in the form of a category label is often withheld until the end of a trial.

In contrast to unsupervised learning, the results of supervised category learning experiments generally reveal not facilitation but rather an overshadowing of correlations forming part of a rich correlational structure. For example, Gluck and Bower (1988) found that participants were less likely to learn a symptom’s predictiveness of a particular disease if a second predictor was also present. Thus, participants were more likely to learn a correlation between a predictor and an outcome when it was isolated than when it formed part of a richer correlational structure involving two predictors and an outcome. Participants learning about events may similarly consider the task to be one of predicting the outcome of an event, and thus may be less likely to learn further correlations when an adequate predictor of this outcome is found.

There are thus two alternative hypotheses as to the effects of correlational structure on event category learning. Prior work on unsupervised object category learning and real-world verb learning provides evidence for facilitated learning of categories formed around rich correlational structure. Perhaps category learning for events as well as for objects is geared toward learning richly structured categories. Theories as to the structure of verb meanings, however, suggest that most event categories may be structured differently than object categories. If so, event category learning may proceed quite differently from object category learning. Differences between object and event category learning tasks in the way information is revealed also favor this hypothesis. Still, because evidence from learning seems most relevant to the present research question, and this evidence suggests facilitation from correlational structure for both object categories and verb meanings, we favored the first hypothesis that event categories would show facilitated learning with rich correlational structure.

Overview of Experiments

In the present experiments we tested whether event categories with rich correlational structure are learned more easily than less structured categories. Although our predictions were motivated in part by prior work on verb learning (Huttenlocher et al., 1983), we designed our task more closely around prior work on unsupervised object category learning (Billman & Knutson, 1996). Thus, we tested for knowledge of event categories following an unsupervised learning task, in which no category labels were provided. We did this because we believe that the purpose of categorization is more general than that of communication, allowing one to predict future occurrences on the basis of a number of cues, both verbal and nonverbal. Because predictions of the future are made possible by knowledge of past correlations, and a set of correlations among properties can be considered to constitute a category, the learning of correlations can be used as an index of category learning. Thus, we measured category learning by testing a participant’s ability to distinguish events that preserved correlations present during learning from events that broke those correlations.

Our experiments tested whether correlations between event attributes are easier to learn when forming part of a system of correlations than when isolated from other correlations. Of course, when learners are exposed to a system of correlations, there are more correlations available to discover than when they are exposed to isolated correlations, and thus the learner is more likely to discover at least one correlation. But if learners have a bias to learn richly structured categories, they should show better learning of each individual correlation when it forms part of a system of correlations than when it is found in isolation. We hypothesized that the property of richly structured categories that is key to their superior learning is high value systematicity.
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(Barsalou & Billman, 1988; Billman & Knutson, 1996). In systems of correlations with high value systematicity, an attribute that predicts the value of one other attribute also predicts the values of several other attributes. We believe that human categorization is geared toward learning categories with high value systematicity because such categories allow many inferences and are thus very useful.

In the first experiment, we compared the learning of correlations forming part of a rich correlational structure with the learning of the same correlations when part of a matrix organization. The structured condition, similar to the structured condition used by Billman and Knutson (1996) to investigate object categorization, involved a number of intercorrelated attributes in a rich correlational structure. This condition was also consistent with suggestions of Behrend (1990) as to the structure of instrument verb meanings. The matrix condition, in turn, was similar to the orthogonal condition of Billman and Knutson and consistent with the matrix organization suggested for verbs by Huttenlocher and Lui (1979). In particular, each category in the matrix condition was based on a single correlation, with three such correlations representing independent bases for categorizing a given event. Thus, the categories in the structured condition had higher value systematicity than did those in the matrix condition because attributes in the matrix condition varied independently from most others and allowed few predictions as a result.

As we discussed earlier, however, there is another characteristic of matrices that could account for greater difficulty in learning a correlation in the matrix condition compared with the structured condition in Experiment 1. In particular, the matrix condition involved multiple independent correlations that could potentially be used as the basis for categorization. It is possible that these independent correlations could compete for one's attention, with the discovery of one correlation discouraging the discovery of others. Thus, richly structured categories could be easier to learn not because of high value systematicity but rather because there are no competing correlations. To better understand the mechanisms underlying the advantage of richly structured categories, Experiment 2 compared the learning of a correlation forming part of a rich correlational structure with the learning of the same correlation in a condition in which no other correlations were present. Thus, the less structured condition of Experiment 2 differed from that of Experiment 1 in that there were no competing correlations.

In the structured conditions of Experiments 1 and 2, each event was representative of only one category. As we discussed above, however, most events can be categorized according to multiple, independent bases. In Experiment 3 we tested whether people preferentially learn categories on the basis of rich correlational structure even when alternative bases for categorization are present. In Experiment 4 we investigated the generality of facilitation from correlational structure across different types of content. In Experiment 4 we also tied the present work more closely to traditional work on category learning with an additional dependent measure involving the sorting of instances into categories.

Experiment 1

To test the effects of correlational structure on event category learning, we used simple animated events as stimuli. Three frames from an example event are shown in Figure 1. Every event involved a causal interaction between two characters. Within this framework, a number of attributes varied from event to event. We chose event attributes that are specified by verb meanings. For example, the change in state of the affected character was one attribute.

Figure 1. Three frames from an example event. In the first frame, the characters are shown in their starting locations, here with the agent on the left and the patient on the right. In the second frame, the agent has moved to the patient, causing the patient to explode. In the third frame, the remains of the patient have moved away from the agent.
because verbs such as to break and to cut convey different state changes.

Correlations between attributes allowed participants to predict the value of one attribute given the value of another. We presented participants in the structured condition with events exhibiting correlations among four attributes: agent path, manner of motion, state change, and environment (see Figure 2). As with instrument verbs, these attributes included the actions of one object and the change in state of another object resulting from those actions. Unlike instrument verbs, these attributes were correlated not with the appearance of the causing object but rather with the environment in which the event took place to ensure that participants were indeed learning event categories rather than simply categorizing the objects taking part in the events. Because the same values of the correlated attributes always went together, all of the events involving one set of co-occurring values could be considered to constitute an event category. For example, participants in the structured condition could have learned a category of events taking place on a background of squiggly lines in which an agent moved smoothly in pursuit of a second character, causing it to explode when it came into contact (see Figure 3).

We presented participants in the matrix condition with events exhibiting three independent correlations, each involving only two attributes (see Figure 2). These correlations offered independent bases for categorizing the same events. Thus, the same event could be considered an example of a category in which an agent moved smoothly on a squiggly background, a category in which an agent continued to pursue a second character after causing it to explode, or a category in which a blue character and a yellow character interacted (see Figure 3). These categories were completely unrelated, however, so that knowing the manner of motion of an object would not allow one to predict its path. This organization is similar to the way the English language categorizes most events. In English, the verb in a sentence is most often related to the manner of motion of the agent in an event, whereas prepositions or verb particles are related to the path of that agent (Jackendoff, 1987). These two categories combine interchangeably, however, so that knowing the manner of motion of an object (e.g., to run vs. to walk) does not allow one to predict its path (e.g., in vs. out). Thus, the matrix structure in this experiment was similar to the organization of English relational terms, except that all correlations involved nonlinguistic attributes rather than verbal labels because of the unsupervised nature of the task. The use of three independent correlations in this condition also allowed us to equate the number of possible events in the two conditions, with 81 possible events in each condition.

We used each participant's knowledge of one correlation, the target rule, as the primary measure of that participant's learning. We tested knowledge of the target rule by presenting events in which the value of one target rule attribute either matched or mismatched the value predicted by the other target rule attribute. Participants rated test events as to how well they matched learning events. Knowledge of a correlation was indicated by lower ratings for events in which attribute values mismatched than for those in which they matched. Three different target rules were used in this experiment to ensure that any effects of correlational structure were not specific to a particular correlation. We used the same three target rules in both conditions. Each target rule involved at least one dynamic attribute, so that these rules were indeed different from those used in studies of object categorization. We predicted better learning of a target rule when it formed part of a rich correlational structure (i.e., in the structured condition) than when it was independent of all other correlations (i.e., in the matrix condition).

**Method**

**Participants**

Thirty undergraduates at the Georgia Institute of Technology received course credit for their participation in this experiment.

**Stimuli**

*All events.* A square agent and a circular patient interacted in each event. The two characters started in motion when the participant pressed the mouse button. In each event, the agent moved into contact with the patient, causing alterations in the patient's appearance, called the state change, after which the patient moved away from the agent. Each event lasted about 8 s, with a black screen appearing between events for 1 s.

The events varied in a number of ways. The starting position of the patient was chosen randomly from a region in the center of the screen, whereas the agent started at a varying distance away along a
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Structured Condition

Category 1

Category 2

Category 3

Matrix Condition

Category 1

Category 2

Category 3

Figure 3. Schematic depictions of the three categories defined in terms of the manner of motion–environment target rule in Experiment 1. Each rectangle depicts a point in one event just after the agent has come into contact with the patient. Bidirectional arrows represent the manner of motion of the agent, and unidirectional arrows represent agent path. The three rows under the Matrix Condition heading represent the three values of agent path and state change, which covaried with one another but varied independently of the target rule attributes. For example, the three rows under the Category 1 heading of the matrix condition vary on agent path and state change, but all involve a smooth manner of motion and a squiggly background. Variation on agent color, patient color, and patient path is not represented. Patient path varied randomly in both conditions. Agent color and patient color also varied randomly in the structured condition, whereas they covaried with one another but varied independently of all other attributes in the matrix condition.

Learning events. There were 120 learning events. Participants in the structured condition saw events exhibiting correlations among four attributes: environment, agent path, manner of motion, and state change. One correlation from among these attributes was chosen to be each participant’s target rule, either (a) agent path–environment, (b) manner of motion–environment, or (c) agent path–manner of motion. Participants in the matrix condition saw events exhibiting correlations between three independent pairs of attributes. One of these pairs constituted the participant’s target rule, and two other pairs were chosen from the remaining attributes. (Figures 2 and 3 depict the correlations present for participants assigned the manner of motion–environment target rule.) Each value of the correlated attributes was shown on 40 of the learning events. Values of the remaining attributes varied randomly on each event.

Test events. There were 54 test events. Eighteen events tested for knowledge of the target rule, whereas knowledge of two other correlations was tested in the remaining 36 events. In 9 tests of each
rule, the values of the attributes in that rule were matched as they had been during learning and thus are called correct events. In 9 other tests of that rule, these values were mismatched and thus are called incorrect events. The presentation order of test items was determined randomly for each participant.

To ensure that participants in the structured condition could only use knowledge of the rule being tested when rating an event, we obscured the two correlated attributes not participating in that rule. For example, when a participant was tested on the manner of motion-environment target rule, the event was displayed on a blank background, and a cloud covered the patient after contact with the agent. The random state change would have been obscured when testing the target rule attributes and his or her average rating for events involving mismatched values.

**Procedure**

Sessions lasted approximately 45 min. We instructed participants to work at their own pace and to ask questions if anything was unclear. The remaining instructions were presented by the computer. The participant was instructed that there were two kinds of creatures on another planet, one of which always moved to the other and changed its appearance. Participants were instructed that they were to learn about the kinds of events that happen on this planet and that they would later be tested on how well they could differentiate events that could take place on this planet from those that could not.

After the 120 learning events, the 6 example test events were presented. Next, the participant was instructed to rate each of the 54 test events as to “how well it fits in with” the learning events. Participants were instructed not to give an event a low rating just because some attributes were obscured. Participants rated each test event on a 5-point scale by clicking on a button labeled BAD (a rating of 1), one labeled GOOD (5), or one of three unlabeled buttons between them (2, 3, and 4). A sixth button was labeled REPEAT, allowing the participant to view the event as many times as desired. After testing, the experimenter asked participants whether they had noticed any “general patterns or regularities during the learning events.” Participants who reported one correlation were encouraged to report any others they had noticed.

**Results**

Table 2 displays the mean ratings of participants in the structured and matrix conditions for events testing the target rules, and Figure 4 depicts the difference between ratings of correct and incorrect events in each condition. Higher difference scores indicate a better ability to differentiate the two types of test items. We adopted an alpha level of .05 for all analyses in this article. An analysis of variance (ANOVA) on difference scores revealed a significant effect of correla-
structure than when it was independent of other correlations. This finding provides evidence for the hypothesis that event category learning is geared toward categories with high value systematically, extending earlier findings on object category learning (Billman & Knutson, 1996). The existence of correlations independent of the target rule in the matrix condition, however, suggests an alternative account of the present results. A participant who noticed one of these other correlations first may have subsequently paid more attention to the attributes in that correlation at the expense of other attributes, making the target correlation more difficult to discover. Thus, the results of this experiment could reflect facilitation from correlational structure in the structured condition, competition among independent correlations in the matrix condition, or some combination of the two. We designed Experiment 2 to determine whether the advantage of richly structured categories is found even when no independent correlations are present in the less structured condition.

Experiment 2

The design of Experiment 2 was quite similar to that of Experiment 1. There was again a structured condition, in which four attributes were correlated for each participant. Instead of a matrix condition, however, there was in this experiment a condition in which only the two target rule attributes were correlated, and all other attributes varied randomly (see Figure 5). This condition was called the isolated condition because the attributes in the target rule constituted a single, isolated correlation. Thus, the isolated condition was like the matrix condition, except that there were no other independent correlations present to potentially draw attention away from the target rule attributes. If the results of Experiment 1 were entirely due to competition

<table>
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<tr>
<th>Condition</th>
<th>Incorrect events $M$</th>
<th>Incorrect events $SD$</th>
<th>Correct events $M$</th>
<th>Correct events $SD$</th>
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<th>Difference $SD$</th>
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Note. Env = environment; MoM = manner of motion; SC = state change; AP = agent path; AA = agent appearance; PA = patient appearance; PP = patient path. Rules are ordered by difficulty in each condition, with different rules in the two conditions.

Discussion

Participants in this experiment showed better learning of a correlation when it formed part of a rich correlational structure, $F(1, 24) = 8.18, p < .01, \text{MSE} = 2.28$, with means of 2.16 ($SD = 1.69$) in the structured condition and 0.58 ($SD = 1.48$) in the matrix condition. There was also an effect of target rule, $F(2, 24) = 7.96, p < .05, \text{MSE} = 2.28$, with highest difference scores for the correlation between agent path and agent manner of motion. There was no evidence for an interaction, $F(2, 24) < 1$.

Although we assigned each participant one rule as the target rule for direct comparison with the other condition, we also tested each participant for knowledge of two other correlations. These two nontarget rules differed across the two conditions. Still, because each participant was tested for correlations, these two nontarget rules differed across the two conditions. Because each attribute had three possible values, the maximum possible score was 3, with 0 reflecting no correct reports. Trends in interview scores were quite similar to those of target rule rating difference scores, with a correlation of .71 ($p < .001$) between the two measures. An ANOVA on interview scores, however, failed to reveal any significant effects, although the effect of correlational structure approached significance, $F(1, 24) = 3.25, p < .09, \text{MSE} = 1.73$. The structured condition averaged 1.27 ($SD = 1.49$), compared with the matrix condition's average of 0.40 ($SD = 1.06$). Six participants in the structured condition reported all three pairings of the target rule attributes, compared with 2 participants in the matrix condition.
among independent correlations, the two conditions in this experiment should have performed equally well because no attributes covaried independently of the target rule. We predicted, however, that participants would show better learning of the target rule when it formed part of a rich correlational structure (i.e., in the structured condition) than when it was the only correlation present (i.e., in the isolated condition).

Method

Participants

Thirty-six undergraduates at the Georgia Institute of Technology received course credit for their participation in this experiment.

Stimuli

Learning events. The correlations present in the learning events of Experiment 2 differed from those of Experiment 1. We used three new target rules to explore the benefits of correlational structure across a variety of event attributes. These were as follows: (a) state change–environment, (b) agent path–patient appearance, and (c) patient path–(agent) manner of motion. The target rule was the only correlation present for participants in the isolated condition. In the structured condition, two other attributes also correlated with the target rule attributes. These attributes were randomly chosen for each participant from the set of remaining attributes. Filler items seen by participants in the structured condition tested for knowledge of two other correlations present during learning. Participants in the isolated condition had no basis for evaluating filler items because only the target rule had been present during learning.

Design

The two independent variables, manipulated between subjects, were the correlational structure (isolated or structured) and the target rule being tested (state change–environment, agent path–patient appearance, or patient path–agent manner of motion). The primary dependent variable was the difference between each participant’s average rating for events involving correctly matched values of the target rule attributes and his or her average rating for events involving mismatched values.

Procedure

The procedure in Experiment 2 was the same as in Experiment 1.

Results

Table 4 displays the mean ratings of participants in the structured and isolated conditions for events testing the target rules in this experiment, and Table 5 displays ratings of the nontarget rules by participants in the structured condition. Figure 6 depicts rating differences between correct and incorrect events for the two conditions. An ANOVA on difference scores again revealed a significant effect of correlational structure, $F(1, 30) = 8.82, p < .01$, $MSE = 1.39$, with means of 1.78 ($SD = 1.66$) in the structured condition and 0.61 ($SD = 1.54$) in the isolated condition. There was also an effect of target rule, $F(2, 30) = 15.83, p < .001$, $MSE = 1.39$, with the highest difference scores for participants tested on the correlation between state

<table>
<thead>
<tr>
<th>Condition</th>
<th>Incorrect events</th>
<th>Correct events</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>SD</td>
<td>$M$</td>
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<tr>
<td>Structured</td>
<td>Average</td>
<td>2.36</td>
<td>1.14</td>
</tr>
<tr>
<td></td>
<td>SC–Env</td>
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<td></td>
<td>PA–AP</td>
<td>2.85</td>
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<td></td>
<td>PP–MoM</td>
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<tr>
<td>Isolated</td>
<td>Average</td>
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<td></td>
<td>SC–Env</td>
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<td>PA–AP</td>
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</tr>
<tr>
<td></td>
<td>PP–MoM</td>
<td>3.89</td>
<td>0.89</td>
</tr>
</tbody>
</table>

Note. SC = state change; Env = environment; PA = patient appearance; AP = agent path; PP = patient path; MoM = manner of motion.
Table 5

Nontarget Rule Rating Accuracy in the Structured Condition of Experiment 2

<table>
<thead>
<tr>
<th>Rule</th>
<th>Incorrect events</th>
<th>Correct events</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>PA-SC</td>
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<td></td>
<td>5.00</td>
</tr>
<tr>
<td>PA-PP</td>
<td>1.22</td>
<td>0.00</td>
<td>4.11</td>
</tr>
<tr>
<td>AP-SC</td>
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<td>0.39</td>
<td>4.17</td>
</tr>
<tr>
<td>PP-MoM</td>
<td>2.78</td>
<td></td>
<td>4.89</td>
</tr>
<tr>
<td>AA-PA</td>
<td>2.48</td>
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</tr>
<tr>
<td>PP-SC</td>
<td>2.63</td>
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<td>3.98</td>
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<tr>
<td>AP-PP</td>
<td>2.71</td>
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<td>3.84</td>
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<td>MoM-Env</td>
<td>2.86</td>
<td>1.02</td>
<td>3.81</td>
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<td>MoM-SC</td>
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<td>1.01</td>
<td>4.11</td>
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<tr>
<td>PA-MoM</td>
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<td></td>
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<td>AP-MoM</td>
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<td>4.44</td>
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<tr>
<td>AA-MoM</td>
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<td>AP-Env</td>
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<td>3.67</td>
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<td>AA-PP</td>
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<td>4.22</td>
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<td>AA-SC</td>
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<td>3.11</td>
</tr>
<tr>
<td>AA-AP</td>
<td>4.00</td>
<td></td>
<td>2.33</td>
</tr>
</tbody>
</table>

Note. PA = patient appearance; SC = state change; PP = patient path; AP = agent path; MoM = manner of motion; AA = agent appearance; Env = environment. The number of participants tested on each rule varied because the nontarget rules were randomly selected from the correlations seen by a given participant. Dashes indicate that standard deviations were not available for some rules because only 1 participant was tested on each of those rules.

Participants in the structured condition ($M = 1.50$, $SD = 1.47$) also performed better than participants in the isolated condition ($M = 0.67$, $SD = 1.28$) on interview scores, $F(1, 30) = 6.82, p < .05, MSE = 0.92$. Seven participants in the structured condition reported the correct pairings of all three values of the target rule attributes, compared with 4 participants in the isolated condition. There was also a significant effect of target rule on interview scores, $F(2, 30) = 19.91, p < .001, MSE = 0.92$. Interview scores averaged 2.50 ($SD = 1.17$) on the correlation between state change and environment, 0.50 ($SD = 1.00$) on the correlation between patient appearance and agent path, and 0.25 ($SD = 0.87$) on the correlation between patient path and agent manner. As with rating accuracy, there was no evidence for an interaction, $F(2, 30) < 1$. The similarity between rating accuracy and interview scores was further highlighted by a correlation of .87 ($p < .001$) between the two measures.

Discussion

Participants in Experiment 2 showed better learning of a target rule when it formed part of a rich correlational structure than when no other correlations were present. The results of this experiment cannot be explained in terms of competition among attributes or conflict among multiple possible classifications for a participant's attention because only one correlation was present in the condition in which performance was worse. The key difference between conditions thus seems to be value systematicity. Each target rule attribute was predictive of the values of several other attributes in the structured condition, whereas it was only predictive of one other attribute in the isolated condition.

In addition to the effects of correlational structure, both Experiments 1 and 2 revealed differences in learnability among the different target rules. Although it is difficult to account for these differences given the limited amount of data on event categories, the results of the next two experiments offer some suggestions as to what makes some correlations easier to learn than others. Further discussion of this issue follows the presentation of the results of these experiments.

Experiment 3

Experiments 1 and 2 demonstrated facilitated learning of event correlations forming part of a rich correlational structure and environment. There was no evidence for an interaction, $F(2, 30) < 1$.

Participants in the structured condition ($M = 1.50$, $SD = 1.47$) also performed better than participants in the isolated condition ($M = 0.67$, $SD = 1.28$) on interview scores, $F(1, 30) = 6.82, p < .05, MSE = 0.92$. Seven participants in the structured condition reported the correct pairings of all three values of the target rule attributes, compared with 4 participants in the isolated condition.
structure. Such correlational structure may be similar to that associated with instrument verbs. As we discussed previously, however, the attributes associated with most verbs combine interchangeably with other event attributes, such as those associated with prepositions or verb particles. Thus, unlike the events seen by participants in the structured conditions of Experiments 1 and 2, most events are representative of multiple, independent categories. For example, an event involving running into a building can be thought of either as a running event or an into (i.e., entering) event.

We designed Experiment 3 to determine whether correlational structure facilitates the learning of event correlations embedded within a matrix organization, similar to the one described above. To this end, we used a mixed design involving one within-subjects variable and one between-subjects variable. We tested each participant on the learning of not one but rather two target rules constituting the within-subjects variable. One target rule formed part of a system of correlations, whereas the other was isolated from other correlations (see Figure 7). To control for rule difficulty, we counterbalanced the assignment of which rule was structured and which was isolated across two between-subjects conditions. Thus, for one group of participants, the path rule formed part of a system of correlations and the manner rule was isolated, whereas for a second group, the manner rule was structured and the path rule was isolated. As a result, the learning of each target rule when isolated could be compared with learning when it was structured, just as in the previous experiments. We predicted that participants would show facilitated learning of each target rule when it formed part of a system of correlations compared with when it was isolated.

We used two new target rules in this experiment to explore further the generality of the effects of correlational structure on event category learning. One was called the path rule, involving a correlation between the paths of the agent and of the patient. For example, one category based on this target rule involved events in which the patient approached the agent until the two characters met, after which the agent pursued the patient in the other direction. The second target rule was called the manner rule because it involved two aspects of the manner of motion of the agent, namely the motion of its legs relative to its body and the orientation of its body as it moved. For example, one category based on this target rule involved events in which the legs of the agent moved up and down along the length of the agent's body, causing the agent to move head first.

These two rules were involved in one of two configurations of correlations for each participant. For participants in the structured path condition, two facilitator attributes covaried with the two path attributes. For participants in the structured manner condition, the same two facilitators covaried instead with the two manner-of-motion attributes. We predicted better learning of each target rule when it formed part of a rich correlational structure than when it was isolated, resulting in an interaction between the target rule being tested on a particular trial and the configuration of correlations seen by a particular participant. Specifically, we predicted better learning of the path rule in the structured path condition than in the structured manner condition, and we predicted better learning of the manner rule in the structured manner condition than in the structured path condition.

Method

Participants

Thirty-six participants at the Georgia Institute of Technology received course credit for their participation in this experiment.

Stimuli

All events. We made the events in Experiment 3 somewhat more complex to accommodate the increased number of correlations associated with this design. Because the design required a set of four intercorrelated attributes together with an independent pair of correlated attributes, the existing seven attributes would have left only one of these attributes to vary randomly, perhaps making the task too easy. To make the task more difficult, we replaced the previous attribute, manner of motion, with two attributes, resulting in a total of eight attributes in this experiment. One of these new attributes involved the orientation of the agent as it moved (see Figure 8). Some agents moved in the directions they faced, some moved sideways, and some backed up. To make this attribute meaningful, we changed the appearance of the agent from a square to an elongated object with a head, tail, body, and legs. The second new attribute involved the leg motion of the agent, defined by different motions of the legs relative to the body. Orientation and leg motion can together be considered to constitute an agent's manner of motion because they implicate a particular mechanism for achieving locomotion. We also made changes in the appearance of the patient, making it more elongated with eyes at one end to make it look similar to the agent. Finally, to preserve the speed of the animation despite this added complexity, we now defined the environment by pictures in unoccupied corners of the screen rather
than by background texture. The three environments were a mountain, a swamp, and a desert.

**Learning events.** The learning events in Experiment 3 differed from those of the previous experiments in the correlations that were present. Every participant was assigned the same two target rules: (a) the path rule, agent path–patient path; and (b) the manner rule, orientation–leg motion. In addition, state change and environment covaried with the two path attributes for participants in the structured path condition, whereas these two attributes covaried instead with the two manner-of-motion attributes for participants in the structured manner condition.

**Test events.** To provide convergent validity for the finding of facilitation from correlational structure, we designed Experiment 3 to involve a different test procedure from that of the previous experiments. In particular, we used a forced-choice test rather than a rating task. In each test trial, we presented a participant with two events, one after the other. The participant's task was to choose which event was a better example of the events seen during learning. The two events varied on the value of one correlated attribute. Half varied on agent path, testing for knowledge of the agent path–patient target rule, and half varied on orientation, testing for knowledge of the orientation–leg motion target rule. We obscured the two facilitator attributes, state change and environment, throughout testing in the same manner as in the previous experiments, so that only knowledge of the target rule being tested could be used to successfully choose the correct event. All other attributes held constant values across the two events in each trial. There were 4 example trials, followed by 18 test trials, 9 of which tested each target rule.

**Design**

There were two independent variables in Experiment 3. One was the target rule being tested (orientation–leg motion, agent path–patient path), manipulated within subjects. The other variable, configuration, was manipulated between subjects. This variable specified which target rule participated in a system of correlations and which was isolated (structured path or structured manner). The primary dependent variable was the number of correct choices in the forced-choice test.

**Procedure**

The procedure of Experiment 3 differed from the previous experiments in that participants were presented with only 90 learning events to add further difficulty to the task. The test procedure was also different. We instructed participants that they were to choose which of two events was a better example of the events seen during learning. They were first shown four example trials. In each trial, participants saw the first event, after which they pressed a button labeled Next Event to see the second event. No choices were required during the examples, with participants instead instructed after each pair of events about the different ways of obscuring attributes, as in the example test events of the previous experiments. They were next presented with 18 test trials. After each pair of events, participants pressed one of three buttons. One button, labeled Repeat, allowed participants to see the two events again. The other two buttons were labeled First Event and Second Event, allowing participants to indicate which event better exemplified the learning events.

**Results**

Figure 9 depicts the accuracy of participants in the structured path and structured manner conditions on the forced-choice test, with 50% representing chance performance. Recall that the prediction of facilitation from correlational structure would receive support not from a main effect but rather from an interaction of configuration and target rule. An ANOVA on forced-choice accuracy revealed this interaction to be significant, F(1, 34) = 8.24, p < .01, MSE = 402.65. As we predicted, participants in the structured path condition were more accurate on tests of the path rule. These participants averaged 86% correct (SD = 20%), compared with an average of 68% (SD = 26%) in the structured manner condition, t(34) = 2.34, p < .05 (one-tailed). On tests of the manner rule, participants in the structured manner condition were more accurate. These participants averaged 61% (SD = 17%), compared with an average of 51% (SD = 13%) in the structured path condition, t(34) = 1.81, p < .05 (one-tailed). Participants in general performed much better with the path rule than with the manner rule, producing a significant main effect of target rule, F(1, 34) = 19.69, p < .001, MSE = 402.65. The main
effect of configuration did not approach significance, $F(1,34) < 1$.

Interview scores revealed a similar pattern of results, although the interaction of configuration and target rule only approached significance, $F(1, 34) = 3.08, p < .09, MSE = 1.30$. With the path rule, participants in the structured path condition averaged 2.0 ($SD = 1.28$) correct reports of value pairings, compared with an average of 1.28 ($SD = 1.41$) in the structured manner condition. Although this difference only approached significance, $t(34) = 1.61, p < .06$ (one-tailed), the trend in interview scores was quite similar to that in forced-choice accuracy with this rule, producing a correlation of .77 ($p < .01$). Ten participants in the structured path condition reported all three pairings of the path rule, compared with 6 participants in the structured manner condition.

With the agent rule, participants in the structured manner condition averaged 0.33 ($SD = 0.84$) correct reports, compared with an average of 0.11 ($SD = 0.47$) in the structured path condition. Although this trend was in the same direction as the trend in forced-choice accuracy with this rule, the difference between conditions was not significant, $t(34) = 0.98, p > .10$. Moreover, the correlation between interview scores and forced-choice accuracy was not significant for this rule, $r(34) = .32, p > .10$. The failure of this correlation to reach significance is likely a result of a floor effect in interview scores. Only 4 participants reported any knowledge of the manner rule: 3 participants in the structured manner condition and 1 participant in the structured path condition. Only 1 participant, in the structured manner condition, reported all three pairings of the manner rule. Thus, there was much less reporting of the manner rule than the path rule, producing a significant main effect of target rule, $F(1, 34) = 27.69, p < .001, MSE = 1.30$. The main effect of configuration again did not approach significance, $F(1, 34) = 1.16, p > .10, MSE = 0.97$.

Leg motion seems to have been the source of difficulty for participants in reporting the manner rule. Although very few participants reported associations between orientation and leg motion, 9 participants in the structured manner condition reported associations between orientation and state change. Only 4 participants reported associations between leg motion and state change, and 3 of these also reported associations involving orientation. Thus, participants almost never reported associations involving leg motion in the absence of associations between orientation and state change.

**Discussion**

The results of Experiment 3 revealed greater learning of each target rule when it formed part of a rich correlational structure than when it was isolated, even when another, unrelated correlation was present in the events. Participants revealed more knowledge of the path rule in the structured path condition than in the structured manner condition. With the manner rule, participants in the structured manner condition performed better than participants in the structured path condition in the forced-choice test, whereas trends in interview scores were not significant but in the predicted direction. These results again provide evidence for facilitated learning of correlations involving high value systemat-

...
Leg motion, although dynamic and analogous to manner verbs in English (e.g., to walk, to strut), may have been linked more to object than to event categories in this experiment.

Orientation, in turn, seems to have played a mediating role between these two types of category. This makes sense given that orientation involves the motion of the agent as a whole, yet this motion is most easily defined in terms of parts of the agent (e.g., direction of motion relative to the direction the agent’s head is pointing). Thus, people may have been able to infer the relation of leg motion to state change only by first noticing the relation of state change to orientation and the relation of orientation to leg motion. If people indeed have difficulty associating object attributes with global event attributes, this should have implications for degree of facilitation. In particular, a covarying object attribute should offer little facilitation to an event target rule, whereas a covarying event attribute should not facilitate an object target rule. We investigated this prediction in Experiment 4.

Experiment 4

In Experiment 4 we had three objectives. First, we sought to replicate the findings of facilitation from correlational structure with the mixed design of Experiment 3. Second, we wanted to further investigate the notion that certain object attributes are difficult to associate with global event attributes. To do this, we compared the learning of two target rules. The object rule was based on object attributes, namely the body and legs of a complex agent. For example, one category based on this target rule involved agents with square, black bodies and three red legs on each side. The event rule was based on global event attributes, namely agent path and environment. For example, one category based on this target rule involved events that took place on a desert background in which the agent pursued the patient after contact. A third attribute covaried with the attributes in the object rule for half of the participants and with the attributes in the event rule for the other half. This facilitator attribute was either agent head, the object facilitator, or state change, the event facilitator. If object parts are difficult to associate with event properties, one would expect agent head to facilitate the object rule to a greater extent than state change, even though state change may be much more salient. In contrast, the event rule would be expected to show more facilitation from state change than from agent head.

A third objective of Experiment 4 was to study the effects of correlational structure on a more traditional measure of category learning, the sorting of instances into categories (Fried & Holyoak, 1984; Homa & Culbertson, 1984). We also wanted to examine the relationship of this measure to the rating measure used in the previous experiments. After the rating task, we administered two different sorting tasks, each testing for knowledge of one of the two target rules. In the event-sorting task, we instructed participants to sort entire events into three categories. Participants who learned the event rule were expected to be more likely to base their event sorts on agent path and environment than were participants who did not learn this correlation. In the object-sorting task, we instructed participants to sort the agents appearing in the events. Participants who had knowledge of the object rule were expected to be more likely to base these object sorts on agent body and agent legs than participants who did not learn this correlation.

We thus made the same predictions for the rating task and the sorting task. In particular, we predicted that participants would show greater knowledge of each target rule when it formed part of a rich correlational structure than when it was isolated. Moreover, we predicted greater facilitation of the object rule when an object attribute (i.e., agent head) acted as facilitator than when a global event attribute (i.e., state change) acted as facilitator. In contrast, we predicted greater facilitation of the event rule when a global event attribute acted as facilitator than when an object attribute acted as facilitator. Thus, we predicted not only an interaction of the configuration of correlational structure with target rule, in replication of Experiment 3, but also a three-way interaction of configuration, target rule, and facilitator attribute.

Method

Participants

Thirty-two undergraduates at the Georgia Institute of Technology received course credit for their participation in this experiment.

Stimuli

All events. The events in Experiment 4 differed from those in Experiment 3 in that the head, body, tail, and legs of the agent varied independently of one another, rather than always appearing in the same three combinations for a given participant. Orientation no longer varied in this experiment. Instead, all characters moved head first.

Learning events. The learning events in Experiment 4 differed from those in Experiment 3 in the correlations that were present. We assigned every participant the same two target rules: (a) the event rule, agent path–environment; and (b) the object rule, agent body–agent legs. In addition, a third attribute covaried with the event rule for participants in the structured event condition or with the object rule for participants in the structured object condition. State change played this role for half of the participants, whereas agent head did so for the other half.

Test events. In Experiment 4 we employed the rating task used in Experiments 1 and 2 rather than the forced-choice task used in Experiment 3. The forced-choice task would likely have influenced participants’ sorting performance because only one attribute varied across events in each forced-choice trial, making participants more likely to realize the importance of that attribute and thus use it as the basis for their sorts. Participants rated 36 test events, with 18 testing each target rule. The facilitator attribute for a particular participant was obscured throughout testing. In addition, either environment or agent body was obscured in each event, depending on which target rule was being tested. Body parts were obscured by blackening them, similar to the way the agent and patient as a whole were blackened in the previous experiments. State change and environment were obscured as in the previous experiments.

Sorting trials. After the test events, we presented each participant with 36 sorting trials, divided into two groups of 18. For one group, we instructed the participant to sort the events into three
categories. After each event, three buttons appeared at the bottom of the screen. Initially, these buttons were labeled Category 1, Category 2, and Category 3, respectively. Participants were able to change these to more meaningful labels, however, by clicking on each label and typing a different label. For the other group of events, we instructed the participant to sort the agents appearing in the events into three categories. The procedure was otherwise the same.

Throughout the sorting trials, the facilitator attribute was obscured. This was done so that participants would not sort on the facilitator attribute. Otherwise, participants would be more likely merely by chance to be credited with a sort consistent with the attributes participating in a richer correlational structure. obscuring the facilitator attribute equated the baseline probability of choosing an attribute from either target rule as the basis for sorting.

**Design**

The primary dependent variable in Experiment 4 was the difference between each participant's average rating for events involving correctly matched values of the target rule attributes and his or her average rating for events involving mismatched values. There were three independent variables. One was the target rule being tested (event rule or object rule), manipulated within subjects. The other two variables were configuration, specifying which target rule formed part of a rich correlational structure and which was isolated (structured event or structured object), and the identity of the facilitator attribute (event facilitator or object facilitator), both manipulated between subjects.

**Procedure**

We presented 90 learning events by using the same procedure as in Experiment 3. Thirty-six test events then followed, with the same rating task as in Experiments 1 and 2. The rating task was followed by 36 sorting events. We instructed participants to sort 18 events on the basis of the agents in those events. They were told that there were three kinds of agents (referred to as "Truoids") throughout the experiment on this planet, and that they were to indicate which type of agent they saw in each event by clicking on one of the three buttons at the bottom of the screen. Participants were allowed to change the labels on the buttons as soon as they had finished the instructions for the sorting task, but they were not obligated to do so and could change a given label more than once. The instructions for the event-sorting task were the same except that we instructed participants to sort events instead of agents. Half of the participants sorted events first, and half sorted agents first. The labels on the buttons reverted to Category 1, Category 2, and Category 3 before beginning the second sorting task.

**Results**

**Rating Data**

Tables 6 and 7 display the mean ratings of events testing the two target rules for participants in the structured event and structured object conditions, and Figure 10 depicts rating differences. An ANOVA revealed no significant main effects of configuration, F(1, 28) = 2.50, p > .10, MSE = 0.99, facilitator attribute, F(1, 28) = 1.48, p > .10, MSE = 0.99, or target rule, F(1, 28) = 2.75, p > .10, MSE = 0.99. The prediction of facilitation from correlational structure, however, would receive support not from a main effect but rather from an interaction of the configuration of correlations with target rule. This interaction of target rule and configuration was significant, F(1, 28) = 12.30, p < .01, MSE = 0.91, replicating Experiment 3. Rating accuracy was higher with each target rule when it formed part of a rich correlational structure. With the event rule, rating accuracy was higher in the structured event condition (M = 1.35, SD = 1.73) than in the structured object condition (M = 0.12, SD = 0.67), t(30) = 2.65, p < .01 (one-tailed). With the object rule, rating accuracy was higher in the structured object condition (M = 0.57, SD = 0.83) than in the structured event condition (M = 0.12, SD = 0.73), although this difference only approached significance, t(30) = 1.61, p < .06 (one-tailed).

As we predicted, the pattern of facilitation we described above was moderated by the choice of facilitator attribute, resulting in a significant three-way interaction of target rule, configuration, and facilitator, F(1, 28) = 4.20, p < .05, MSE = 0.91. With the event rule, the advantage of the structured event condition over the structured object condition was for the most part carried by participants who were assigned the event facilitator (i.e., state change). A post hoc Fisher's least significant difference (LSD) test revealed that rating accuracy with the event rule was higher in this condition than in any of the other three combinations of configuration and facilitator (p < .05), whereas there were no differences among these other three groups. With the

**Table 6**

<table>
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<th>Correct events</th>
<th>Difference</th>
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**Table 7**

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<th>Correct events</th>
<th>Difference</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
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<td>0.90</td>
<td>3.43</td>
</tr>
<tr>
<td>Event facilitator</td>
<td>3.52</td>
<td>0.90</td>
<td>3.55</td>
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<tr>
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<tr>
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<tr>
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<tr>
<td>Object facilitator</td>
<td>3.07</td>
<td>0.60</td>
<td>4.15</td>
</tr>
</tbody>
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**Note.** The object rule involved a correlation between agent body and agent legs. The event facilitator was state change, and the object facilitator was agent head.
structured event condition and 0.25 (SD = 0.68) in the structured object condition, t(30) = 0.45, p > .10. Only 1 participant, in the structured event condition, reported all three pairings with this rule.

As with rating accuracy, this pattern of facilitation with interview scores was moderated by the choice of facilitator attribute, producing a three-way interaction, F(1, 28) = 4.25, p < .05, MSE = 0.83. With the event rule, participants assigned to the structured event condition with the event facilitator reported more knowledge than did participants in the structured object condition assigned either facilitator (p < .05). There were no other significant differences between groups, nor were there any significant differences between groups on reports of the agent rule.

The only other significant effect was a main effect of configuration, F(1, 28) = 8.70, p < .01, MSE = 0.79, with participants in the structured event condition performing better than participants in the structured object condition. Overall, the trends in interview scores and rating accuracy were quite similar for the event rule, as indicated by the correlation between these two measures, r = .71, p < .01. In contrast, there was no significant relation between the two measures with the object rule, r = .01, p > .10.

### Sorting Data

We generated two sorting scores. The event sorting score reflected the degree to which participants sorted events on the basis of the attributes in the path rule, agent path and environment. The object sorting score reflected the degree to which participants sorted agents on the basis of the attributes in the object rule, agent body and legs.

Sorting scores indexed the number of changes that would have to be made in a participant's sort to make it entirely consistent with the values of the target rule attributes. To compute this score, we first determined which of the three categories was assigned most consistently to a single pair of values of the target rule attributes. We then counted the number of times this category was assigned to other values of the target rule attributes. Next, we determined which of the remaining two categories was assigned more consistently to one of the remaining two pairs of values. The number of times this category was assigned to the other pair of values was then added to the previous count. We finally added to the sorting score the number of times the third category was assigned to a pair of values other than the remaining pair. Thus, a score of 0 reflected a sort that was perfectly consistent with the values of the target rule attributes, and the highest possible score was 12 (with 18 of each type of sorting event, the participant could not help but get at least 6 right). We predicted that event sorting scores would be lower (and thus better) in the structured event condition than in the structured object condition, whereas object sorting scores would be lower in the structured object condition.

We performed an ANOVA on sorting scores with configuration and facilitator as between-subjects variables and target rule (event sort vs. object sort) as a within-subject variable. Preliminary analyses revealed no significant main

### Interview Data

Interview scores also revealed an interaction of configuration and target rule, F(1, 28) = 5.45, p < .05, MSE = 0.83. The event rule was reported more often in the structured event condition (M = 1.25, SD = 1.44) than in the structured object condition (M = 0.06, SD = 0.25), t(30) = 3.26, p < .01 (one-tailed). Six participants in the structured event condition reported all three pairings of the values of the event rule attributes, but none did in the structured object condition. The two groups did not differ in reports of the agent rule, however, with means of 0.38 (SD = 0.89) in the object rule, the advantage of the structured object condition was greater with the object facilitator (i.e., agent head) than with the event facilitator, although an LSD test showed no significant differences between groups.

This pattern of results also produced two other significant interactions. First, there was an interaction of target rule and facilitator, F(1, 28) = 6.17, p < .05, MSE = 0.91. Rating accuracy on the event rule was higher for participants who were assigned the event facilitator, whereas accuracy on the object rule was higher for participants assigned the object facilitator. Second, there was a significant interaction of configuration and facilitator, F(1, 28) = 5.85, p < .05, MSE = 0.99. Aggregating the two rules, participants in the structured event condition performed more accurately with the event facilitator, whereas participants in the structured object condition performed better with the object facilitator.

### Sorting Data

We generated two sorting scores. The event sorting score reflected the degree to which participants sorted events on the basis of the attributes in the path rule, agent path and environment. The object sorting score reflected the degree to which participants sorted agents on the basis of the attributes in the object rule, agent body and legs.

Sorting scores indexed the number of changes that would have to be made in a participant's sort to make it entirely consistent with the values of the target rule attributes. To compute this score, we first determined which of the three categories was assigned most consistently to a single pair of values of the target rule attributes. We then counted the number of times this category was assigned to other values of the target rule attributes. Next, we determined which of the remaining two categories was assigned more consistently to one of the remaining two pairs of values. The number of times this category was assigned to the other pair of values was then added to the previous count. We finally added to the sorting score the number of times the third category was assigned to a pair of values other than the remaining pair. Thus, a score of 0 reflected a sort that was perfectly consistent with the values of the target rule attributes, and the highest possible score was 12 (with 18 of each type of sorting event, the participant could not help but get at least 6 right). We predicted that event sorting scores would be lower (and thus better) in the structured event condition than in the structured object condition, whereas object sorting scores would be lower in the structured object condition.

We performed an ANOVA on sorting scores with configuration and facilitator as between-subjects variables and target rule (event sort vs. object sort) as a within-subject variable. Preliminary analyses revealed no significant main

![Figure 10](image-url)
effect or interactions involving the order of the two tasks, so order was not included as an independent variable in the final analysis. Consistent with rating and interview data, this analysis revealed an interaction of configuration and target rule, F(1, 28) = 4.97, p < .05, MSE = 12.87. Event sorting scores were lower in the structured event condition (M = 2.75, SD = 3.19) than in the structured object condition (M = 5.00, SD = 4.05), t(30) = 1.75, p < .05 (one-tailed). Seven participants in the structured event condition produced sorts that were entirely consistent with values of the event rule attributes, compared with 4 in the structured object condition. Object sorting scores, in turn, were lower in the structured object condition (M = 4.81, SD = 5.12) than in the structured event condition (M = 6.56, SD = 4.75), although this difference was not significant, t(30) = 1.00, p > .10. Five participants in the structured object condition produced sorts that were entirely consistent with the values of the object rule attributes, compared with 4 in the structured event condition.

The only other effect to attain significance was the main effect of facilitator, F(1, 28) = 5.92, p < .05, MSE = 22.33. Sorting scores were lower with the event facilitator, averaging 2.31 (SD = 3.22) and 4.38 (SD = 4.86) on the event sorting score and object sorting score, respectively, compared with averages of 5.44 (SD = 3.71) and 7.00 (SD = 4.80) on the same two sorts with the object facilitator. The main effect of target rule also approached significance, F(1, 28) = 4.08, p < .06, MSE = 12.87, with lower scores on event sorts (M = 3.88, SD = 3.77) than on object sorts (M = 5.69, SD = 4.93).

As we predicted, the trend in event sorting scores was highly related to the trends with the event rule in both rating accuracy (r = −.50, p < .01) and interview scores (r = −.56, p < .01), with the correlations being negative because lower sorting scores reflected better performance. In contrast, object sorting scores were not significantly related to rating accuracy (r = .25, p > .10) or interview scores (r = −.12, p > .10) with the object rule.

Discussion

Experiment 4 revealed that an object attribute facilitated the learning of an object correlation to a greater extent than did an event attribute, whereas the event attribute produced more facilitation of an event correlation. A correlation between two body parts, agent body and agent legs, showed little facilitation from a covarying state change, even though state change was found to be a highly salient facilitator of event correlations in this and earlier experiments. The object rule was facilitated to a greater extent by a covarying object part, namely agent head. This finding is consistent with other work showing facilitated learning of object correlations in the presence of additional, covarying object properties (Billman & Knutson, 1996). In contrast, the event rule showed much greater facilitation from state change than from agent head. Taken together, these findings provide evidence for a certain degree of encapsulation of object properties within the representations of events in which those objects participate. More generally, the degree of facilitation from correlational structure is a function not only of the saliences of the individual attributes involved but also the relatedness of those attributes.

Sorting scores as well as rating scores replicated the interaction of the configuration of correlational structure with target rule found with the rating task in Experiment 3. Participants were more likely to sort on the basis of the target rule attributes when a third attribute covaried with those attributes. In particular, participants were more likely to sort events on the basis of the attributes of the event rule in the structured event condition than in the structured object condition, whereas they were more likely to sort agents on the basis of the attributes of the object rule in the structured object condition. This finding of convergence between a measure of correlation learning and a more traditional measure of category learning provides evidence that the learning of event correlations can be taken as a measure of event category learning.

Event sorting scores were significantly correlated with rating accuracy on the event rule, indicating that participants who learned the agent path–environment correlation tended to sort events on the basis of the values of one or both of these attributes. Although the correlation between these measures was not overwhelming, it is likely to have been attenuated to some extent by participants who failed to learn any correlations but by chance happened to choose one of the correlated attributes as the basis for sorting. This outcome was particularly likely with participants for whom state change was obscured during sorting. These participants had to choose one of the other attributes as a basis for sorting, with the most “eventlike” of the remaining attributes being agent path, environment, and patient path, two of which participated in the event rule.

Unlike event sorts, object sorting scores were not significantly correlated with rating accuracy on the object rule. This null result may be related to the lack of correlation between rating accuracy and interview scores with this target rule. Some participants were apparently tapping implicit knowledge of this target rule when performing the rating task. A lack of explicit knowledge of the agent body–agent legs correlation may explain why these participants were no more likely than other participants to base their object sorts on these attributes. Particularly compelling evidence for an influence of implicit knowledge on rating accuracy comes from participants in the structured object condition assigned the object facilitator. These participants rated correct events testing the object rule more than 3/4 of a point higher than they did incorrect events, but not one of these participants reported any knowledge of this correlation in postexperimental interviews.

It thus seems that rating performance may have been influenced by partial, difficult-to-articulate knowledge to which the interview and sorting tasks were not sensitive. As a result, rating data from Experiment 4 provide evidence for facilitated learning of each target rule when it formed part of a rich correlational structure, whereas interview and sorting scores only reveal facilitation for the target rule of which participants had explicit knowledge, namely the event rule.
General Discussion

In the research reported here we examined the unsupervised learning of event categories based on differently organized sets of correlations among a number of attributes. The results of four experiments revealed facilitated learning of correlations when they formed part of a rich correlational structure. Of the 10 target rules we used in these four experiments, all 10 showed the predicted pattern. Experiment 1 revealed that an individual correlation was learned better when forming part of a rich correlational structure than when independent of other correlations. Experiment 2 showed that this effect could not be explained entirely in terms of competition among independent correlations in the matrix condition, revealing the same effect when no independent correlations were present. Experiment 3 revealed facilitated learning of correlations forming part of a rich correlational structure, even when that structure was embedded within a matrix organization. Experiment 4 provided converging evidence for facilitated learning of categories based on rich correlational structure, revealing effects of correlational structure on the sorting of events into categories. Experiment 4 also provided evidence regarding the role of object categories in event representations, as we discuss below.

The Relation Between Object and Event Categories

The pattern of results found in these experiments is similar to that found with experiments on the unsupervised learning of object categories (Billman & Knutson, 1996). Apparently, similar learning biases operate in both domains to facilitate the learning of correlations forming part of a rich correlational structure. Coupled with the observation that verb meanings have much less correlational structure than do nouns, however, this finding poses a puzzle. It is possible that such structure is indeed rare in the domain of events, accounting for the weaker correlational structure associated with verbs. But an alternative is that events do have a rich correlational structure, which people know about, but factors specifically linked to language are responsible for the lack of correlational structure in verb meanings. That is, the role of verbs may be to select one aspect of an event as being most important to its description, with additional detail specified by its arguments.

Verbs may therefore express a relatively abstract level of event categories. The predictive work carried by verbs may primarily emerge in combination with its arguments. For example, the meaning of the verb to chase in isolation seems to primarily convey the notion of one character following after another in the same direction, perhaps along with implications for speed and effort on the part of both participants in the event. When the objects cheetah and gazelle are inserted into these argument slots, however, many more inferences are possible, including a possible outcome. Thus, object and event categories may be fundamentally similar in structure and in the biases that affect their learning, but additional factors may constrain the structure of verb meanings.

Learnability may be one factor that affects the structure of verb meanings. Talmy (1985) has suggested that an immense lexicon would be required if a language involved many verbs that expressed more than a few attributes of meaning. For example, a language involving verbs with specific meanings such as “cheetah chases gazelle” would require a verb for each combination of objects that take part in events involving chasing. The large number of such verbs coupled with the low frequency of use of each individual verb would make such a language very difficult to learn.

If object and event categories are indeed fundamentally similar in the way they are learned and in their resulting mental representations, how do these two types of category differ? It is possible that they reflect two different levels in a representational hierarchy. The common motion of the parts of an object may segregate that object from the rest of an event, producing an encapsulated representation for that object (Kellman & Spelke, 1983). This encapsulation would explain the results of Experiments 3 and 4, which revealed that participants were much better at associating object parts and their motions with other object-related attributes than with more global event attributes. The role of object information in event categories may thus be mediated by object category representations. Event representations may include labels or pointers to the categories of objects playing roles within those events, but obtaining further object information may require consulting object category representations directly.

This hypothesis allows one to integrate the results of Experiment 4 with earlier work on the perception of causality. In particular, Cohen and Oakes (1993) found that 10-month-old infants associated agents in causal events with their effects on other objects, as indicated by dishabituation when an agent produced the wrong effect. This is similar to Michotte’s (1946/1963) finding that the effect in a causal event was perceived as belonging to the agent, even when only the patient carried the effect. Both of these findings, however, involve a relation between an effect and a whole object, rather than an object part. It is possible that people categorize objects independently of their effects on other objects, on the basis of object features such as parts and part motions. This conclusion is suggested by the finding of Experiment 4 that state change produced little facilitation of the correlation between agent body and agent legs, apparently because it was difficult for participants to relate state change to object parts. The resulting object categories, however, may become associated with characteristic effects of that category of objects on other objects, representing this information as part of an event category.

There thus seems to be a part–whole relation between objects and events, with objects forming part of an event category representation, if only at the level of a category label or pointer. One could argue, in fact, that objects play a similar role in event representations as do features in object representations, if one believed object features to be categories in their own right rather than primitives (Schyns, Goldstone, & Thibaut, in press). Clearly, however, events are composed of other types of features besides objects. For example, the role of temporal information in events would
be difficult to account for solely in terms of object information. Although we have suggested that object categories include information about the characteristic motions of those objects (see also Kersten & Billman, 1995) and that representing such motions may require reference to time, such motions seem to be continuous and repeating. In contrast, events often seem to have a much more complex temporal structure, often involving long durations ending in an irreversible outcome. Clearly, understanding the role of time in representations is central to understanding differences between object and event categories.

**Implications for Category Learning Models**

Many more models have been proposed to account for supervised learning than for unsupervised, and most categorization experiments tend to focus exclusively on supervised learning. Although these models were not designed to be applied to unsupervised learning, adapting them to model the present task could be useful in trying to understand differences between supervised and unsupervised learning. One possibility would be to treat one of the target rule attributes as analogous to a category label. Thus, the task for a model would be to learn to predict the values of this target rule attribute on the basis of the values of other attributes.

When adapted in this way, prominent models of category learning (e.g., Gluck & Bower, 1988; Kruschke, 1992; Trabasso & Bower, 1968) predict effects opposite to those found in our experiments. In these models, multiple predictors of an attribute compete for predictive strength. Because predictive strength is treated as limited, learning the predictiveness of one cue reduces the likelihood of learning the predictiveness of a second cue. In the present task, there were multiple predictors of each attribute that participated in a system of correlations. According to competitive learning models, these predictors should compete for predictive strength, and thus, correlations should be better learned when isolated than when forming part of a system of correlations. For example, in Experiment 4, participants should have been less likely to learn that environment was predictive of agent path if state change was also predictive.

The fact that supervised learning models cannot account for the present results does not invalidate these as models of supervised learning so much as to point to differences between supervised and unsupervised learning. It is not surprising that cue competition occurs in supervised tasks because it is clear to participants that the prediction of category membership is sufficient for successful performance in these tasks, and thus they need look no further once they have discovered an adequate predictor. In contrast, a participant may be more open to new information when it is not as clear what information is required for the task.

Differences in temporal relations, in and of themselves, do not seem to be responsible for the different results found in supervised and unsupervised learning tasks. The temporal relations in the present unsupervised task were quite similar to those in many supervised tasks, with some types of information revealed before others. A few participants did report treating state change as the attribute to be predicted in this task, similar to a category label in supervised learning tasks. These participants generally demonstrated knowledge of only one predictor of state change, similar to findings from supervised tasks. As indicated by the group results, however, most participants did not treat the task in this way.

The key difference between supervised and unsupervised tasks thus seems to be the singling out of one type of information as most important to predict. A useful avenue of future research may be to assess how well different categorization tasks in the world map onto supervised and unsupervised learning in the laboratory.

We next consider one model of unsupervised learning (Billman & Heit, 1988) that accounts for the results of these experiments. Relatively few models have been designed specifically to account for unsupervised learning (Anderson, 1991; Billman & Heit, 1988; Martin, 1992; Schyns, 1991), though a number have been developed in the machine learning community (e.g., Fisher, 1987). Nor have there been many applications of supervised models to concept learning tasks that lack discriminative feedback (Heit, 1994; Medin, Altom, Edelson, & Freko, 1982). Some of these other models might be able to account for our results by extending their implementations to address our task, and we would be interested in the results of such extensions.

The internal feedback model of unsupervised learning (Billman & Heit, 1988) predicts the pattern of facilitation we sought and found in the current experiments. Unlike supervised learning models, this model does not single out a particular attribute as being most important to predict. Instead, the model chooses in each trial a particular attribute whose value is to be predicted. This prediction is made on the basis of an internalized rule involving the value of a second, predictor attribute. The predicted value of this attribute is then compared with the actual, presented value of the attribute, providing internal feedback as to the predictive power of the rule.

Initially, all rules are equal in strength, and thus the system is no more likely to predict one value of an attribute over another. Yet with predictive success, a rule is strengthened and as a result is used more often to predict the correct value of the attribute in question. Critically, however, each rule is specific to a particular pair of attributes. Rules are selected only if the relevant attributes are sampled, and attributes are sampled proportional to their salience. **Focused sampling** is the mechanism that allows the model to account for benefit from rich correlational structure. When a correct prediction is made, the salience of the attributes involved increases. As a result, these attributes are sampled more frequently and thus other rules in which those attributes play a part become more likely to be learned. The internal feedback model thus predicts that a correlation will be better learned when it forms part of a system of correlations than when it is in isolation.

We illustrate the focused sampling procedure by describing the actions of a hypothetical participant in the structured event condition in Experiment 4. On discovering a correlation between state change and environment, the participant would allocate extra attention to those attributes, taking attention away from each attribute not involved in that
correlation. Because attention would be diverted away from a number of attributes toward only two attributes, however, less attention would be taken away from each attribute not yet discovered to be correlated than would be redirected toward each correlated attribute. As a result, each pairwise combination of state change, environment, and agent path would receive more total attention than if no attentional reallocation had occurred, making the participant more likely to discover the target correlation between environment and agent path.

Focused sampling is a useful procedure for learning categories formed around rich correlational structure because the attributes participating in such structure are predictive of many other attributes. Thus, allocating attention to attributes found to be predictive makes finding other correlations that form those categories more likely. Such an attentional reweighting procedure could be added to other models to make them more consistent with the present findings, as well as previous findings of facilitation from correlational structure (Billman, 1989; Billman & Knutson, 1996; Cabrera & Billman, 1996).

Interactions of Content With Correlational Structure

As we noted earlier, the different correlational rules we used in these experiments varied not only in general learnability but also in degree of facilitation from correlational structure. The internal feedback model may help to clarify how these two issues are related. According to the internal feedback model, facilitation of a particular target rule occurs when one first notices a correlation between one of the two target rule attributes and a third, facilitator attribute. The attentional reallocation resulting from this discovery encourages the discovery of other correlations involving these attributes, such as the target rule. Thus, facilitation is most likely to be found when a correlation involving the facilitator attribute is easier to learn than the target rule itself. If the target rule were much easier to learn than the correlations involving the facilitator attribute, one would expect little facilitation because the correlations involving the facilitator would not be learned until after the target rule and thus would not aid in its discovery. In addition, if a target were very difficult to learn, additional attention directed to that rule may still not be sufficient for one to notice that correlation. Degree of facilitation may thus be a function of the learnability of the target rule relative to the other correlations present.

There remain many open questions as to the factors influencing the learnability of correlational rules. On the basis of the results of Experiments 3 and 4, it seems likely that a theory of learnability will have to account for attribute relatedness as well as the individual salience of attributes. People may never hypothesize a relation between certain attributes even if they are individually very salient. For example, participants in Experiment 3 apparently had difficulty associating leg motion with state change, even though both were subjectively very salient. In contrast, people may overestimate the degree of correlation between attributes that intuitively seem like they should be related. For example, Chapman and Chapman (1967) found that both clinicians and naive judges overestimated the frequency of co-occurrence of the trait "suspiciousness" with unusual drawings of eyes in the Draw-a-Person test, apparently because suspiciousness is intuitively associated with the eyes. Noticing a correlation between attribute values in an event may depend on the availability of past instances in which those values were paired (Tversky & Kahneman, 1973) or on the ability of learners to construct a theory as to how those values may be related (Murphy & Medin, 1985).

Conclusions

In summary, these experiments make several distinct contributions. First, the results provide evidence that people have biases that facilitate the learning of richly structured categories, in the domain of events as well as of objects. Second, these experiments expand our knowledge of learning from observation when supervision or feedback are not provided. Finally, this research provides a useful building block in the study of event categories, encouraging further study of why some types of event correlations are easier to learn than others.

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