A Division of Labor Between Nouns and Verbs in the Representation of Motion

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This study examines the association of nouns and verbs with 2 different kinds of motion. Extrinsic motion is the motion of 1 object with respect to another object, whereas intrinsic motion is the motion of an object (or its parts) defined with respect to itself. Several experiments are reported that compare the association of these types of motion with novel nouns and verbs. Adult participants demonstrated a bias to associate verbs with extrinsic motion to a greater extent than intrinsic motion and a bias to associate nouns with intrinsic motion to a greater extent than extrinsic motion. These results suggest a division of labor between nouns and verbs, with verbs specialized to convey relational information, whereas nouns are specialized to convey information about individual objects. The distinction between intrinsic and extrinsic motion may be related to the neuroanatomical distinction between the “what” and “where” systems.

Verbs are often thought of as the primary vehicles for conveying motion. Most verbs, however, only describe certain aspects of a motion event, and other kinds of words are necessary to provide a more complete description of motion: Prepositions, verb particles, and adverbs are examples of other word classes that may participate in the description of motion. Nouns are not generally thought to describe motion. Nouns are instead thought of as labels for conceiving motion. Nouns are not generally thought to describe motion. Nouns are instead thought of as labels for conveying motion. Most verbs, however, only describe

 review evidence for earlier learning of path terms than of manner of motion terms. An alternative explanation, however, is that manner of motion is simply less salient or more difficult to learn than path. I argue against this alternative by reviewing evidence that manner of motion is readily associated with nouns. This work suggests that different biases may function when learning nouns than when learning verbs. Five experiments with adult participants are then reported in which different types of motion are equally strongly related to both nouns and verbs, but different patterns of associations are revealed.

TYPES OF MOTION DESCRIBED BY RELATIONAL TERMS

In English, prepositions and verb particles are used in conjunction with verbs in the description of motion. In particular, Jackendoff (1987) has proposed that English prepositions tend to convey motion with respect to an external frame of reference, such as the path of one object with respect to another. For example, in and out describe motion into and out of some reference object. I refer to this type of motion as extrinsic motion. In contrast to extrinsic motion, Jackendoff has proposed that English verbs tend to express the motion of an object with respect to an internal frame of reference. For example, run, walk, and saunter describe different ways of moving the arms and legs relative to the body. I refer to this type of motion as intrinsic motion. Thus, these different kinds of motion form a hierarchy, with extrinsic motion conveying the general path of movement and intrinsic motion describing the detailed motions that produce this path.

Although both intrinsic and extrinsic motion need to be conveyed in order to describe a motion event in any detail, evidence from language acquisition suggests that young children at first focus on extrinsic motion. In particular, English-speaking children often learn to use verb particles before they learn to use verbs. For example, words such as
up and down, in and out, and on and off are some of the first motion-related terms used by children learning English, whereas verbs are used only infrequently until several months later (Bowerman, 1978; Farwell, 1977; Gentner, 1982; Gopnik & Choi, 1995; Greenfield & Smith, 1976; McCune-Nicolich, 1981; Nelson, 1974; Smiley & Huttenlocher, 1995; Tomasello, 1987). Although verb particles such as in and out can eventually be used to describe a number of different types of motion, some of which do not involve extrinsic motion (e.g., reach out), Lindner (1982) proposed that such uses are metaphorical extensions of the prototypical extrinsic paths that are initially associated with these words. Not only do English-speaking children learn to use verb particles before verbs, they often seem to treat verb particles as if they were verbs, producing "sentences" such as kitty down and leaf off my neck (Tomasello, 1987). Furthermore, most of the first verbs used by the children in a study by Bowerman (1978) are similar to verb particles in that they describe the path of one object with respect to another. For example, come and go describe paths toward and away from the speaker. Thus, the first relational terms used by these children seem to convey extrinsic motion.

There is also cross-linguistic evidence for earlier learning of relational terms that convey extrinsic motion. In many languages, however, extrinsic motion is conveyed primarily through verbs rather than prepositions. According to Talmy (1985), across languages the most common type of motion verb describes the path of an object with respect to another object (i.e., extrinsic motion). Although such path-specifying verbs are not common in English, there are a few examples, such as enter and pass. In contrast, the most common type of verb in English is the manner-specifying verb, describing the manner in which an object moves (i.e., intrinsic motion), but conveying no information about the path of that motion (Talmy, 1975).¹

Choi and Bowerman (1991) compared the use of relational terms by English-speaking children to children learning Korean, a language that more frequently employs path-specifying verbs. Unlike the English-speaking children observed in the study, Korean children started to use verbs at around 14–16 months, the same point at which English prepositional use by the English-speaking children in the study began. In fact, the Korean children tended to use verbs in the same types of situations in which the English-speaking children used prepositions. For example, when putting two pieces of a toy together, the English-speaking children tended to produce prepositions such as on, whereas the Korean children used verbs such as kkita, translated to mean fit. Although such path-specifying verbs are most common in Korean, there are also some verbs that describe the manner of motion of an object. Only one child in Choi and Bowerman’s sample used such a verb, however. Thus, in Korean as well as English, terms that describe extrinsic motion are used earlier than terms that describe intrinsic motion.

An apparent counterexample to the general finding of an advantage of extrinsic motion over intrinsic motion when learning verbs comes from Huttenlocher, Smiley, and Charney (1983). They found that children comprehended intrinsic motion verbs such as kick, walk, and run earlier than verbs with an extrinsic component such as put down and pick up. There are a number of possible reasons for this advantage of intrinsic motion verbs, however. Most notably, because verb particles can by themselves convey extrinsic motion, these verbs convey a more complex meaning. For example, many verbs in this study implied the actions of an external agent to cause motion (e.g., put down, pick up, give, and take) or a change in state (e.g., clean, fix, and make) in an object. This complexity associated with the actions and intentions of an external agent was in fact the reason why Huttenlocher, Smiley, and Charney (1983) predicted difficulty in learning these verbs. Furthermore, as discussed earlier, verb–particle combinations often take on meanings that are only metaphorically related to the prototypical path associated with the particle. For example, pick up does not necessarily involve upward motion. If children were asked to distinguish simple extrinsic motions of individual objects (e.g., go up vs. go down), they would perhaps perform as well or better than with intrinsic motion verbs.

Why are relational terms that describe extrinsic motion seemingly learned earlier than those that describe intrinsic motion? One possibility is that extrinsic motion is inherently more salient or easier to associate with words than is intrinsic motion. If this is the case, one would expect relations involving extrinsic motion to be generally easier to learn than those involving intrinsic motion, not only for relational terms but also for other types of words, such as nouns. Alternatively, the facilitated learning of extrinsic motion may be specific to relational terms, resulting from learning biases that come into play only when learning relational terms. In support of this second hypothesis, I present evidence that nouns, in contrast to verbs, are more readily associated with intrinsic motion than with extrinsic motion.

### TYPES OF MOTION DESCRIBED BY NOUNS

One does not tend to think of nouns as conveying much information about motion. Instead, nouns are generally thought of as labels for objects. Objects seem to be categorized primarily based on their parts (Tversky & Hemenway, 1984), and thus nouns convey information about particular configurations of object parts. According to Tversky and Hemenway, however, the most prototypical object parts are those that have functional significance, and one of the most important functions of objects is motion. Many objects are capable of motion, and the way an object is configured makes it particularly good at moving in a

¹In the later version of the theory (Talmy, 1985), manner-specifying verbs are grouped together with cause-specifying verbs (e.g., blow, push, pull, throw). Unlike manner-specifying verbs, cause-specifying verbs seem to involve an extrinsic component, expressing a relation between an external agent and an object in motion. For example, “John threw the ball” implies a separation of the ball from John over time. Interestingly, push, pull, and throw were some of the first verbs used by one of Choi and Bowerman’s (1991) English-speaking children, possibly because of the extrinsic component in these verbs’ meanings.
particular manner. For example, the human body is configured so that we move best on two legs while our arms swing at our sides. The fact that animate objects have characteristic manners of motion makes it likely that these manners of motion are conveyed by the nouns that label those objects.

Evidence for a role of manner of motion in animate object categories comes from work on event perception. In this work, observers are asked to identify degraded object stimuli. Although this identification involves a large perceptual component, it also involves the categorization of an object as an example of a particular class of objects. A classic example of this type of work is given by Johansson (1973), who presented observers with points of light representing the motions of a person, without displaying any static information about the person. When observers were shown points of light representing human walking, they were without exception able to identify the motions of the points as being representative of humans. When observers were instead shown static frames from these films, none was able to identify the points as being representative of humans. Thus, the motions of the points of light, not their static configuration, allowed observers to categorize these stimuli.

Other work has demonstrated that people can more specifically categorize the motions of points of light. For example, Kozlowski and Cutting (1977) and Runeson and Frykholm (1983) have demonstrated that observers can discern the gender of a walker from his or her motion. Cutting and Kozlowski (1977) have further demonstrated that observers can identify people they know on the basis of their motions. Thus, people not only can categorize the motions of points of light as being examples of male or female humans, they also can identify specific exemplars of humans in motion.

Johansson (1973) interpreted the results of his experiments on point-light walkers using his theory of perceptual vector analysis (Johansson, 1950). In this theory, he proposed that the common motion shared by perceptual elements is first extracted. Residual motions are then interpreted in relation to this common motion. Thus, when viewing a walking human, one extracts components of motion shared by all points on the human, that is, those components reflecting the translation of the body as a whole. With this common motion factored out, the motions of individual body parts are perceived with respect to the body as a whole, which acts as a frame of reference.

Johansson's (1973) theory implicates intrinsic motion as the type of motion important in identifying humans. Perceptual vector analysis reveals that all points on a walker's leg share in a pendular motion relative to the hip, whereas all points on a walker's arm share in a pendular motion relative to the shoulder. This knowledge of the intrinsic motion of human limbs relative to the body could allow an observer to categorize the point-light stimuli as representing human motion. Observers cannot use extrinsic motion to categorize the stimuli because only one object is represented in the displays (but see Bertenthal & Pinto, 1994, for evidence of a role of the orientation of the walker with respect to the earth). Thus, it seems that particular intrinsic motions are associated within the concept HUMAN. This association seems to be learned at a very early age, as infants as young as 3 months old can discriminate point-light displays of human walking from scrambled point-light displays (Bertenthal, Proffitt, & Cutting, 1984).

Further evidence that animate nouns convey information about intrinsic motion can be found in sentences in which nouns are used in conjunction with manner-specifying verbs. Although such verbs can be thought of as specifying intrinsic motion, it is not clear whether this information is conveyed specifically by the verb or instead is conveyed by the verb in combination with a noun. For example, the verb walk conveys different motions depending on whether it is used in combination with man or horse. In fact, the interpretation of many verbs requires particular objects or classes of objects. For example, the verbs gallop and trot require horses or similarly configured four-legged animals, whereas the verb scurry seems to require small, four-legged animals such as rodents. It is thus not clear whether the interpretation of motion in the sentence “The mouse scurried into its hole” is based primarily on motion information conveyed by the verb scurry or by the noun mouse.

Gentner (1981) provided evidence that nouns tend to dominate over verbs when the two convey discrepant information about the actions of an object. She demonstrated that when the verb in a sentence specifies an action that the object implicated by the noun is not capable of performing, the action specified by the verb is adjusted more than the action specified by the noun. For example, participants produced interpretations of “The lizard worshipped” such as “The small gray reptile lay on a hot rock and stared unblinkingly at the sun.” Thus, participants’ interpretations of the sentence were based on the different actions capable of being performed by lizards and not by the types of actions typically associated with the verb worshipped. Object concepts, then, may include information about the different types of actions that those objects are capable of performing, and the role of manner-specifying verbs may be to select which of those actions is relevant for the interpretation of a particular sentence.

Motion associated with objects interacts more with manner-specifying verbs than with path-specifying verbs, because the interpretation of manner-specifying verbs more often requires reference to the objects carrying out the actions described by the verbs. Thus, as discussed previously, the interpretation of the verb walk depends to a large extent on the noun used in conjunction with that verb. In contrast, the information conveyed by path-specifying verbs remains largely the same regardless of the objects carrying out the actions described by those verbs. For example, the interpretation of the verb enter seems not to require reference to the object in motion. Instead, the object can be conceived of as a point (Jackendoff, 1987), with the verb specifying the motion of this point into another object. Thus, nouns seem to contribute to the interpretation of intrinsic motion verbs more than to the interpretation of extrinsic motion verbs.

The evidence reviewed so far suggests that animate nouns convey more information about intrinsic motion than about extrinsic motion, arguing against the hypothesis that extrinsic motion is generally more salient or easier to associate
with words than is intrinsic motion. Instead, the advantage of extrinsic motion in learning relational terms may reflect a learning bias particular to relational terms.

There have been some suggestions, however, that certain nouns also convey information about extrinsic motion. Although not explicitly framed in terms of motion, Barr and Caplan (1987) have proposed that object concepts involve both intrinsic and extrinsic features. For example, has a handle would be an intrinsic feature of HAMMER, whereas used to work with would be an extrinsic feature, because it represents the relation between the hammer and an external object, namely the person using the hammer. In support of this theory, when participants were asked to list features of object categories, they listed not only features of objects considered in isolation but also features involving relations to other objects. Extrapolating from Barr and Caplan’s theory, one may expect both extrinsic and intrinsic motion to be important to nouns.

A second theory also suggests a role for extrinsic motion in object categories. In particular, Nelson (1983) has proposed that an object is initially categorized by its function, or the role it plays within an event. For example, one’s concept of a FOOTBALL may initially be represented as something that is passed or handed between people playing on a field with lines on it. Thus, if someone with this concept were to see a rugby match, he or she may mistakenly call the ball a football, as the balls play similar roles in both sports. This representation seems to include an extrinsic motion component because the role an object plays within an event is in part determined by the different ways it interacts with other objects in the event.

Although Nelson’s (1983) theory suggests a role for functional (i.e., extrinsic) information in early noun learning, the weight of the evidence suggests that this is not the case. Huttenlocher and Smiley (1987) found that fewer than 20% of young children’s object terms were used in consistent functional contexts. Even these words were always used to label objects of the appropriate form, and thus it is not clear whether children categorized these objects on the basis of form, function, or both. In a study of comprehension, Gentner (1978) found that whereas older children extended a novel noun on the basis of both the form and function of an object, young children extended the noun primarily on the basis of form. Furthermore, Smith, Jones, and Landau (1996) found that although the function of an object influenced children’s performance in a similarity task, the same function did not significantly influence children’s performance in a novel noun-learning task.

Taken together, these findings provide strong evidence that object concepts and nouns convey information about intrinsic motion and less evidence that they convey information about extrinsic motion. Evidence that nouns convey intrinsic motion comes primarily from animate nouns, and it remains possible that inanimate nouns convey little information about intrinsic motion. Unlike with relational terms, however, there is little evidence to suggest that extrinsic motion is easier to associate with nouns than is intrinsic motion. This suggests that the greater ability of children to learn relational terms for extrinsic motion than for intrinsic motion may reflect the operation of a learning bias specific to relational terms.

A DIVISION OF LABOR IN THE REPRESENTATION OF MOTION

I propose a theory of motion representation in language that accounts for the findings described previously as well as the experiments that follow. The underlying assumption in this theory is that motion is generally conveyed not through individual words but rather through interactions between the words in a sentence. For example, Talmi (1985) has noted that verbs, beyond encoding the fact that motion is occurring, tend to convey only one aspect of a motion event. Thus, other words are needed to convey other aspects of the event. There are exceptions to this rule, such as instrument verbs (e.g., to saw, to hammer), that express specific combinations of aspects of meaning such as the identity of an object in an event, the motion of the object, and the result of the event (Behrend, 1990; Kersten & Billman, 1997). If an entire language were organized around a system of such verbs, it would allow for very terse conversations because only one or a few words would be needed to describe an event. It would be very difficult to learn such a language, however, because it would have to employ an immense lexicon, requiring a word for each specific combination of aspects of meaning. Because language, instead, employs a combination of words to describe most situations, I propose that a useful strategy for representing motion in language involves a division of labor between different types of words, with different words conveying different aspects of a motion situation.

I propose that learning biases function to encourage a division of labor between nouns and relational terms in the description of motion. Experiment 1 tested this general notion that there are different learning biases when learning verbs compared to when learning nouns. More specifically, I propose that an extrinsic motion bias is in effect when learning relational terms, which focuses attention on extrinsic motion at the expense of intrinsic motion. This bias would help people to learn verbs and prepositions that specify the path of an object, whereas it would retard the acquisition of verbs that specify manner of motion. This bias was tested in Experiments 2 and 5 by presenting participants with verbs that were equally related to an extrinsic motion attribute and an intrinsic motion attribute and testing which relations participants were better at learning. It was also tested in Experiment 3A by examining associations of verbs with an intrinsic motion attribute when an extrinsic motion attribute was sufficient to fully differentiate verbs. These associations were compared to associations in Experiment 3B, when extrinsic motion was unrelated to verbs, in order to determine whether extrinsic motion overshadows intrinsic motion in verb learning.

In contrast to verbs, I propose that an intrinsic motion bias is in effect when learning nouns. Thus, nouns and relational terms provide different information about a motion situation and must work together to provide a complete description of motion. For example, in the sentence “The man entered the
store,” enter describes the path of motion, whereas intrinsic motion information associated with the concept of man allows one to infer the manner in which this motion is achieved (e.g., walking). The intrinsic motion bias was tested in Experiments 2 and 5 by presenting participants with nouns that were equally related to an intrinsic motion attribute and an extrinsic motion attribute and testing which relations participants were better at learning.

A bias to associate relational terms with extrinsic motion would eventually have to be overcome to learn manner-specifying verbs such as run and saunter. I propose that to learn manner-specifying verbs, language learners aggregate over characteristics of the different objects whose actions have been described by a particular verb. If many diverse objects were described as performing a particular action, this aggregation would yield a quite abstract concept. For example, the meaning of the verb walk is quite abstract (i.e., locomotion with at least one foot on the ground at all times) because many different creatures are capable of walking. If a verb is associated with only one or a small class of objects, however, such as the case with trot and gallop, the verb is closely tied to information about this object (e.g., horse). This mechanism can also account for the acquisition of verbs that provide categorical information about the object in motion. Such verbs are rare in English (e.g., rain, snow) but are common in many languages (Talmy, 1985).

I propose that the role of manner-specifying verbs is to select from a number of possible manners of motion that can be carried out by a particular object. This is done by comparing the information conveyed by a verb with each of the possible manners of motion for that object. The manner of motion that most closely matches the verb is then selected as the interpretation of the sentence. Thus, the interpretation of a sentence such as “The lizard worshipped” is more likely to be consistent with the noun than with the verb because the interpretation is selected from the possible actions of the referent of the noun. This hypothesis was tested in Experiments 2, 3A, 3B, 4, and 5 by presenting participants with sentences in which the noun and verb were associated with different manners of motion and asking participants which manner of motion better exemplified the meaning of each sentence.

These claims about motion representation are related to several theories described previously. First, it shares with the theory of Jackendoff (1987) the notion of division of labor between different parts of speech in the description of motion. In contrast to this theory, however, my theory implicates a role for nouns in the description of motion. Jackendoff proposed that verbs are responsible for the expression of intrinsic motion in English, whereas in my theory this role is mediated by nouns.

These claims are also related to Gentner’s (1981) theory about the relative importance of nouns and verbs in determining the interpretation of a sentence. Consistent with her claims, in my theory nouns dominate over manner-specifying verbs in conveying intrinsic motion. In contrast to Gentner (1981), however, nouns do not take precedence to path-specifying verbs in my theory. Instead, each part of speech makes a separate contribution to the overall description of motion, with nouns conveying intrinsic motion and verbs conveying extrinsic motion.

My theory is also related to the theories of Barr and Caplan (1987) and Nelson (1983). These researchers have suggested that nouns convey information about extrinsic motion. My theory does not rule out the possibility that nouns may eventually come to convey extrinsic motion, just as verbs may eventually come to be associated with object information. Many nouns (e.g., knife) are frequently used in conjunction with particular verbs (e.g., cut). In this case, information associated with the verb may become associated with the noun. As a result, an object may need to be able to perform the actions described by the verb in order to be categorized as an example of that noun. In early noun learning, however, my theory implicates a larger role for intrinsic motion than for extrinsic motion.

**EXPERIMENT 1**

The following five experiments examined the influence of different learning biases on adult participants’ learning of nouns and verbs. Within an animated microworld, events were created in which one character moved in relation to a second character. Novel nouns and verbs were equally strongly related to one or more attributes of these events. Thus, if the learning of these relations is influenced only by general factors such as attribute salience, then one would expect nouns and verbs to be equally strongly associated with these different attributes. If, instead, associations are subject to learning biases particular to nouns or to verbs, then one would expect nouns and verbs to be differentially associated with these different attributes.

Experiment 1 was designed to test whether learning biases are in part responsible for differences in learning nouns and verbs. This experiment also tested the usefulness of this experimental method for examining these biases. Rather than contrasting extrinsic and intrinsic motion, this first experiment focused on a seemingly more fundamental difference between nouns and verbs, namely, that nouns tend to label objects, whereas verbs tend to label actions. If this experimental method is to be useful in revealing learning biases involving different kinds of motion, then it should be able to show a more fundamental bias to associate nouns with objects and verbs with actions.

It is possible, however, that learning biases are not in fact responsible for differences between nouns and verbs, and thus would not be found using any method. This possibility is suggested by the work of Maratsos and Chalkley (1980), who proposed that the differences between nouns and verbs are primarily syntactic rather than semantic in nature. Thus, the syntactic category NOUN is formed around words that are preceded by articles and sometimes have an s at the end, whereas the category VERB is formed around words that follow nouns or auxiliaries such as is and have and often have ing at the end. Quite similar semantic information can often be expressed by either type of word (e.g., an attack vs. to attack).

Although there is considerable overlap in the meanings of nouns and verbs in the adult lexicon, the majority of the first
nouns learned by children refer to objects (although children also use nouns that do not refer to objects; see Nelson, Hampson, & Shaw, 1993). In contrast, the first verbs used by children generally refer to actions. Furthermore, even adults consider the prototypical nouns to be object terms and prototypical verbs to be action terms. Nagy and Gentner (1990) presented adults with novel nouns and verbs in the context of a story. Although the initial presentation of each noun or verb was accompanied by information about both an object and an action, subsequent testing revealed that participants were more likely to associate nouns with objects than with actions, whereas they were more likely to associate verbs with actions than with objects. These learning biases would have to be overcome in the face of conflicting syntactic information, however, in order to learn less prototypical nouns and verbs.

To test for biases affecting the learning of nouns and verbs, participants in Experiment 1 were presented with a number of events, each accompanied by a sentence involving a novel noun and verb. Across a series of events, nouns and verbs were correlated with the values of several attributes of the events. Two of these attributes were equally strongly related to nouns and verbs. One attribute involved a body part of one of the two characters in the event, whereas the other involved the motion of one character relative to the other character. I predicted that participants would more strongly associate nouns with object parts than with motions, whereas they would more strongly associate verbs with motions than with object parts.

Method

Participants

Ten undergraduates at the Georgia Institute of Technology in Atlanta, GA, received course credit for participation in this experiment.

Stimuli

All events. Events were displayed on Macintosh II (Apple Computers, Inc., Cupertino, CA) computers using MacroMind Director 2.0 (Macromedia, Inc., San Francisco, CA). An example event is shown in Figure 1. Two characters appeared in each event. One of the characters, the agent, moved throughout the course of the event, whereas the other, the patient, remained stationary. Each character was composed of three attributes: head, body, and legs. Each of these attributes had four possible values, as shown in Figure 2. An agent's motion could be described by three attributes, as shown in Figure 3. One attribute was the path of the agent, or the direction or directions taken by the agent relative to the patient. The second motion-related attribute was the leg motion of the agent. The third attribute was the orientation of the agent, that is, whether the agent faced forward, backward, left, or right as it moved. A static background, or environment, was also present in each event. Two identical line drawings appeared in two unoccupied corners of the screen throughout each event (as shown in Figure 1). The four possible environments were a swamp, a desert, a mountain scene, and a rocky plain.

At the beginning of each event, a black screen faded away to reveal the starting positions of the two characters. The agent's starting location was randomly chosen from a set of points near the center of the screen. The patient's starting location was randomly chosen from eight possible directions relative to the agent, either north, south, east, west, northeast, northwest, southeast, or southwest. An event ended when the agent reached the patient or had traveled an equivalent distance in the direction opposite the patient.

Learning events. There were 80 learning events. Each learning event was accompanied by a sentence, presented by the computer in a female voice. The sentence began when the agent started in motion and finished toward the end of the event. Each sentence involved a novel noun, preceded by the, and a novel verb, preceded by is. There were four different nouns (i.e., racha, doovil, zeebee, and taigo) and four different verbs (i.e., spogging, morping, yimming, and wunking). At the end of each learning event, a button labeled Next Event allowed a participant to continue.
or verb and a particular attribute value was indicated by his or her ability to choose the entirely correct event as the better example of the word.

Eight trials tested for associations involving agent body, whereas eight tested for associations involving path. Half of these trials tested for knowledge of nouns, whereas half tested for knowledge of verbs. In addition, four trials tested for associations between nouns and the values of agent head, whereas four tested for associations between verbs and orientations. In a particular trial, all attributes that were not being tested took on values as they had during learning. Thus, if an attribute was correlated with nouns and verbs during learning, it was given a value consistent with the noun or verb in the test trial. If an attribute varied randomly during learning, it varied randomly throughout testing.

**Procedure**

Sessions lasted approximately 45 min. Participation was self-paced. Instructions were presented on the computer. Participants were instructed to view a number of events depicting life on another planet and to learn the meanings of words accompanying those events. They were then presented with 80 learning events. At the end of learning, participants were instructed that they would be tested on their knowledge of the nouns and verbs heard during learning. They were then presented with 24 test trials, each involving two events. At the end of the first event in each trial, the participant clicked on a button labeled Next Event to see the second event in the trial. At the end of the second event, participants pressed one of three buttons. One button, labeled Repeat allowed participants to view the two events again. The other two buttons were labeled First Event and Second Event. Participants clicked on

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*Figure 2.* The four possible values of each of the static attributes in the events.

Across these events, nouns and verbs were correlated with several attributes. The correlations for an example participant are depicted in Figure 4. As shown in Figure 4, each noun was always accompanied by an agent with a particular type of head, and each verb was always accompanied by a particular orientation of the agent. For example, the noun *zeebee* labeled an agent with a round head, and the verb *morping* labeled motion of the agent to the left. If a participant merely wanted to be able to tell the four nouns and verbs apart, he or she would not have to look any further than these two attributes. Two additional attributes, however, were correlated with both nouns and verbs. One was an object attribute, agent body, whereas the other was a motion attribute, path.

For each participant, agent body and path had two values. Each of these values was correlated with two nouns and two verbs. For example, the square body in Figure 4 is correlated not only with the nouns *zeebee* and *doovil*, but also with the verbs *morping* and *spogging*. The path directly toward the patient is correlated with the same two nouns and two verbs. Thus, there was a shared superordinate structure for nouns and verbs, with two nouns and two verbs correlated with one body and one path and two other nouns and two other verbs correlated with the other body and path. All of the remaining, uncorrelated attributes (i.e., agent legs, patient head, patient body, patient legs, environment) took one of four values, chosen at random in each event.

**Test events.** There were 24 trials testing associations with individual nouns and verbs. Each trial involved a forced choice between two events. During each test trial, the first event was presented along with a question about an individual noun (e.g., “Is this a zeebee?”) or verb (e.g., “Is this morping?”). During the second event, participants were asked the same question. Participants were then asked to choose the event that was a better example of the noun or verb. One event in each trial was entirely consistent with the noun or verb, whereas the other included one attribute value that had never accompanied that noun or verb during learning. A participant’s knowledge of the relation between a noun

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*Figure 3.* The four possible values of each of the dynamic attributes in the events. Arrows represent the direction of motion. A = agent; P = patient.
 override motion 41

Figure 4. Correlations seen by an example participant in Experiment 1. A = agent; P = patient.

Design

The primary dependent measure in this experiment was accuracy at choosing the correct events in the test trials. The independent variables were the part of speech of the word accompanying each test trial (noun vs. verb) and the attribute being tested (agent body vs. path).

Results

An analysis of variance (ANOVA) on forced-choice accuracy did not reveal a significant effect (i.e., $p < .05$) of either part of speech, $F(1, 9) = 0.03, p > .10$, $MSE = 501.74$, or attribute, $F(1, 9) = 0.04, p > .10$, $MSE = 432.29$. As predicted, however, there was a significant interaction of these two variables, $F(1, 9) = 24.44, p < .01$, $MSE = 696.18$. This interaction is depicted in Figure 5. On trials testing associations with nouns, participants averaged 95% correct ($SD = 11$%) on tests involving agent body, compared to an average of 53% ($SD = 32$%) on tests involving path. A $t$ test revealed this difference to be significant, $t(9) = 4.64, p < .001$ (one-tailed). Moreover, performance on tests of relations between nouns and paths was not significantly different from the chance rate of 50% ($p > .10$). On trials testing associations with verbs, participants averaged 55% ($SD = 33$%) on tests involving agent body, compared to an average of 95% ($SD = 11$%) on tests involving path. A $t$ test involving these scores was also significant, $t(9) = 3.36, p < .01$ (one-tailed). Performance on tests of relations between verbs and bodies was also not significantly different from chance ($p > .10$).

Performance was also evaluated on trials involving agent head and orientation, each of which was tested in association with only one part of speech. This was done to insure that participants were indeed able to differentiate nouns and verbs on the basis of these other attributes and thus were not compelled by the experimental task to associate words with body or path. Participants averaged 83% ($SD = 17$%) on trials testing associations between nouns and the values of agent head. Participants also averaged 83% ($SD = 33$%) on trials testing associations between verbs and orientations.

Discussion

As predicted, participants more strongly associated nouns with a static attribute, agent body, than with a dynamic attribute, path. In contrast, participants more strongly associated verbs with path than with agent body. Thus, the results of this experiment capture the notion that nouns tend to label clusters of object attributes, whereas verbs tend to label dynamic information. Therefore, biases that reflect regulari-
ties in natural language influenced learning in this task. This finding is consistent with the finding of Nagy and Gentner (1990) that adult readers made different inferences about the meaning of a novel word depending on whether it was a noun or a verb. The fact that the present method was able to capture this difference between nouns and verbs suggests that it may be useful in uncovering other differences between nouns and verbs, namely in the roles played by intrinsic and extrinsic motion.

EXPERIMENT 2

Experiment 2 was designed to test the prediction that nouns tend to be more strongly associated with intrinsic motion than with extrinsic motion, whereas verbs tend to be more strongly associated with extrinsic motion. Two motion attributes were correlated with both nouns and verbs. One motion attribute, path, involved extrinsic motion, representing the motion of one object relative to another. The second motion attribute, leg motion, involved intrinsic motion, representing the motions of legs relative to the body of the agent. As in Experiment 1, each noun was also correlated with one value of an object attribute. Rather than agent head, the legs of the agent played this role. The manners of motion of real-world objects are highly correlated with the appearance of the parts responsible for those motions, and thus it seemed reasonable to preserve these correlations in this experimental task (see Kersten & Billman, 1995, for an experiment in which the appearance of the legs was random). Also as in Experiment 1, each verb was correlated with one value of orientation. I predicted that participants would more strongly associate nouns with leg motions (i.e., intrinsic motion) than with paths (i.e., extrinsic motion) and more strongly associate verbs with paths than with leg motions. Thus, I again predicted an interaction of part of speech with the identity of the attribute being tested.

A second test provided an opportunity to further examine the notion of a division of labor between nouns and verbs. In particular, it provided a test of the prediction that nouns are more important than verbs in conveying leg motion, whereas verbs are more important than nouns in conveying path. Note that this is a stronger prediction than one of different learning biases for nouns and verbs. For example, nouns could be more strongly associated with leg motion than path, whereas verbs could be more strongly associated with path than leg motion, but verbs could still be more strongly associated than nouns with both leg motion and path if there were an overall advantage to verbs. To test which type of word was more important in conveying each type of motion, sentences were created in which the noun and verb were mismatched on leg motion and path. The two events in each trial varied on either leg motion or path, with one event involving a value consistent with the noun and the other involving a value consistent with the verb.

Participants had to choose which of the two events was a better example of each such sentence. If a participant chose the event in which one attribute was consistent with the noun but inconsistent with the verb, this would provide evidence that participants considered nouns to be more important than verbs in conveying information about this attribute. If, on the other hand, the participant chose the event in which the attribute was consistent with the verb but inconsistent with the noun, this would indicate that the verb was more important in conveying this information.

Method

Participants

Twenty-four undergraduates at the Georgia Institute of Technology received course credit for participation in this experiment.

Stimuli

Learning events. The learning events in Experiment 2 were generated in the same way as in Experiment 1 except that different attributes were correlated with the nouns and verbs. Agent legs differentiated the four nouns in this experiment, whereas orientation again differentiated the four verbs. In addition, an intrinsic motion attribute, leg motion, and an extrinsic motion attribute, path, were equally strongly related to nouns and verbs. Thus, each participant saw two values of leg motion and two values of path. Each value was correlated with two nouns and two verbs, as in Experiment 1. The correlations for an example participant are shown in Figure 6.

Word Association Test events. The Word Association Test events in Experiment 2 were generated in the same way as the test events in Experiment 1. Associations of nouns with legs, leg motion, and path were tested, as were associations of verbs with orientation, leg motion, and path.

Mismatch test events. Sixteen test trials involved combinations of nouns and verbs that had not been presented during learning. As can be seen in Figure 6, during learning each noun occurred in the same sentence with only two of the four verbs. Similarly, each verb occurred with only two of the four nouns. In each mismatch trial, a noun was paired with a verb it had never accompanied during learning. For example, a participant who was assigned the schema in Figure 6 would have heard the noun zeebee paired with yimming or wunking in the mismatch trials. This noun (i.e., zeebee) would not have accompanied either of these verbs during learning because it was correlated with different values of leg motion and path.

Each mismatch trial involved two events. In one event, the values of leg motion and path were consistent with the verb in the sentence but inconsistent with the noun. In the other event, one attribute took a value consistent with the verb, but the other attribute took a value consistent with the noun and inconsistent with the verb. At the end of each trial, participants were asked to choose one of the two events as better exemplifying the meaning of the sentence. Leg motion varied in eight trials, whereas path varied in the other eight. In every event, the value of agent legs was consistent with the noun, whereas the value of orientation was consistent with the verb. All other attributes were assigned values in the same way as during learning. For example, Figure 7 depicts the two events in a trial in which path varied. In this example, path is consistent with the noun in the first event, whereas it is consistent with the verb in the second event.

Procedure

The procedure in Experiment 2 was identical to that in Experiment 1 except for the mismatch trials. After the Word Association Test trials, participants were instructed to interpret the meanings of sentences involving combinations of nouns and verbs not found
together during learning. They were instructed that there were no right or wrong answers to this test and that they were to use their judgment to choose one of the two events in each trial. There were 16 mismatch trials, each involving two events. The test procedure was otherwise identical to that of Experiment 1.

**Design**

There were two dependent measures in this experiment. The primary dependent measure was accuracy in the Word Association Test trials. The independent variables for this dependent measure were the part of speech of the word (noun vs. verb) and the attribute being tested (leg motion vs. path). A second dependent measure was the percentage of choices that were consistent with the verb rather than the noun in the mismatch trials. The independent variable for this dependent measure was the attribute being tested (leg motion vs. path).

**Results**

An ANOVA on accuracy in the Word Association Test trials revealed the predicted interaction of part of speech and attribute, $F(1, 23) = 12.23, p < .01, MSE = 212.86$. This interaction can be seen in Figure 8. On trials testing associations with nouns, participants averaged 77% ($SD = 24\%$) correct on tests involving leg motion, significantly greater than the average of 68% ($SD = 23\%$) on tests involving path, $t(23) = 1.89, p < .05$ (one-tailed). Both scores, however, were significantly different from chance ($p < .05$). On trials testing associations with verbs, participants averaged 79% ($SD = 19\%$) correct on tests involving leg motion, significantly less than the average of 91% ($SD = 21\%$) on tests involving path, $t(23) = 2.20, p < .05$ (one-tailed). There was also a significant main effect of part of speech, $F(1, 23) = 6.90, p < .05, MSE = 543.48$, with participants performing more accurately on verb trials than on noun trials. The main effect of attribute was not significant, however, $F(1, 23) = 0.06, p > .10, MSE = 406.48$.

Participants were also tested on their learning of relations between nouns and agent legs and between verbs and orientation. Participants averaged 84% ($SD = 23\%$) correct on trials testing relations between agent legs and nouns. Participants averaged 77% ($SD = 31\%$) on trials testing relations between orientations and verbs.

In the mismatch trials, either path or leg motion varied in each trial. When path varied, participants chose the value of path that was consistent with the verb but inconsistent with the noun on 88% ($SD = 20\%$) of trials. This number was significantly greater than 50% ($p < .001$), indicating that participants considered verbs to be more important than nouns in conveying path. On trials testing leg motion, participants chose the value consistent with the verb on only 57% ($SD = 34\%$) of trials. This number was not significantly different from 50% ($p > .10$), indicating that nouns and verbs were considered to be equally important in conveying leg motion. There was a significant main effect of attribute, $t(23) = 3.90, p < .001$, with more choices consistent with the verb on trials in which path varied. Thus, there was a stronger tendency to choose paths (i.e., extrinsic motion) consistent with verbs than to choose leg motions (i.e., intrinsic motion) consistent with verbs.

**Discussion**

Experiment 2 provides evidence that people are biased to attend to different kinds of motion when learning nouns compared to when learning verbs. Although objectively nouns were equally strongly related to leg motion and to path during learning, participants more strongly associated nouns with leg motion, an intrinsic motion attribute, than

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**Figure 6.** Correlations seen by an example participant in Experiment 2. A = agent; P = patient.
with path, an extrinsic motion attribute. Unlike Experiment 1, participants performed above chance on trials testing associations between nouns and paths. This is consistent with Barr and Caplan’s (1987) and Nelson’s (1983) suggestions that object concepts can become associated with extrinsic as well as intrinsic features. In contrast to nouns, verbs were more strongly associated with path than with leg motion. This was the case even though many English verbs convey not path but rather manner of motion, an example of which is leg motion (e.g., walk). There was no main effect of attribute, indicating that neither attribute was generally more salient than the other. This experiment thus did not support a simple salience explanation for the advantage of extrinsic motion over intrinsic motion in associations with verbs.

Although leg motion was more strongly associated with nouns than was path and path was more strongly associated with verbs than was leg motion, leg motion was in fact approximately equally strongly associated with nouns and verbs. This is consistent with the idea that manner-specifying verbs are based on the same object information as are nouns. On the basis of work by Gentner (1981), however, it was expected that when nouns and verbs were mismatched on leg motion in the mismatch trials, participants would favor the leg motion conveyed by the noun. Instead, participants chose the leg motion consistent with the verb about as often as that consistent with the noun. The next experiment explored a possible explanation for this finding.

EXPERIMENTS 3A AND 3B

Participants in Experiment 2 did not show a preference in the mismatch trials for leg motion to be consistent with the noun rather than the verb. A possible explanation is that path was always consistent with the verb on mismatch trials in which leg motion varied. Thus, in each mismatch trial, one event involved values of path and leg motion that had been paired together during learning, whereas the other involved values that had never been paired together.

For example, in Figure 6, consider a test sentence in which the noun zeebee is paired with the verb yimming. During learning, the leg motion associated with the noun zeebee (i.e., a rotating motion) always co-occurred with a direct path and never co-occurred with an indirect path. In the mismatch trials, however, when leg motion varied, the path was indirect, a path consistent with the verb yimming. Thus, to choose the leg motion consistent with the noun zeebee (i.e., a rotating motion), one would have to choose a combination of leg motion and path that had never gone together during learning (i.e., a rotating motion and an indirect path). Participants may have been hesitant to choose these novel pairings. This may have offset a bias toward choosing the leg motion consistent with nouns, causing participants to equally often choose the leg motion consistent with verbs. It is important to note that this explanation does not pertain to the Word Association Test trials. When leg motion varied in these trials, all other attributes were consistent with the word being tested.

Experiment 3A

Experiment 3A was designed to reduce this potentially biasing influence of path on judgments of leg motion.
Instead of the two attributes that were used in Experiment 2, leg motion and path, only leg motion was equally strongly related to nouns and verbs in Experiment 3A. Agent legs differentiated the four nouns, as in Experiment 2. Because participants demonstrated that it was natural to associate verbs with paths in Experiments 1 and 2, path was chosen to differentiate the four verbs in this experiment. Thus, in each mismatch trial, the value of agent legs was always consistent with the noun, path was always consistent with the verb, and leg motion was consistent with the noun in one event and consistent with the verb in the other. If participants considered nouns to be more important than verbs in conveying leg motion, this would be revealed in choices consistent with nouns and inconsistent with verbs.

Method

Participants

Twenty-four undergraduates at the Georgia Institute of Technology received course credit for participation in this experiment.

Stimuli

The learning events in Experiment 3A were generated in the same way as in Experiment 2 except that different attributes were correlated with the nouns and verbs accompanying the events. In contrast to Experiment 2, only leg motion was equally related to nouns and verbs. Path was the attribute that fully differentiated the four verbs, whereas agent legs differentiated the four nouns.

The Word Association Test events differed from those in Experiment 2 in that only the relations of nouns with legs and leg motions and the relations of verbs with paths and leg motions were tested. Each of these relations was tested on eight trials. The mismatch trials were the same as in Experiment 2, except that only relations involving leg motion were tested.

Procedure

The procedure of Experiment 3A was identical to that of Experiment 2 except that there were 32 Word Association Test trials and eight mismatch trials.

Design

There were two dependent measures in this experiment. The primary dependent measure was accuracy at choosing the correct events in the Word Association Test trials. The independent variable for this measure was the part of speech of the word accompanying each test trial (noun vs. verb). A second dependent measure was the percentage of choices that were consistent with the verb in the mismatch trials.

Results

The results of the Word Association Test trials are depicted in Figure 9. In contrast to Experiment 2, leg motion was more strongly associated with nouns than with verbs, t(23) = 2.78, p < .05. On trials testing nouns, participants averaged 73% (SD = 21%), compared to an average of 59% (SD = 25%) on trials testing verbs. Participants were also evaluated on their learning of relations between nouns and verbs with extrinsic motion, with path being an example. In Experiment 2, however, path took only two values. Thus, a participant who first tried to associate verbs with path would have had limited success, as path would only separate the four verbs into two subgroups. To fully differentiate the four verbs, the participant would have had to look further. A participant at this point could have looked to orientation,
which indeed differentiated the four verbs. Participants, however, could equally likely have looked to leg motion and learned its relation to verbs. In contrast, a participant in Experiment 3A who looked first at path would have been able to fully differentiate the four verbs. The discovery that path was sufficient to distinguish the different verbs may have discouraged participants from noticing the relations of verbs to further attributes, such as leg motion. This reduced likelihood of noticing relations involving a less salient attribute (i.e., leg motion) when a more salient attribute (i.e., path) was diagnostic would be an example of overshadowing, predicted by theories of animal learning (e.g., Rescorla & Wagner, 1972) as well as by prominent categorization theories (e.g., Gluck & Bower, 1988; Kruschke, 1992).

**Experiment 3B**

Experiment 3b was designed to test whether differences in the role of path were responsible for differences in the results of Experiments 2 and 3A. This experiment was identical to Experiment 3A except that orientation differentiated the four verbs, whereas path was random. Thus, a participant who looked first to path would not have been able to differentiate the four verbs and would have had to look further. I predicted that participants would associate leg motion equally well with nouns and verbs, just as in Experiment 2.

**Method**

**Participants**

Twenty-four undergraduates at the Georgia Institute of Technology received course credit for participation in this experiment.

**Stimuli**

The learning events in Experiment 3B were generated in the same way as in Experiment 3A except that orientation differentiated the four verbs. Eight Word Association Test trials tested this relation of verbs to orientation rather than path.

**Procedure and Design**

These were identical to those of Experiment 3A.

**Results**

The results of the Word Association Test trials are depicted together with those of Experiment 3A in Figure 9. As predicted, participants associated leg motion equally strongly with nouns and verbs. Participants averaged 68% (SD = 26%) on tests of the relation of leg motion to nouns compared to an average of 72% (SD = 28%) on tests of relations to verbs, t(23) = 0.73, p > .10. Participants averaged 81% (SD = 23%) on tests of the relation of nouns to agent legs, whereas they averaged 72% (SD = 32%) on tests of the relation of verbs to orientation. In the mismatch trials, participants averaged 50% (SD = 37%) choices consistent with the verb, not significantly different from chance (p > .10). This indicates that participants relied equally on nouns and verbs in conveying leg motion.

The only difference between Experiments 3A and 3B was in the choice of attribute to fully differentiate the four verbs. Thus, participants' responses in the word association test trials of the two experiments were analyzed together, with differentiating attribute (orientation vs. path) and part of speech (noun vs. verb) as independent variables. In this analysis, there was not a main effect of differentiating attribute, F(1, 46) = 0.33, p > .10, MSE = 974.16, nor of part of speech, F(1, 46) = 2.16, p > .10, MSE = 301.60. There was, however, a significant interaction of these two variables, F(1, 46) = 6.24, p < .05, MSE = 301.60, as shown in Figure 9.

**Discussion**

The results of Experiment 3B were quite different from those of Experiment 3A. Participants in Experiment 3A were much more likely to discover the relation of verbs to path (96% correct) than were participants in Experiments 3B to discover the relation of verbs to orientation (72%). Participants in Experiment 3A who discovered a relation between verbs and paths were apparently less likely to look for further relations involving verbs, such as those involving leg motion. This is not an anomalous finding, as it has been replicated in an experiment with a similar design and a larger sample size (see Appendix B of Kersten, 1995). The implications of this apparent overshadowing of leg motion by path are considered further in the GENERAL DISCUSSION.

The results of Experiment 3B were qualitatively similar to those of Experiment 2, however. As in Experiment 2, participants associated leg motion equally strongly with nouns and verbs. Further, participants relied equally on nouns and verbs in the mismatch trials. This indicates that nouns did not dominate in sentences in which they mismatched verbs, in contrast to the results of Gentner (1981). The difference between the results of this research and those of Gentner (1981) may reflect the specificity of the motions conveyed by verbs in this work compared to the motions conveyed by verbs in natural language. Manner-specifying verbs such as run and walk describe markedly different motions depending on the object carrying them out. The motions conveyed by such verbs in isolation are thus likely to be quite abstract, and the nouns accompanying them are likely to have much more influence in the interpretation of novel sentences. In contrast, even though two different types of legs carried out each leg motion in these experiments, the particular motion carried out by each leg was exactly the same in both cases. Thus, the motions conveyed by these verbs were quite specific. When a noun and a verb make equally specific predictions for manner of motion, the noun and verb may contribute equally to the interpretation of a sentence in which they mismatch.

**EXPERIMENT 4**

Experiment 4 was designed to rule out a possible alternative interpretation of the results of the previous experiments.

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**Note:** The text above contains a mix of experimental results and discussion, indicating that it is from a research paper. It appears to be discussing the use of verbs to describe leg motion in a series of experiments, with particular emphasis on how participants' attention to verbs versus path affects their ability to learn and remember the relationship between actions and their descriptions.
In particular, it remained possible that participants did not in fact explicitly associate leg motion with nouns, but rather simply learned which leg motion was performed by each pair of legs. When leg motion was tested, the appearance of legs was always consistent with the noun, and thus participants could still have performed successfully on tests of relations between nouns and leg motions. In particular, the legs of the agent moved as they had during learning in one event of each trial, whereas they moved differently in the other. The fact that participants performed better with nouns than with verbs in Experiment 3A speaks against this hypothesis, as the same information was available in both noun and verb trials. Participants in Experiment 3A, however, may not have thought to consider the appearance of the legs on tests of verbs.

Experiment 4 was designed to rule out this interpretation through changes to the test procedure. The learning events were generated in exactly the same way as in Experiment 3B. Participants were then tested with events in which the legs of the agent were replaced by black boxes (see Figure 10). These boxes moved as the legs of the agent had moved during learning. Thus, participants could not use the relation between agent legs and leg motion as a basis for choosing, but rather had to select on the basis of the relation between nouns and leg motion.

Stimuli

The learning events in Experiment 4 were identical to those of Experiment 3B. Agent legs differentiated the four nouns, whereas orientation differentiated the four verbs. Leg motion was equally strongly related to nouns and verbs. Note that because each noun co-occurred with only two verbs, each noun co-occurred with only two of the four orientations.

The test procedure in Experiment 4 was identical to that of Experiment 3B except for two changes. First, as shown in Figure 10, the legs of the agent were occluded by boxes throughout both the Word Association Test and mismatch trials. These boxes performed the motions that had been performed by the legs during learning. Second, participants were not tested on the relation of nouns to agent legs. Instead, they were tested only on the relations of nouns to leg motions and orientations.

Procedure

The procedure was identical to that of Experiment 3B except that participants were instructed that the legs of the agent would be occluded during testing, such that they would not be able to use the appearance of the legs to make their choices.

Design

The design was identical to that of Experiment 3B.

Results and Discussion

Participants performed above chance on Word Association Test trials testing the relation of leg motion to both nouns and verbs ($p < .001$). Participants averaged $75\%$ ($SD = 20\%$) on tests of relations between leg motions and nouns, not significantly different from the average of $78\%$ ($SD = 27\%$) on tests of relations between leg motions and verbs, $t(23) = 0.39$, $p > .10$. Participants associated orientation more strongly with verbs ($M = 77\%, SD = 25\%$) than with nouns ($M = 59\%, SD = 25\%$), $t(23) = 2.98$, $p < .01$, not surprising given that orientation was fully diagnostic for verbs but only weakly so for nouns. Participants associated nouns more strongly with leg motion than with orientation, $t(23) = 3.16$, $p < .01$, whereas associations between verbs and the two attributes were not significantly different, $t(23) = 0.15$, $p > .10$. In the mismatch trials, participants averaged $57\%$ ($SD = 36\%$) choices consistent with the verb, not significantly different from $50\%$. Thus, as in Experiments 2 and 3B, participants relied equally on nouns and verbs to convey leg motion.

Participants thus learned more than just relations between the appearance of the legs and the way they moved. Learning only this relation would not have resulted in above-chance performance in Experiment 4. In addition, the fact that participants did better on tests of the relation of nouns to leg motion than to orientation suggests that they were not simply using the relation of leg motion to orientation to make their choices. This relation of leg motion to orientation was available on tests of both leg motion and orientation and thus would have produced equal performance on tests of both attributes. Thus, participants must
have learned the relation of leg motion to nouns independently of agent legs and orientation.

EXPERIMENT 5

The results of Experiments 3A and 3B revealed that participants were less likely to notice relations of verbs to leg motions when path differentiated verbs than when orientation did so. The proposed explanation for these results is that people look first at prototypical verb attributes such as path when learning verbs and thus tend not to look further when one of these attributes is sufficient to distinguish verbs. If this explanation is correct, participants should also show reduced learning of relations between verbs and leg motion when some other prototypical verb attribute differentiates verbs. One particularly salient type of information that is specified by many verbs is the change in state of an object following a causal interaction (e.g., break, cut, tear). Thus, in Experiment 5, the four verbs corresponded to four different state changes exhibited by the patient after being contacted by the agent. As in Experiment 2, leg motion and path were equally related to nouns and verbs. Because state change was sufficient to distinguish verbs, however, I predicted that leg motion would not be as strongly associated with verbs as with nouns.

Experiment 5 was also designed to provide a more specific characterization of the types of path information that people prefer to associate with verbs. It is possible that the actual trajectory of motion is not so important as the end point of that path or where the object ends up. To test this possibility, the agents in this experiment always ended up in contact with the patient, such that the end point did not vary. The path of motion did vary, though, as some agents moved directly toward the patient, whereas others moved along an indirect path toward the agent. Thus, if only the end point of motion was important, participants should have shown little learning of relations involving path. If, however, the actual trajectory of motion is important, participants should have continued to show a bias to associate verbs with path.

Method

Participants

Thirty undergraduates at Indiana University in Bloomington, IN, participated in this experiment in partial fulfillment of introductory psychology course requirements.

Stimuli

All events. The events were generated in the same way as in the previous experiments except that orientation no longer varied, but rather all agents moved head first. In place of orientation, a new attribute varied, namely state change. After the agent came in contact with the patient, the event continued with the patient moving away from the agent and displaying one of four values of state change: (a) shrinking, (b) expanding, (c) flashing on and off, and (d) rotating. In order to display these complicated state changes while preserving the speed of animation, the appearance of the patient was reduced to a unitary attribute, similar to patient body in Figure 2 except that eyes were added. The agent remained motionless while the patient displayed the state change.

Learning events. These were generated in the same way as those in Experiment 2 except that state change rather than orientation differentiated the four verbs.

Test events. These were generated in the same way as those in Experiment 2 except that in the word-association test events, verbs were tested in relation to state changes rather than orientations.

Procedure and Design

The procedure and design of Experiment 5 were identical to those of Experiment 2.

Results

The results of the word-association test events are depicted in Figure 11. An ANOVA on forced-choice accuracy revealed no significant main effect of part of speech, $F(1, 29) < 1$, or of attribute, $F(1, 29) < 1$. In replication of Experiment 2, there was a significant interaction of part of speech and attribute, $F(1, 29) = 13.64, p < .01, MSE = 773.17$. Participants averaged 77% ($SD = 28\%$) on tests of relations between nouns and leg motion, compared to an average of only 58% ($SD = 27\%$) on tests of relations between nouns and path, $t(29) = 2.39, p < .05$ (one-tailed). In contrast, participants averaged 78% ($SD = 25\%$) on tests of relations between verbs and path, compared to an average of only 59% ($SD = 32\%$) on tests of relations between verbs and leg motion, $t(29) = 2.60, p < .01$ (one-tailed). Thus, as predicted, participants associated leg motion more strongly with nouns than with verbs in the word-association trials of this experiment, $t(29) = 2.46, p < .05$.

Participants were also tested on their learning of relations between nouns and agent legs and between verbs and state change. Participants averaged 82% ($SD = 23\%$) on tests of relations between nouns and agent legs, whereas they averaged 91% ($SD = 19\%$) on tests of relations between verbs and state change.

The results of the mismatch trials were consistent with those of the word-association trials. On trials in which path varied, participants chose the path consistent with the verb and inconsistent with the noun on 68% ($SD = 22\%$) of the trials. This number was significantly greater than 50%.

![Figure 11. Results of Experiment 5.](image-url)
motion varied, participants chose the leg motion consistent with the verb and inconsistent with the noun on only 35% (SD = 26%) of the trials. This number was significantly less than 50% (p < .01), indicating that participants associated leg motion more strongly with nouns than with verbs. The difference between path trials and leg motion trials was significant, t(29) = 6.59, p < .001.

**Discussion**

The results of Experiment 5 provide support for the hypothesis that in the process of verb learning, leg motion can be overshadowed by more prototypical verb attributes. As in Experiment 3A, participants in this experiment showed little learning of relations between verbs and leg motion. Leg motion was in fact more strongly associated with nouns than with verbs. Path, however, was again more strongly associated with verbs than with nouns. Moreover, in the mismatch trials, participants relied on nouns to convey leg motion and verbs to convey path. This experiment thus provides strong support for a division of labor between nouns and verbs in the description of motion. In addition, this experiment provides evidence that participants associated verbs with the path of motion of the agent, and not just with the end point of that motion.

**GENERAL DISCUSSION**

These experiments tested the hypothesis that there is a division of labor between nouns and verbs in the description of motion. I have proposed a set of learning biases that enforce such a division of labor. People are biased to associate nouns with intrinsic motion, or the motion of an object with respect to an internal frame of reference, such as the motion of the legs of a creature relative to its body. In contrast, people are biased to associate verbs with extrinsic motion, or motion defined with regard to an external frame of reference, such as the path of one object with respect to another.

Several experiments provide support for these predictions. Experiment 1 revealed that the path of an object (i.e., extrinsic motion) was strongly associated with verbs but not significantly associated with nouns. Experiment 2 showed that verbs were more strongly associated with path than with leg motion (i.e., intrinsic motion), whereas nouns were more strongly associated with leg motion than with path. In Experiment 3A, when path was sufficient to fully differentiate verbs, participants showed little learning of relations between verbs and leg motions. Experiment 3B revealed better learning of relations between verbs and leg motions when orientation instead of path differentiated the four verbs, suggesting that path overshadowed leg motion in Experiment 3A. Experiment 4 insured that when participants were tested on relations between nouns and leg motions, they could not simply rely on nonlinguistic information, but rather had to have explicit knowledge of relations between nouns and leg motions. Experiment 5 provided further support for the hypothesis that prototypical verb attributes, such as state change and path, can overshadow leg motion in the process of verb learning.

**Origins of the Biases**

The evidence for these biases prompts one to wonder how they may have arisen. One possibility is that they are in place prior to language learning, evolved specifically for the purposes of language learning. This account is similar to Markman's (1990) account of the origins of biases in noun learning, such as the whole object assumption and the mutual exclusivity constraint. Markman proposed that these biases function to limit the number of hypotheses that a child initially entertains when learning nouns. The evolutionary advantage of these biases would presumably be to encourage efficient communication by creating a division of labor between different types of words. Similar to the way children must relax the mutual exclusivity constraint in order to learn superordinate and subordinate categories, children would eventually have to relax these biases in order to acquire the full expressive power of language. For example, there are nouns such as attacker that express relational information, whereas verbs such as run and saunter express intrinsic motion. These biases remain in some form, however, as indicated by participants' performance in this task.

An alternative to the innate origins view is that these biases are formed early in language learning as a result of general information-processing influences. This early learning may then bias later language learning even when those influences are no longer present. This explanation is similar to Smith, Jones, and Landau's (1992) account of how children learn to attend to shape when learning a novel noun, with early learning of relations between nouns and shapes influencing later learning.

One example of a general processing influence on language learning is correlational structure. Rosch, Mervis, Gray, Johnson, and Boyes-Braem (1976) proposed that people form basic level object concepts around sets of correlated properties in the environment. These object concepts are generally labeled by nouns. For example, the concept BIRD involves a number of correlated attributes such as wings, beaks, feathers, flying, nesting in trees, and so forth. Not all of these attributes are equally related to this concept, however. Not all birds nest in trees, yet almost all birds fly (even penguins flap their wings to get around; they just require a thicker medium for it to be effective). Because the intrinsic motions performed by animate objects are highly constrained by their form, whereas extrinsic motions involve external factors and thus are more variable, children may associate their first nouns more strongly with intrinsic motion than with extrinsic motion. This early learning may bias later learning of animate nouns and possibly all nouns, even when the contingencies do not favor intrinsic over extrinsic motion, as in this task.

Given that nouns are more strongly associated with intrinsic motion than with extrinsic motion, different general processing influences may bias verbs in the direction of
extrinsic motion. One possibility is that verbs with an extrinsic motion component to their meanings are used frequently in speech to young children (e.g., get; Huttenlocher, Smiley, & Ratner, 1983), biasing later learning of verbs. An alternative general processing explanation is that relational terms involving extrinsic motion are more conceptually distinct from nouns and may be easier to acquire for that reason. For example, the preposition in conveys information quite different from that conveyed by nouns. Most objects are equally capable of moving in and out of something and thus moves in is not likely to be associated with nouns. In contrast, verbs for intrinsic motion such as walking may be much more difficult to differentiate from nouns. For example, Jackendoff (1987) proposed that “A visual representation of the action of walking . . . requires by its very nature a walking figure, say a generalized human” (p. 103). In fact, Jackendoff proposed further that the only way to distinguish the representation of WALKING from that of HUMAN is by noting whether it is linked to an ACTION TYPE or a THING TYPE concept. Given this similarity between nouns and intrinsic motion verbs, children may have difficulty distinguishing them, learning nouns first because they involve richer correlational structure (Gentner, 1981; Huttenlocher & Lui, 1979). Relational terms for extrinsic motion may be easier to learn than those for intrinsic motion because of their greater distinctiveness, biasing later learning of relational terms such as verbs in favor of extrinsic motion.

It is difficult to evaluate whether the biases revealed in these experiments are innate or learned early in language acquisition. Developmental work is necessary and underway to better understand the origins and developmental course of these biases in early language learning. There is evidence in these results, however, that suggests that participants’ learning strategies were based in part on knowledge of their native language, lending credence to the more general notion that early language learning can bias later learning. In particular, participants’ strategies for learning verbs in this task may have been based on their knowledge of verbs in English. Huttenlocher and Lui (1979) and Talmy (1985) have noted that verbs tend to convey information about either path (i.e., extrinsic motion) or manner (i.e., intrinsic motion), but not both. For example, manner of motion verbs such as run and walk provide no information about the path taken by an object, whereas path verbs such as enter and exit specify no information about manner. Consistent with English verbs, participants in these experiments were less likely to look for relations of verbs to leg motion when path was sufficient to differentiate the verbs.

The finding that participants were less likely to look to further attributes after discovering that path was related to verbs is consistent with the notion that participants based their learning strategies on their prior learning history with English verbs. An alternative explanation, however, is that this finding reflects the operation of more general mechanisms. In particular, this finding seems to be an example of overshadowing, first described in the context of animal conditioning (Rescorla & Wagner, 1972), but also predicted by theories of category learning (e.g., Gluck & Bower, 1988). In overshadowing, one cue’s predictiveness of a particular outcome is less likely to be learned when a second, more salient predictor is also present. This is proposed to result from competition among cues for predictive strength. For example, a rat would be less likely to learn the predictiveness of a tone for shock if a more salient light were also predictive. Given a bias to associate verbs with extrinsic motion, path would be very salient to participants when learning verb meanings. As a result, path may have overshadowed leg motion when it was sufficient to differentiate the verbs.

If the finding of overshadowing is a result of general learning mechanisms, then findings with nouns should be similar to those with verbs. If, on the other hand, findings with verbs are a result of participants’ prior learning history with verbs, then findings with nouns should be quite different, as object concepts have been proposed to be structured quite differently from verbs. In particular, object concepts are thought to involve a number of correlated components of meaning (Gentner, 1981; Huttenlocher & Lui, 1979; Rosch et al., 1976). Consistent with the latter hypothesis, participants seem to have employed different learning mechanisms, then findings with nouns should be quite different, as object concepts have been proposed to be structured quite differently from verbs. In particular, object concepts are thought to involve a number of correlated components of meaning (Gentner, 1981; Huttenlocher & Lui, 1979; Rosch et al., 1976). Consistent with the latter hypothesis, participants seem to have employed different learning strategies when learning nouns compared to when learning verbs. In particular, there were significant positive correlations between the different measures of noun learning in Experiments 2, 3A, 3B, and 4 (see Table 1). Thus, after their first discovery of a relation between a noun and an individual attribute, participants continued to look for further relations involving other attributes. In contrast, there was only one significant correlation between different measures of verb learning, and this same correlation failed to attain significance in two other experiments. Participants thus seem to have entered the present experimental task with different expectations about the amount of information conveyed by nouns and verbs.

One may argue that these different learning strategies do not reflect the different learning histories associated with

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2I would like to thank Linda Smith for this suggestion.
nouns and verbs but instead reflect different innate tendencies in the ways humans conceptualize objects and events. Kersten and Billman (1997) have argued against this notion, however, in their work on unsupervised event category learning. This work revealed facilitation in learning a correlation between event attributes when other attributes also covaried, similar to findings with object attributes (Billman & Knutson, 1996). For example, some participants were tested on whether they noticed that a particular path of an agent in an event always co-occurred with a particular path of a patient. Participants were more likely to notice this correlation when the appearance of the patient changed in a predictable way upon contact with the agent, compared to when this state change was unrelated to the paths of the objects. In contrast, participants in the present experiments were less likely to notice a relation involving an event attribute when a more salient event attribute was also related. The events in this prior work were quite similar to those in these experiments, except that learning was unsupervised, with no category labels provided. Thus, the learning strategies found here were not triggered by characteristics of the events but rather by the accompanying words. Moreover, the finding that learning strategies with verbs differed from those with nouns suggests that knowledge of verbs in particular rather than words in general was responsible for overshadowing in these experiments.

There is thus some evidence that participants' prior language-learning history influenced their performance in this task. This finding makes it seem possible that the extrinsic- and intrinsic-motion biases revealed in this work are also a product of early language learning. Evidence for influences of prior learning, however, does not rule out the possibility that these biases are already in place prior to the onset of language learning.

The Association of "What" and "Where"
Information With Nouns and Verbs

The distinction between intrinsic and extrinsic motion is similar to a distinction between two information pathways in the brain (Ungerleider & Mishkin, 1982). The occipitotemporal pathway is proposed to be specialized for object perception, representing "what" an object is. In contrast, the occipitoparietal pathway is proposed to be specialized for object localization, representing "where" an object is. The mapping between extrinsic motion and the "where" system is quite straightforward because the "where" system has been argued to represent not only the static locations of objects but also the relative motions of objects. For example, Tresch, Sinnamon, and Seamon (1993) have demonstrated that a task in which participants had to locate a stationary asterisk in a field of moving asterisks selectively interfered with a task in which participants had to remember the location of an individual object but did not interfere with a task involving memory for object form. This suggests that the relative motions of objects are represented in the "where" system and not in the "what" system.

The mapping between intrinsic motion and the "what" system is less straightforward. The "what" system has traditionally been characterized as being nonspatial in nature and thus would seem incapable of representing intrinsic motions, such as the motions of legs relative to the bodies of creatures. Indeed, Ungerleider and Mishkin (1982) have proposed that it is the loss of spatial information that allows the "what" system to recognize the shapes of objects regardless of their spatial locations. Baylis and Driver (1993), however, have suggested that the shape of an object is not unitary in nature but rather depends on the relative locations of the contours of that object. Thus, "what" information, like "where" information, may be spatial in nature. Baylis and Driver suggest that "where" information involves the locations of objects in a scene-based (i.e., extrinsic) frame of reference, whereas "what" information involves the relative locations of object parts in an object-based (i.e., intrinsic) frame of reference. If the "what" system indeed encodes the relative locations of object parts, it is very likely that this system also encodes changes in the relative locations of those parts (i.e., intrinsic motion).

Quite compelling evidence for Baylis and Driver’s (1993) characterization of the "what" versus "where" distinction comes from two neuropsychological cases reported by Humphreys and Riddoch (1994). Both patients exhibited evidence of visual hemineglect, a condition resulting from brain lesions in which patients have difficulty attending to one hemifield of space. Interestingly, different patterns of neglect were exhibited by these patients depending on whether a stimulus was represented as a single perceptual object or as multiple objects in a particular relation. For example, one patient often misidentified the left sides of words when instructed to read them, thus treating the entire word as a single perceptual object. In contrast, the same patient neglected the right sides of letter strings when instructed to read aloud the letters in the word, thus treating each letter as an individual perceptual object. Consistent with the theory of Baylis and Driver, these results suggest that representations of "what" information as well as "where" information may be spatial in nature. In particular, they provide evidence that the distribution of spatial attention over the parts of an object operates independently of attentional processes involving multiple objects.

Saiki and Hummel (1996) have provided further evidence that the shape of an object is not a unitary attribute. Instead, they proposed that the shape of an object can be described by the shapes of its parts along with the relative locations of those parts. Thus, given the evidence for a shape bias when learning object categories (Landau, Smith, & Jones, 1988; Smith, Jones, & Landau, 1992), Saiki and Hummel hypothesized that conjunctions between the shape of a part and the location of that part relative to the rest of the object should be easier to learn than other correlations such as between the shape and color of a part. This prediction was upheld in an object category learning task. This result may be related to a finding by Kersten and Billman (1995) involving noun learning. Kersten and Billman (1995) found that participants were better at associating nouns with leg motions when the appearance of the legs also covaried. Thus, participants apparently associated nouns with conjunctions between the shapes of parts (i.e., the legs) and the changes in location of
those parts relative to the body (i.e., leg motion). If the shape of an object is considered to involve not only the relative locations of parts but also the relative motions of these parts, then this finding of Kersten and Billman (1995) would also seem to support the notion of a shape bias.

If one accepts intrinsic motion and extrinsic motion as examples of "what" and "where" information, respectively, then the present findings provide information regarding the association of these two types of information with different classes of words. Landau and Jackendoff (1993) have proposed that object terms, typically nouns, draw upon the "what" system, whereas locational terms, typically prepositions in English, draw upon the "where" system. As a result, when compared to nouns, prepositions tend to code object properties only very coarsely. There has been some debate, however, about how verbs fit into the "what" versus "where" framework. Unlike prepositions, verbs such as rain and snow implicate rather specific object properties in their meanings. Whereas such verbs are relatively rare in English, many Native American languages such as Atsugewi generally encode object properties in verb roots (Talmy, 1975). For example, Atsugewi has a verb that can be translated to mean dirtied or for a dirty substance to move along some path specified by a suffix to the verb. Landau and Jackendoff have acknowledged that verbs are different from prepositions in that they are open class and are capable of encoding many types of information, but they do not specify how verbs fit in with their proposal.

The results presented in this article suggest that people are biased to associate verbs with "where" information but that this bias is flexible. When "where" information (e.g., path) was sufficient to differentiate verbs, participants were quite adept at learning these relations but had difficulty learning relations of verbs to "what" information such as leg motion. This finding suggests that path-specifying verbs such as enter and exit may be similar to English prepositions in that they draw exclusively upon the "where" system. In experiments where path information was not sufficient to differentiate verbs, however, participants were able to relax the extrinsic motion bias in order to notice the relation of verbs to "what" information. Manner-specifying verbs such as run and roll may similarly draw upon the "what" system in order to convey object information, leaving to other terms such as prepositions the job of conveying "where" information. Thus, as suggested previously, a common knowledge base may underlie the meanings of nouns and manner-specifying verbs. In support of this conjecture, nouns and verbs have been found to be equally strongly associated with leg motion in every experiment in which relational information (i.e., path or state change) was insufficient to differentiate verbs (see Experiments 2, 3b, and 4 of this article; Experiment 5 of Kersten, 1995; Kersten & Billman, 1995).

According to this analysis, this common knowledge base may reside in the "what" system.

This research thus provides evidence for a division of labor between the different words in an English sentence, with some words conveying "what" information and other words conveying "where" information. Landau and Jackendoff's (1993) theory predicts that such a division of labor is also present in other languages, although the particular types of words that carry each type of information may vary across languages. In contrast, Brown (1994) has proposed that individual words in the Mayan language Tzeltal encode both "what" and "where" information. An alternative construal of Tzeltal locative terms is possible, however, if one adopts Baylis and Driver's (1993) redefinition of "what" information as involving not global shape but rather the relative locations of object parts.

Brown (1994) has described several ways of conveying location information in Tzeltal. First, the general preposition ta is used to locate an object at a particular place or along an axis projecting from a geographical landmark. This way of expressing location seems to draw only upon "where" information. A second way to convey location is to use an object-centered system, which assigns anthropomorphic body parts to a ground object and locates a figure as being directly adjacent to one part of the ground object. For example, a figure could be located "at the butt of the bottle" (p. 750). Whereas this system seems to draw upon both "what" and "where" information, the fact that the figure must be strictly adjacent to the ground to use this system suggests a different interpretation. Using this system may involve construing the figure-ground configuration as a single object, with the figure representing one part of the object that is located with respect to the rest of the object. This object-centered system would then draw exclusively upon the "what" system. In contrast, in a third way to convey location, strict adjacency is not necessary. This system makes reference to axes extrinsic to the objects involved (e.g., uphill, above). This third system thus seems to draw upon the "where" system. Finally, a fourth dispositional description system describes the configuration of the figure in relation to the ground. For example, one verb describes an object as being vertically erect with its end stuck in something else. Like the object-centered system for conveying location, this seems to involve construing the figure and ground as a single object, again drawing upon the "what" system. Indeed, Brown (1994) has stated that "it is the INTRINSIC properties of objects (including shape and position and configuration of multiple objects) that define the coordinates or 'frame of reference' for relating objects spatially" (p. 782).

These four systems for conveying spatial location can thus be used to express different aspects of an event. Two systems construe the figure and ground as comprising a single object, thus drawing on the "what" system to describe the relation between those objects. Two other systems construe the figure and ground as separate objects or locations and thus draw upon the "where" system to describe the relation between them. Thus, whereas Tzeltal construes spatial relations differently from Indo-European languages, it is possible that individual words draw either upon the "what" or "where" system, but not both. Multiple words are thus used in combination to convey different aspects of meaning, just as English verbs and prepositions are used in combination.
Conclusions

These experiments provide evidence for different learning biases that operate during the learning of nouns and verbs. Participants' performance revealed a bias to associate nouns with intrinsic motion, or motion defined with regard to the object carrying out that motion. In contrast, participants were biased to associate verbs with extrinsic motion, or motion defined with regard to an external object. When verbs were indeed related to extrinsic motion, participants were unlikely to look for further relations involving verbs. This finding is similar to overshadowing in animal conditioning and supervised category learning in humans. Participants were better at learning relations between verbs and intrinsic motion when verbs were unrelated to extrinsic motion. In contrast to verbs, there was no evidence for overshadowing in learning nouns. Instead, participants who discovered the relation of one attribute to nouns were likely to discover other relations. Effects of correlational structures thus seem to be different in the learning of nouns and verbs.

Further work is being conducted to determine how well these learning biases generalize to other types of motion. One line of research uses this task to examine whether the same biases are revealed when different attributes are used to operationalize intrinsic and extrinsic motion (Kersten, in press). At present it is not clear whether there is something special about leg motion and path or whether they are examples of larger classes of motion. Another line of research examines whether a bias to associate nouns with intrinsic motion also holds when learning about inanimate objects. The objects in this task were generally thought of as bugs and thus were responsible for their own motions. Inanimate objects, in contrast, are not capable of generating motion on their own. They do, however, have properties that affect their manner of motion once an external agent acts upon them (e.g., mass, elasticity). Results in these lines of research similar to those found here would constitute evidence for a fundamental distinction in the way humans conceptualize different kinds of motion.

References


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