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Assessing the Causal Structure of Function

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Theories typically emphasize affordances or intentions as the primary determinant of an object's perceived function. The HIPE theory assumes that people integrate both into causal models that produce functional attributions. In these models, an object's physical structure and an agent's action specify an affordance jointly, constituting the immediate causes of a perceived function. The object's design history and an agent's goal in using it constitute distant causes. When specified fully, the immediate causes are sufficient for determining the perceived function—distant causes have no effect (the causal proximity principle). When the immediate causes are ambiguous or unknown, distant causes produce inferences about the immediate causes, thereby affecting functional attributions indirectly (the causal updating principle). Seven experiments supported HIPE's predictions.

Function is a central construct in cognitive science and cognitive neuroscience. Cognitive psychologists have shown that the categorization of an artifact depends not only on its physical properties, but also on its function (e.g., Barton & Komatsu, 1989; Keil, 1989; Rips, 1989; but see Malt & Johnson, 1992; Malt & Sloman, in press). Developmental psychologists have shown this as well (e.g., Gentner, 1978; Gentner & Rattermann, 1991; Keil, 1989; Kemler-Nelson, 1995; Tomikawa & Dodd, 1980; Tversky, 1989; but see Landau, Smith, & Jones, 1998; Smith, Jones, & Landau, 1996). Indeed, children as young as 2 years old use function in categorization (e.g., Kemler-Nelson, Russell, Duke, & Jones, 2000). Function also plays a central role in inductive inference for both adults (e.g., Heit & Rubinstein, 1994; Medin, Lynch, Coley, & Atran, 1997; Ross & Murphy, 1999) and children (e.g., Gelman, 1988; Keil, 1989; but see Farrar, Raney, & Boyer, 1992). Chaigneau and Barsalou (in press) reviewed factors that modulate the effects of function in categorization and inference across children and adults.

In neuroscience, function has played a central role in theories of lesion-based categorical deficits (e.g., Cree & McRae, 2003; Warrington & Shallice, 1984). Knowledge about function has been localized in brain systems that implement action (e.g., Chao & Martin, 2000; Kellenbach, Brett, & Patterson, 2003; Martin, 2001). In artificial intelligence, researchers have developed computational accounts of function (e.g., Chandrasekaran & Josephson, 2000; Forbus, 1993). Philosophers have also developed accounts (e.g., Wimsatt, 1972; Wright, 1973).

The Affordance Versus Intention Debate

Recently a debate has arisen in developmental psychology about the sense of function that is most important as people represent and process categories. On the one hand, researchers who hold the affordance view argue that an object's functional affordance is the sense of function most central to category processing. Following Gibson (1950, 1979), an affordance is the perceived use of an object given by its physical structure and an agent's physical capabilities. A chair's physical structure, together with a human's physical capabilities, affords the function of sitting. Conversely, a chair's physical structure, together with a whale's capabilities, does not. In support of this view, researchers have shown that young children attend to affordance information and use it centrally in categorization (e.g., Kemler-Nelson, Frankenfield, Morris, & Blair, 2000; Kemler-Nelson, Russell, et al., 2000; Madole & Oakes, in press; Smith, 1999).

On the other side of the debate, researchers who hold the intentional view argue that an object's design history is the sense of function most central to category processing (e.g., Bloom, 1996, 1998; Diesendruck, Markson, & Bloom, 2003; Gelman & Bloom,

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2000; Matan & Carey, 2001; Prasada, 1999). According to this view, what an object's creator intended it to be is more important than its afforded use on a given occasion. For example, an artifact designed to be a teapot remains a teapot even when used to water plants—it never truly becomes a watering can but always remains a teapot. In a variety of paradigms, intentional theorists have shown that an object's history does indeed play a role in how children categorize.

The HIPE Theory of Function

An implicit assumption in the affordance–intentional debate is that these positions are mutually exclusive. In the HIPE theory of function, Barsalou, Sloman, and Chaigneau (in press) proposed that these positions are compatible. According to HIPE, people possess a large amount of functionally relevant knowledge for an object category, which includes (a) the object's design history (H), (b) the object's physical structure and the physical settings in which it is found (P), and (c) the events that arise during the object's use, such as agent actions, object behaviors, and outcomes (E). On a given occasion, an agent has an intention (I) for conceptualizing one particular sense of the object's function and constructs it dynamically using a subset of the available knowledge. Rather than there being a single sense of function, a large family of senses exists (cf. Barsalou, 1987, 2003b).

Within the HIPE framework, a functional sense is represented as a complex relational structure. A function is not a simple unitary feature of an object, as in some psychological theories (e.g., *chair* → *used to sit in*). As theories in artificial intelligence demonstrate, representing the full structure of a functional sense requires an integrated set of conceptual relations (e.g., Chandrasekaran & Josephson, 2000; Forbus, 1993). HIPE uses a related tool from artificial intelligence, causal modeling, to represent the structure of functional senses. This approach assumes that a linked set of causal states—a causal model—supports inferences about actual and imagined action (e.g., Glymour, 2001; Pearl, 2000). Increasing empirical research indicates that causal models play central roles in categorization and other forms of conceptual processing (e.g., Ahn, 1998; Ahn & Kalish, 2000; Kim & Ahn, 2002; Sloman & Lagnado, 2004; Sloman, Love, & Ahn, 1998; Waldmann, 1996).

Figure 1 illustrates three examples of causal chains that could be constructed within HIPE. Each chain can be viewed as representing a different sense of function that people could construct dynamically. Figure 1A illustrates how HIPE captures the central causal structure in affordance theories, namely, an object's physical structure and an agent's capability for action cause a functional outcome to occur. Thus, a chair's physical structure and a person's actions cause the functional outcome of sitting.

Clearly, a number of important causal elements are not included in this causal model that affordance theorists would certainly acknowledge as relevant, such as a setting that affords the functional event (e.g., being on land as opposed to being in water) and the agent having the goal to achieve the functional outcome. Although the HIPE theory includes these causal elements, along with others, we omit them here to highlight the *central* causal structure that distinguishes affordance and intentional views. Furthermore, HIPE assumes that when conceptualizers construct causal models of object function, they do not include all physically necessary components. Typically, they include only a subset (e.g., participants' incomplete causal accounts of physical phenomena in Rozenblit & Keil, 2002). Partial models like those in Figure 1 illustrate this assumption of the theory.

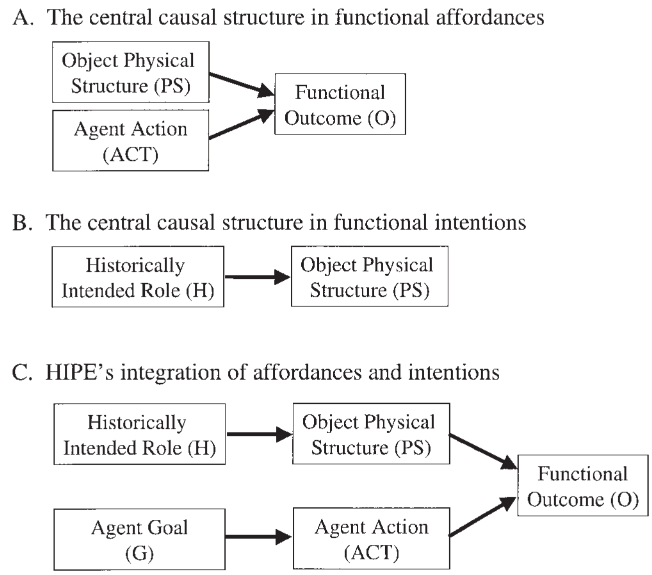

Figure 1. Causal models from HIPE that represent the central causal structure of the affordance view (Panel A) and of the intentional view (Panel B) of function. Other causal structure may enter into these views but is less central. In Panel C, the causal model integrates the central causal structures in affordance and intentional models while adding an agent's goal. As described in the text, these causal models reflect HIPE's dynamical ability to construct functional interpretations. Because these causal models are conceptualizations of function—not accounts of physical causality in the world—they do not contain all necessary causal components and relations.

Figure 1B illustrates how HIPE captures the central causal structure in intentional theories; namely, an agent conceives of an intended functional role for an imagined object, which is then created to have the requisite physical structure. From this design stance on function, physical structure is, most importantly, an *effect* of the historical process—not a *cause* of function, as in the affordance view. Analogous to the affordance causal model, not all physically necessary components are shown (e.g., a manufacturing process, an agent's action, a functional outcome). Again, though, this highlights the central causal structure in the intentional view and also HIPE's assumption that conceptualized causal models are typically incomplete.

Figure 1C illustrates how HIPE integrates the central causal models for affordance and intentional views into a single causal model. The intentional model on the top left produces a physical object that enters into an affordance model on the right, with physical structure as the overlapping element. We have added an agent's goal as an additional causal factor, given its obvious importance in functional events. Intuitively, an agent has a goal, which leads to an action, which contributes to a functional outcome. HIPE assumes that people can conceptualize the integrated causal model in Figure 1C when task situations make all of it relevant. If a situation focuses on both the design history and the affordance of an object, people represent the object's function in this integrated manner.

Task Overview

The experiments reported in this article contrasted predictions of the HIPE theory with those of affordance and intentional theories. Participants in these experiments read scenarios about novel artifacts and then made functional judgments about them. As Figure 2 illustrates, each scenario contained information about four components: the object's history, the agent's goal, the agent's action, and the object's physical structure.

Scenario structure. Each of the four critical scenario components was either adequate or compromised. When a component was adequate, it took a form that allowed the object's function to be realized. When a component was compromised, it took a form that interfered with the object's function. For example, an adequate description of a mop's physical structure included physical properties that achieved a mop's function (e.g., rags attached to the end of a stick). Conversely, a compromised description included a physical property that made achieving the mop's function difficult (e.g., plastic bags attached to a stick). Appendix A presents the adequate and compromised forms of the four components for all objects across most experiments.

In a baseline scenario, all four components of an object were adequate. The history component described the object being created intentionally for the function pursued by the agent. The goal component described the agent as having an explicit goal to use the object for its historically created function. The action component described the agent performing an action with the object that was sufficient to produce the desired outcome. The physical structure component described the object as having the requisite physical structure to achieve the intended function.

To assess each component's importance in conceptualizing function, a compromised description of it was constructed. A compromised history described the object being created accidentally. A compromised goal described the agent using the object unintentionally. A compromised action described an action that was not sufficient to produce the desired outcome. A compromised physical structure described the object as lacking the requisite physical structure to achieve the function.

To assess the importance of each causal factor in the initial experiment, we constructed four compromised scenarios for each object. In each scenario, one and only one of the four causal factors was compromised, thereby creating the compromised history scenario, the compromised goal scenario, the compromised action scenario, and the compromised structure scenario. These scenarios can be obtained by replacing a component of a baseline scenario in Appendix A with its compromised counterpart. Figure 2 illustrates a compromised history scenario.

Rating measures. After participants read a scenario, they rated it either for causality, function, or naming on a scale ranging from 1 to 7. Figure 2 illustrates these three ratings for the mop scenarios. A given participant performed only one type of rating over the course of an experiment.

The causality ratings assessed whether participants perceived history, agent goal, agent action, and physical structure as causes of functional outcomes. To see this, consider the difference in causality ratings between a compromised structure scenario and its associated baseline scenario (e.g., for the mop). If participants rated the compromised structure scenario significantly lower than its baseline scenario, then this indicates participants' belief that physical structure causally affects the functional outcome. When structure is compromised in the scenario, the scenario is less likely to cause the desired functional outcome than when structure is adequate. Conversely, if the compromised structure scenario is not rated lower than the baseline scenario, then participants do not perceive physical structure as contributing causally to the desired outcome. Because the outcome remains the same, physical structure has no causal effect.

The difference between each of the other three compromised scenarios and the baseline scenario similarly assessed whether participants perceived history, agent goal, and agent action as causes of functional outcomes. If these factors causally influence outcomes, then compromising them should also produce lower

Baseline Mop Scenario

One day Jane wanted to wipe up a water spill on the kitchen floor, but she didn't have anything to do it with. So she decided to make something. She looked around the house for things that would allow her to make an object for wiping up a water spill on the kitchen floor. She gathered all the materials and made it. When she finished, she left it in the kitchen so she could use it later. The object consisted of a bundle of thick cloth attached to a 4 foot long stick. Later that day, John was looking for something to wipe up a water spill on the kitchen floor. He saw the object that Jane had made and thought that it would be good for wiping up a water spill on the kitchen floor. He grabbed the object with the bundle of thick cloth pointing downward, and pressed it against the water spill.

Compromised History Mop Scenario

One day Jane was cleaning the attic. She picked up a bunch of useless things and put them all inside a big cardboard box. Because the box was overflowing, she used a long stick to shove things down. As she did this, something became attached to the stick. Then, Jane carried the box downstairs. She didn't notice that as she did this, the stick and the thing that was attached to it fell together, as a single object to the floor. The object consisted of a bundle of thick cloth attached to a 4 foot long stick. Later that day, John was looking for something to wipe up a water spill on the kitchen floor. He saw the object that Jane had made and thought that it would be good for wiping up a water spill on the kitchen floor. He grabbed the object with the bundle of thick cloth pointing downward, and pressed it against the water spill.

Causality Question

How likely would it be that, as a result of the events described above, John wiped up the water spill?

Function Question

How well does this scenario illustrate the function of a mop?

Naming Question

Is it appropriate to call this object a mop?

Figure 2. Examples of a baseline scenario and a compromised history scenario. The bold text in the compromised scenario is the changed part of the baseline scenario for history only. All other components for agent goal, agent action, and physical structure remain the same. For each scenario, participants rated it on one of the three rating questions, which were manipulated between participants.

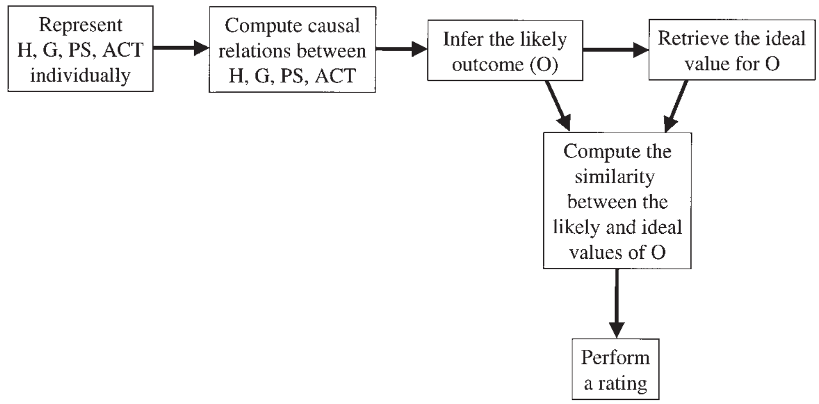

Figure 3. Processing assumptions for how participants represent scenarios, draw causal inferences, and evaluate inferred functional outcomes. H = history; G = goal; PS = physical structure; ACT = agent action.

causality ratings than when they are adequate. In addition, the relative sizes of these differences establish the relative causal impact of the four causal factors: The larger the difference, the greater the impact.

The function ratings similarly assessed the importance of the four scenario components in people's conceptions of function. Whereas the causality ratings focused participants' attention on the outcome component of the causal model in Figure 1C, the function ratings allowed participants to assess function in a less directive and more holistic manner. The function ratings perhaps assessed the function construct with the highest construct validity, given that they asked directly about function.

Finally, the name ratings assessed the importance of the four scenario components for assigning an object to a named category. If a component is central to people's willingness to assign category names, then compromising it should produce lower name ratings than when it is adequate.

Processing Assumptions

We made two sets of assumptions about how participants process the scenarios. The first set addressed how participants comprehend the scenarios and perform judgments. The second set addressed the causal reasoning that arises during the comprehension and judgment processes.

Assumptions about comprehension and judgment. As Figure 3 illustrates, participants first represent each of a scenario's components individually as they read it. As participants read the history component in Figure 3, they represent the events that underlie it (i.e., the events involved in Jane constructing a mop). Readers similarly represent the components for physical structure, goal, and action as they read about them. As individual scenario components are comprehended, causal relations between them are computed. If a mop was created intentionally, for example, readers might infer that the process of intentional creation caused the mop's physical structure to be effective. Conversely, if a mop was created accidentally, readers might infer that the process of accidental creation caused its physical structure to be flawed.[1]

As Figure 3 illustrates, participants next infer a likely outcome for the scenario, given that the scenario states nothing about an outcome (see Figure 2). When all scenario components are adequate, the inferred outcome is one of relative success. Conversely, when a scenario component is compromised, the inferred outcome may reflect failure to some extent. For example, if a mop's physical structure includes the information that it has plastic bags at the end for soaking up water, the predicted outcome might be that water is not absorbed.

As participants comprehend a scenario, they know that they will later have to answer a question about its outcome (i.e., a causality, function, or naming question). As Figure 3 illustrates, we assumed that these questions would induce participants to represent the ideal outcome for the scenario. For the causal question, the ideal outcome was explicitly stated in the rating question (e.g., "How likely is it that this mop will wipe up the spill?"). For the function question, the ideal outcome was implicit, asking how well the object in the scenario achieves the object's standard function (e.g., "How well does this mop achieve a mop's function?"). We assumed that the ideal function for a familiar object resides in memory and that participants would retrieve it in response to the function question. We similarly assumed that the naming question would implicitly activate an ideal. When participants were asked how well the name "mop" applied to the object in a scenario, they would retrieve the ideal function for *MOP* from memory and use it to help determine the name's appropriateness.

Once participants represent both the likely outcome and the ideal outcome for a scenario, we assumed that they compute the similarity between them. When the similarity was high, partici-

[1] From our theoretical perspective, we assume that readers represent scenario components as reenactments or simulations of modality-specific experiences, similar to mental imagery but not necessarily conscious (e.g., Barsalou, 1999, 2003a, 2003b). Increasing evidence in the language comprehension literature supports the hypothesis that simulations underlie the conceptual representation of texts like these (e.g., Fincher-Kiefer, 2001; Glenberg & Kaschak, 2002; Glenberg & Robertson, 2000; Hauk, Johnsrude, & Pulvermüller, 2004; Kaschak & Glenberg, 2000; Richardson, Spivey, Barsalou, & McRae, 2003; Spivey, Tyler, Richardson, & Young, 2000; Stanfield & Zwaan, 2001; Zwaan, Stanfield, & Yaxley, 2002). We hasten to add, however, that nothing in our experiments requires the simulation assumption. If standard representational schemes, such as propositions expressed in predicate calculus, represent the meanings of texts instead, all of the same predictions follow.

pants should provide a high rating for causality, function, or naming. Because the likely outcome approximated the ideal outcome, the causal effectiveness of the object would be high, the object's ideal function would be realized, and the name would be appropriate. Conversely, as the likely outcome diverged from the ideal outcome, participants should provide lower ratings. The causal effectiveness of the object would be less, its function would be achieved more poorly, and the name would not be as appropriate. Clearly, other factors differed between the three judgments, but we assumed that comparisons between likely and ideal outcomes were common to all.

Causal reasoning assumptions. The next four assumptions were central to HIPE's predictions in the later experiments. The first assumption was that causal reasoning plays central roles in people's conceptualization of function. Specifically, causal reasoning arises at two points in the process model of Figure 3: (a) when causal relations are computed between scenario components and (b) when a likely outcome is inferred. We made no commitment to the specific forms that causal reasoning would take but assumed that it would likely use causal mechanisms (e.g., Ahn & Bailenson, 1996; Ahn, Kalish, Medin, & Gelman, 1995), statistical computation (e.g., Cheng, 1997; Cheng & Novick, 1992), and associative strength (e.g., Shanks, 1991; Waldmann & Holyoak, 1992).

The second assumption was that the causal model in Figure 1C underlies participants' functional reasoning. As participants attempt to integrate history, physical structure, agent goal, and agent action, they organize them according to Figure 1C's causal structure. Specifically, they assume that history causes physical structure and that agent goal causes agent action (i.e., causal relations computed between scenario components in Figure 3). Furthermore, when participants infer an outcome, they assume that physical structure and agent action constitute its immediate causes. Experiment 5 assessed whether this was indeed the causal model that underlies participants' causal reasoning.

We refer to our third assumption about participants' causal reasoning as the *causal proximity principle*. According to this principle, the causes that immediately precede an outcome are sufficient for producing it. Consider HIPE's causal model in Figure 1C. As can be seen, physical structure and agent action are joint immediate causes of the outcome. According to the causal proximity principle, physical structure and agent action are sufficient for causing the outcome because of their immediate proximity to it. No other causes are relevant at this point in the causal process. Once the physical structure and the agent action are known, the outcome follows. In Figure 3's process model, this final inference occurs when a likely outcome is inferred from scenario components.

We refer to our fourth assumption about causal reasoning as the *causal updating principle* (cf. Spellman, 1997). According to this principle, distant causes shape immediate causes, thereby influencing the final outcome indirectly. In Figure 1C, the distant causes (history and agent goal) shape the immediate causes (physical structure and agent action), thereby indirectly influencing the outcome. Central to this principle is the assumption that an immediate cause does not take a single rigid form. Physical structure, for example, does not take one rigid form but varies widely (e.g., different physical structures for mops). Similarly, agent action can take many forms. Although the final forms of physical structure and agent action are sufficient to determine the outcome (the causal proximity principle), earlier causes indirectly affect the outcome by shaping the specific forms of the immediate causes before the immediate causes act. History, for example, determines a mop's physical structure, thereby influencing the outcome indirectly. When history specifies that plastic bags were used to create a mop, the resultant physical form leads to a different outcome than if rags had been used to create the mop during its history instead. In Figure 3, we assume that causal updating occurs when causal relations are computed between scenario components.

HIPE Predictions

Now that we have established our assumptions about comprehension, causal reasoning, and judgment, we turn to three predictions that follow from the HIPE theory.

Immediate causes dominate when specified. When a scenario specifies the physical structure and agent action for an object, HIPE predicts that they will dominate inferences about the likely outcome—the distant causes (history, agent goal) should be much less important. This prediction follows from HIPE's causal model in Figure 1C, together with the causal proximity principle. If participants use HIPE's causal model to reason, and if the scenario provides adequate information about the outcome's immediate causes, then sufficient information exists to determine the likely outcome. Distant causes should have little potential to affect it. Experiments 1, 3, and 6 offer tests of this prediction.

Distant causes have minor impact when immediate causes are not fully specified. Nevertheless, potential may exist for the distant causes to have minor effects. To the extent that a scenario describes an immediate cause ambiguously, potential exists for a distant cause to influence it and to thereby influence the outcome indirectly. For example, if the physical description of a mop is somewhat vague, then the mop's history can influence how participants conceptualize its physical structure, which in turn can influence the outcome. If the mop's history is compromised—the mop was created accidentally—participants may infer that the mop's physical structure is likely to be somewhat flawed. In contrast, if the mop was created intentionally, participants may infer that its physical structure is likely to be better and will therefore lead to a more ideal outcome. Experiments 1, 2, 3, and 6 offer tests of this prediction.

This account leads to an additional prediction. If the ambiguity of an immediate cause determines the amount of causal updating it receives, then an immediate cause should exhibit greater causal updating when it is vague than when it is detailed. For example, when the physical structure of a mop is vague, varying history should have more impact on the outcome than when the mop's physical structure is well specified. Experiment 7 tested this prediction.

Distant causes have large impact when immediate causes are absent. HIPE's causal model, coupled with the causal updating principle, predicts that the absence of an immediate cause offers a distant cause much potential to affect outcomes. Because the immediate cause is completely unspecified, much potential exists for a distant cause to shape its form. Because the scenario provides no constraint on the immediate cause, participants must infer it, using preceding causes to help do so. Imagine that a scenario contained no description of a mop's physical structure but did describe its history. When history is adequate (i.e., the mop was created intentionally), participants should infer that the physical structure is likely to be adequate. When an agent intentionally sets out to build something, a reasonable chance exists that the outcome will be successful. Conversely, when history is compromised (i.e., the mop was created accidentally), participants should infer that the physical structure is likely to be flawed. When an agent creates something accidentally, a reasonable chance exists that the outcome will be unsuccessful. Experiment 6 tested this prediction.

Affordance versus intentional causes. According to the predictions just presented for HIPE, the affordance causes (physical structure, agent action) should have more impact on functional reasoning than the intentional causes (history, agent goal).[2] It is important to note, however, that the affordance causes are not important in HIPE because they are affordance causes per se, but because they are immediate causes. In further contrast to affordance theories, HIPE predicts that intentional causes should have indirect effects on functional outcomes via causal updating, especially when the immediate causes are vague or missing. Thus, the relative impact of affordance and intentional causes in HIPE does not reflect intrinsic differences between them. Instead, it reflects their different positions in causal models.

Predictions for Affordance and Intentional Theories

Affordance theories. As we saw earlier, affordance theories focus on physical structure and agent action in reasoning about function, while ignoring history and agent goal (Figure 1A). As a result, these theories predict that physical structure and agent action should determine inferences about functional outcomes but that history and agent goal should not. To the extent that history and agent goal do affect outcomes, affordance theories provide inadequate accounts of how people represent and process function.

Affordance theories do not state explicitly that history and agent goal are unimportant. Instead, they typically imply this by omission. It does not follow that affordance theorists, if pressed, would not acknowledge the potential importance of history and goals. Nevertheless, these causes are typically missing from their accounts.

Intentional theories. Intentional theories predict that history should dominate reasoning about function (Figure 1B). When an object's history is adequate—creation was intentional—its perceived functionality should be high. When its history is compromised—creation was accidental—its perceived functionality should be low.

Much previous work in philosophy (e.g., Putnam, 1975) and in developmental psychology (e.g., Bloom, 1996, 1998; Gelman & Bloom, 2000; Matan & Carey, 2001) has argued that history is especially important for naming (but see Sloman & Malt, 2003). When agents intentionally create an object, part of the creation process is envisioning the object as belonging to a particular category and then dubbing the object with the category name. According to this view, these christenings give objects an essence that they retain throughout their existence.

When a mop is built intentionally, for example, the builder envisions it as belonging to the category of *MOPS,* and gives it the name "mop." On later occasions, if people know that this object was created intentionally to be a mop, they should be willing to call it a "mop," even if its physical structure has been compromised in some way. Because the mop's history is most important for determining its name, history dominates its subsequent naming. Conversely, if people know that an object was not intentionally created to be a *MOP*, they should be unwilling to call it a "mop," even if it has adequate physical structure. Again, history dominates.

Notably, Bloom (1996, 1998) views physical structure as an important part of the historical process. In particular, an object's physical structure is the causal result of an agent having the intention to create an object that fulfills a particular function. A mop's physical structure, for example, reflects an agent's attempt to create an object that will soak up liquids. Thus, an adequate history includes the realization of an adequate physical structure, initiated by the intention to create an object of a specific type.

Gutheil, Bloom, Valderrama, and Freedman (2004) explored a different relation between history and physical structure. According to them, historical intentions are sufficient to override physical damage to an artifact that compromises its functionality. Gutheil et al. reported that human adults, when presented with a crushed plastic fork, continue to call the crushed remains a fork. Gutheil et al. concluded that the historical intention to create a particular kind of object dominates its later categorization and naming, even when the object is no longer physically functional.

Thus, intentional theories make multiple predictions about whether a compromised physical structure should compromise naming. On the one hand, if a category's physical structure does not implement the category's intended function, it should not be a good category member (Bloom, 1996, 1998). On the other hand, if a category's physical structure is compromised, its history might still be sufficient to maintain its category membership (Gutheil et al., 2004). We addressed this issue further in Experiment 6.

Intentional theories make one clear prediction about our experiments. According to intentional theories, people should *not* apply a category name to an object having the requisite physical structure if the object was not created intentionally to be a category member. Without the correct historical intention, something should not be a clear category member, even if it has adequate physical structure. If people willingly apply category names to such objects, however, this prediction of intentional theories fails. The following experiments tested this prediction.

Experiment 1

This first experiment assessed the importance of history, agent goal, agent action, and physical structure on causality, function, and name ratings. Each participant judged baseline scenarios and compromised scenarios for all four components. A given participant, however, provided only one type of rating.

The average judgment for each compromised scenario was compared with the average judgment for the respective baseline scenario. If the HIPE theory is correct, large differences should occur when the immediate causes are compromised (physical

[2] To this point, we have focused primarily on the intentions that underlie the creation of objects (i.e., their histories). For similar reasons, however, some intentional theories might also predict that an agent's intention to use an object in a particular way affects its perceived functionality. In each case, an agent's intention establishes a functional essence in the conception of an object, either at the time of creation or at the time of use. Thus, from here on, we include both history and agent goal as intentional causes.

structure, agent action), and small differences should occur when the distant causes are compromised (history, agent goal). Because the scenarios specified the immediate causes reasonably well, these causes should dominate inferred outcomes via the causal proximity principle. Distant causes should also have effects, albeit smaller, because the immediate causes were somewhat ambiguous, thereby allowing modest amounts of causal updating to occur.

If affordance theories are correct, differences between compromised and baseline scenarios should occur only for physical structure and agent action—not for history and agent goal. If intentional theories are correct, history should produce the largest difference, especially for naming.

Method

Design and participants. The experiment used a 5 × 3 mixed design, with the 5 scenario types as a within-participants factor, and with the 3 rating types as a between-participants factor. Participants were 72 Emory undergraduates (61 women, 11 men) participating for course credit, with 24 assigned randomly to each rating condition. Participants read and rated 15 critical scenarios.

Materials. The 15 scenarios resulted from crossing five types of scenarios with three objects (mop, whistle, pencil). Each scenario described one character who creates an object and a second character who uses it. Each scenario included four components: the object's history, the object's physical structure, an agent's goal, and an agent's action.

In the baseline scenario for each object, all four components were adequate for the object to achieve its function effectively. In the four compromised scenarios for each object, one and only one component was compromised. When intentional history was compromised, the scenario described an object being created accidentally rather than intentionally (the compromised history scenario). When the goal was compromised, the scenario described an agent using the artifact without the intention of doing so (the compromised goal scenario). When the action was compromised, the scenario described an agent who did not perform an action sufficient to produce the artifact's usual outcome (the compromised action scenario). When physical structure was compromised, the scenario described the object's physical structure as inadequate to produce the usual outcome associated with the artifact (the compromised structure scenario). Appendix A presents the baseline and compromised components for each object.

Each participant received all 15 possible scenarios. To control for order effects, we constructed four different sequences. Each sequence contained three blocks of five scenarios, with each block containing one instance of each scenario type. In each sequence, no two consecutive scenarios described the same object or the same scenario type. The four sequences were distributed equally across the three rating conditions.

Procedure. Participants received booklets containing the experimental materials and were tested in groups of one to five. Participants received the instructions in writing but also heard them read by the experimenter. Participants then performed three practice trials that, similar to the critical trials, involved two characters but that did not involve function. In each practice trial, one character was described as doing something that might potentially upset her partner, and participants rated how much they believed the partner was upset. To promote correct use of the scale, participants were encouraged to discuss their practice ratings.

After finishing the practice trials, participants worked individually, rating four buffer scenarios and then the 15 critical scenarios. Buffer scenarios had the dual aim of inducing participants to use the full range of the scale and of acquainting them with the general structure of the critical scenarios. These trials used two objects different from those on critical trials (gardening fork, clothes hanger), but the critical judgment was the same (causality, function, or naming).

After reading each scenario, participants rated causality, function, or naming. Ratings were performed on a 7-point scale, with 1 always reflecting the low end and 7 the high end. The causality question described the outcome usually associated with using the artifact and required participants to rate the outcome's likelihood given the information in the scenario. The function question asked participants to rate how well a scenario illustrated the function of an artifact. The name question asked participants to rate the appropriateness of calling the described object an *X,* where *X* was a possible name for the described artifact. Appendix A provides the specific questions.

On finishing, participants answered three questions that probed their understanding of the experiment: First, "What do you believe the hypothesis of the experiment was?"; second, "During the experiment, did anything occur to you about how the different scenarios were related to each other?"; and third, "If you answered yes to Question 2, describe how you thought the scenarios were related."

Results

Figure 4 presents the average ratings across participants and objects from a Scenario × Rating analysis of variance (ANOVA). A violation of the sphericity assumption was handled by correcting degrees of freedom with Huynh-Feldt's epsilon. Sphericity, when violated occasionally, was addressed similarly in later experiments. For clarity of presentation, degrees of freedom are presented without adjustment here and elsewhere. The overall analysis revealed main effects of both scenario, $F(4, 276) = 123.28$, $MSE = 1.61$, $p < .001$, $R^2 = .64$, power = 1, and rating, $F(2, 69) = 5.36$, $MSE = 2.78$, $p < .01$, $R^2 = .13$, power = .83. Scenario and rating interacted, $F(8, 276) = 10.95$, $MSE = 1.61$, $p < .001$, $R^2 = .24$, power = 1.

For each rating condition, we performed eight planned comparisons. Four tested HIPE's prediction that each causal component should affect judgments of function. Specifically, the average rating for each compromised scenario should be lower than the average rating for the baseline scenario. On the one hand, the immediate causes (physical structure, agent action) should affect function because of the causal proximity principle. On the other hand, the distant causes (history, agent goal) should affect function because of causal updating.

Four further planned comparisons tested HIPE's prediction that compromising the immediate causes should undermine function more than compromising the distant causes. Specifically, the average ratings for the compromised structure and compromised action scenarios should each be lower than the average ratings for the compromised history and compromised goal scenarios.

Because the predictions of affordance and intentional theories constituted two subsets of HIPE's predictions, no additional planned comparisons were necessary to test them. For affordance theories, only the compromised structure and compromised action scenarios should be below baseline, and both should be lower than the compromised history and compromised goal scenarios. For intentional theories, the compromised history scenario (and possibly the compromised goal scenario) should be below baseline. Most important, the compromised history scenario should be lower than the compromised structure and compromised action scenarios.

HIPE's predictions fit the data better than the affordance or intentional predictions. For causality ratings, all eight comparisons were significant. All four compromised scenarios received significantly lower ratings than the baseline scenario: compromised history, $F(1, 23) = 7.99$, $MSE = .18$, $p < .01$; compromised goal, $F(1, 23) = 23.84$, $MSE = .34$, $p < .001$; compromised action, $F(1, 23) = 116.15$, $MSE = 1.32$, $p < .001$; compromised structure, $F(1,$

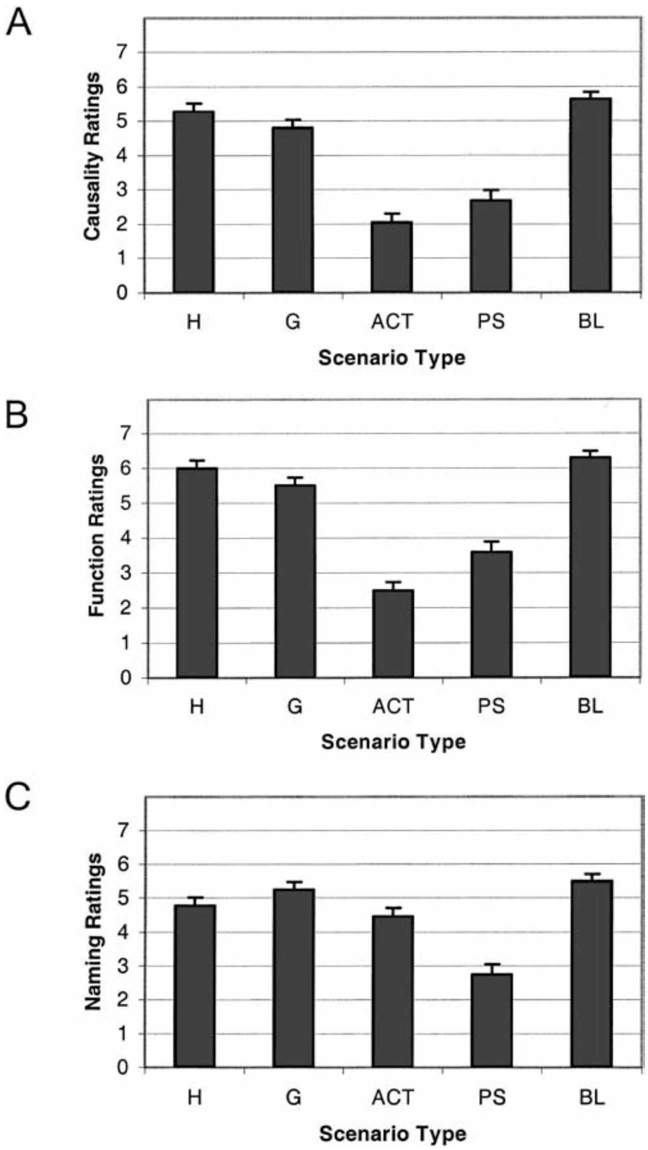

Figure 4. Average causality (Panel A), function (Panel B), and naming (Panel C) ratings in Experiment 1 for the compromised history (H), compromised goal (G), compromised action (ACT), compromised structure (PS), and baseline (BL) scenarios. Error bars are standard errors.

23) = 54.43, *MSE* = 1.91, $p < .001$. The compromised action scenario received lower ratings than both the compromised history and the compromised goal scenarios, respectively, $F(1, 23) = 96.72$, *MSE* = 1.29, $p < .001$; $F(1, 23) = 61.14$, *MSE* = 1.48, $p < .001$. The compromised structure scenario received lower ratings than both the compromised history and the compromised goal scenarios, respectively, $F(1, 23) = 40.57$, *MSE* = 2, $p < .001$; $F(1, 23) = 23.88$, *MSE* = 2.27, $p < .001$.

When the same comparisons were performed for function ratings, all comparisons except compromised history versus baseline were significant, with this comparison being nearly significant: compromised history, $F(1, 23) = 4.20$, *MSE* = .22, $p = .052$; compromised goal, $F(1, 23) = 22.88$, *MSE* = .32, $p < .001$; compromised action, $F(1, 23) = 222.18$, *MSE* = .78, $p < .001$; compromised structure, $F(1, 23) = 97.18$, *MSE* = 1.18, $p < .001$. The compromised action scenario received lower ratings than both the compromised history and the compromised goal scenarios, respectively, $F(1, 23) = 135.04$, *MSE* = 1.11, $p < .001$; $F(1, 23) = 91.85$, *MSE* = 1.20, $p < .001$. The compromised structure scenario received lower ratings than both the compromised history and compromised goal scenarios, respectively, $F(1, 23) = 56.39$, *MSE* = 1.24, $p < .001$; $F(1, 23) = 25.47$, *MSE* = 1.73, $p < .001$.

Name ratings exhibited a somewhat different pattern than causality and function ratings. Although compromised history, compromised action, and compromised structure were rated significantly lower than baseline, compromised goal was not, even though the difference was in the predicted direction: compromised history, $F(1, 23) = 7.59$, *MSE* = .79, $p < .05$; compromised goal, $F(1, 23) = 2.21$, *MSE* = .34, $p = .151$; compromised action, $F(1, 23) = 15.20$, *MSE* = .86, $p < .001$; compromised structure, $F(1, 23) = 69.65$, *MSE* = 1.29, $p < .001$. Compromised action was not significantly lower than compromised history but was significantly lower than compromised goal: respectively, $F(1, 23) = 1.39$, *MSE* = .96, $p = .25$; $F(1, 23) = 11.99$, *MSE* = .63, $p < .01$. Again, compromised structure was significantly lower than both compromised history and compromised goal, respectively, $F(1, 23) = 29.61$, *MSE* = 1.67, $p < .001$; $F(1, 23) = 42.41$, *MSE* = 1.75, $p < .001$.

Because intentional views predict that history should have a greater effect in naming than in causality and function ratings, we contrasted the effect of compromising history across ratings. As predicted, when history was compromised, name ratings were significantly lower than causality and function ratings, $F(1, 69) = 11.67$, *MSE* = 1.29, $p < .01$.

As Figure 4 further illustrates, physical structure was more important than agent action for name ratings, whereas agent action was more important than physical structure for causality and function ratings. In a post hoc test, this interaction was significant, $F(2, 69) = 19.60$, *MSE* = 1.38, $p < .001$. We offer an interpretation of this result in the General Discussion section.

To assess possible practice effects, we performed separate analyses on the first and last blocks—each being a full replication of the five scenario types. If learning from repeated exposure to the scenarios was responsible for the results, the five scenarios should not have differed on the first block but should have shown the pattern in Figure 4 on the last block. In contrast, both blocks exhibited the pattern shown in Figure 4. Thus, the results did not reflect changes associated with practice. Practice effects were assessed similarly in later experiments and did not occur. For detailed accounts of these analyses, see Chaigneau (2002).

To assess possible item effects, we examined the pattern of results separately for the mop, pencil, and whistle.[3] The mop and whistle exhibited the overall pattern for all three ratings. The pencil individually exhibited the overall pattern for the function and name ratings but deviated in the causality ratings, with compromised history being slightly above baseline, not below. Except for this one mean, the overall pattern held across the individual

[3] Because of the low power associated with testing individual items, the results described here for item analyses reflect patterns of means, not patterns of statistical significance.

objects. Item effects were assessed similarly in later experiments, and typically the general pattern across items held for individual items.

To assess possible demand effects, we redid the analyses on only participants who gave no evidence of understanding anything about the experiment's design. On the first debriefing question, no participant correctly described the hypothesis of the experiment or even came close to describing it. On the second and third debriefing questions, a large majority of the participants showed no understanding about the structure of the scenarios. Only two participants (2.8%) noticed all four types of compromised scenarios. Only 17 participants (23.6%) noticed a subset of the possible compromises. When means were recomputed for the remaining 55 participants, the pattern was the same as in Figure 4. Demand was assessed similarly in later experiments. In general, the pattern of results across all participants also held for only those participants who exhibited no awareness of the hypotheses. For complete accounts of the demand analyses, see Chaigneau (2002).

Discussion

Experiment 1 offers evidence for HIPE's first two predictions. In accordance with HIPE's first prediction, the immediate causes (physical structure, agent action) were generally more important for all three judgments than were the distant causes (history, agent goals). The one exception to this pattern was that agent action was not significantly more important than history and agent goal for naming, although the difference was in the predicted direction. In accordance with HIPE's second prediction, the two distant factors nevertheless produced significant decrements relative to baseline.

This pattern of results offers preliminary support for our earlier assumptions about causal reasoning. Participants appeared to use the causal model in Figure 1C to represent the scenarios. Furthermore, participants appeared to follow the causal proximity principle, such that the immediate causes had the largest impact on inferred outcomes. Finally, causal updating appeared to occur, such that the distant causes shaped the somewhat ambiguous immediate causes.

The patterns of results for causality and function judgments were nearly identical. Experiment 2 demonstrates the same pattern. This equivalence suggests that causal reasoning lies at the heart of functional reasoning, as HIPE assumes. In contrast, name judgments deviated modestly from the pattern exhibited by causality and function judgments. As intentional theories predict (e.g., Bloom, 1996, 1998; Putnam, 1975), history was more important for naming than for causality and function. Intentionally creating an object for a purpose strengthened the belief that it belongs to a named category, even when physical structure and action were fully adequate. Regardless, Experiment 1's results suggest that history is less important for function than intentional theorists have suggested. When physical structure and agent action were sufficient to produce a functional outcome, participants readily applied the respective category name even when the object was created accidentally. A historical intention to create the object as a category member was not necessary.

On the surface, these results indicate that the affordance causes—physical structure and agent action—dominate inferences about functional outcomes. Nevertheless, the intentional causes—history and agent goal—also had minor impact. The distinction between affordances and intentions does not provide an adequate account of this pattern. According to the affordance view, history and agent goal should not have effects. According to the history view, history should dominate the affordance causes. Instead, the observed pattern fits HIPE's predictions. Immediate causes dominate because they are specified reasonably well. Distant causes contribute because ambiguity in the immediate causes allows causal updating.

Experiment 2

This next experiment provided an opportunity to further assess the conclusion that causal updating occurs as people reason about function. As we just saw, the distant causes—history and agent goal—both had small but reliable effects, which we interpreted as causal updating. As participants assemble the scenario components into a causal model (Figure 1C), the distant causes shape the forms of the immediate causes, which are somewhat ambiguous.

If this account is correct, it predicts that the effects of causal updating should be cumulative. As an increasing number of distant causes are compromised, detrimental effects on the outcome should increase. To see this, first imagine only one distant cause being compromised. If only history is compromised, a slight drop in ratings should result, as the compromised history leads to a less effective physical structure, relative to baseline. Similarly, if only agent goal is compromised, a slight drop in ratings should result, as the compromised goal leads to a less effective agent action.

Now imagine both distant causes being compromised simultaneously, while physical structure and agent action are both adequate. If causal updating is occurring, each distant cause should lead to a less effective immediate cause. Both physical structure and agent action should be less effective than baseline, given that both history and agent goal are compromised. Most important, the overall impact on participants' judgments should be cumulative. Judgments should be lower than when only one distant cause is compromised. If causal updating is occurring, a cumulative effect should be observed.

To assess this prediction, we gave participants four types of scenarios. As in Experiment 1, the baseline scenarios contained uncompromised descriptions of history, agent goal, agent action, and physical structure. Also as in Experiment 1, participants received scenarios that compromised either history or agent goal. Finally, Experiment 2 contained one new type of scenario in which history and agent goal were compromised simultaneously. Unlike Experiment 1, physical structure and agent action were never compromised—both were adequate in every scenario. Instead the focus was on compromising history and agent goal individually and jointly to test the prediction that causal updating is cumulative.

To reduce the size of the design, Experiment 2 included only causality and function ratings. Later experiments further explored name ratings.

Method

Design and participants. The experiment used a 4 × 2 mixed design, with scenario type as a within-participants factor and function versus cause ratings as a between-participants factor. Participants were 42 Emory undergraduates (36 women, 6 men) participating for course credit, with 21 assigned randomly to each rating condition. Participants read and rated 12 critical scenarios.

Materials. The materials were the same as Experiment 1, with the following exceptions. First, only three of the original five scenario types in Experiment 1 were used—baseline, compromised history, and compromised goal (compromised structure and compromised action were not used). Second, a new scenario type was added that compromised both history and agent goal simultaneously (i.e., the compromised history and goal scenario). We constructed three sequences of the critical trials that replicated all scenario types in each of three blocks but that did not repeat scenarios or objects consecutively. The three sequences were distributed equally across rating conditions.

Procedure. The procedure was the same as that in Experiment 1.

Results

Figure 5 presents the average ratings across participants and objects from a Scenario × Rating ANOVA. The overall analysis revealed a main effect of scenario, $F(3, 120) = 28.71$, $MSE = .49$, $p < .001$, $R^2 = .42$, power = 1; no effect of rating, $F(1, 40) = .41$, $MSE = .79$, power = .1; and no interaction, $F(3, 120) = 1.84$, $MSE = .49$, $p < .143$, $R^2 = .04$, power = .47. As in Experiment 1, causality and function ratings exhibited the same pattern. Given the null effect of rating and no interaction with scenario, we combined results from both ratings in the remaining analyses.

Five planned comparisons assessed the predictions of interest. First, the baseline scenario was compared with each of the other three scenarios. Second, the compromised history and compromised goal scenarios were each compared with the compromised history and goal scenario. Relative to baseline, all other scenarios were significantly lower: compromised history, $F(1, 40) = 11.72$, $MSE = .79$, $p < .01$; compromised goal, $F(1, 40) = 24.32$, $MSE = .84$, $p < .001$; compromised history and goal, $F(1, 40) = 54.84$, $MSE = 1.48$, $p < .001$. Most important, the compromised history and goal scenarios were significantly lower than both the compromised history and the compromised goal scenarios, respectively, $F(1, 40) = 39.61$, $MSE = .9$, $p < .001$; $F(1, 40) = 20.94$, $MSE = .96$, $p < .001$. These planned comparisons were also significant individually (a) for the function ratings: compromised history and goal versus compromised history, $F(1, 20) = 34.01$, $MSE = 2.99$, $p < .001$; compromised history and goal versus compromised goal, $F(1, 20) = 11.57$, $MSE = 3.85$, $p < .01$; and (b) also for the causal ratings: compromised history and goal versus compromised history, $F(1, 20) = 8.55$, $MSE = 2.41$, $p < .01$; compromised history and goal versus compromised goal, $F(1, 20) = 9.75$, $MSE = 1.88$, $p < .01$.

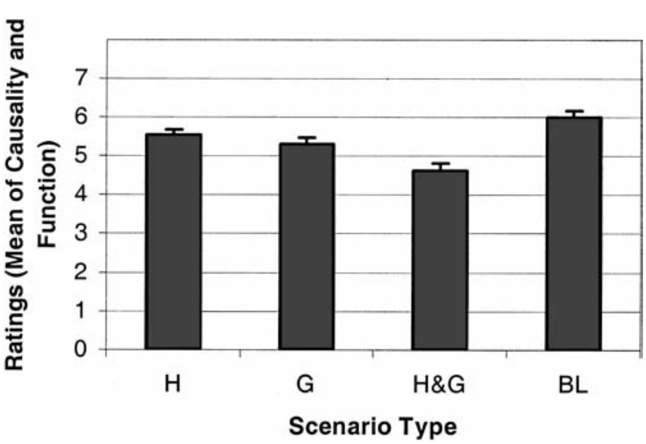

Figure 5. Average causality and function ratings (combined) in Experiment 2 for the compromised history (H), compromised goal (G), compromised history and goal (H&G), and baseline (BL) scenarios. Error bars are standard errors.

Discussion

Compromising the distant causes—history and agent goal—produced a cumulative effect. Causality and function ratings were both significantly lower when both distant causes were compromised than when only one was. This finding confirms HIPE's prediction that causal updating modifies direct causes when they are ambiguous. As an increasing number of distant causes are compromised, their compromising effects on direct causes accumulate, increasingly lowering inferences about functional effectiveness.

Experiment 3

The next three experiments explored methodological questions that arose from the first two. In this next experiment, we assessed whether the results in Experiments 1 and 2 could have reflected the narrative structure of the scenarios. In both experiments, the scenarios always began with history and then followed with object use. A potential concern was that a recency effect may have been present, namely, the information encountered last had the most impact on the ratings. If so, this may have diminished history's effect.

To address this potential problem, half the participants in Experiment 3 received scenarios in which the previous temporal sequence was reversed. These participants first read about the use of the object and later learned about its history. If recency was a factor, then history should have become more important than physical structure when history came last.

On the other hand, we predicted that the principles of causal proximity and causal updating would continue to dominate participants' reasoning about function. Regardless of a scenario's narrative structure, we expected that participants would establish the underlying causal model in Figure 1C and apply these principles to it. As a result, immediate causes should dominate, and distant causes should have minor effects, thereby replicating Experiments 1 and 2.

To reduce the size of the design, we included only function ratings (also because function and causality ratings behaved identically in the previous two experiments). Because our primary interest was in the size of the history and goal effects relative to the physical structure effect, only these three components were compromised (i.e., all scenarios had adequate actions).

Method

Design and participants. The experiment used a 4 × 2 mixed design, with scenario type as a within-participants factor and narrative order as a between-participants factor. Participants were 54 Emory undergraduates (42 women, 12 men) participating for course credit, with 27 assigned randomly to each narrative order. Participants read 12 critical scenarios and performed function ratings only.

Materials. The materials were the same as those in Experiment 1, with the following exceptions. First, only four scenario types were used: baseline, compromised history, compromised goal, and compromised structure (compromised action was not used). Second, the history-first materials presented the functional event in its previous narrative structure (history, physical structure, agent goal, agent action), whereas the history-last materials reversed this structure by putting history last (agent goal, physical structure, agent action, history). Again three sequences of the critical trials were constructed that did not repeat objects or scenarios consecutively and that were distributed equally across the two narrative orders.

Procedure. The procedure was the same as that in Experiment 1.

Results

Figure 6 presents the average function ratings across participants and objects from a Scenario × Narrative Structure ANOVA. The overall analysis revealed an effect of scenario type, $F(3, 156) = 42.78$, $MSE = 1.62$, $p < .001$, $R^2 = .451$, power = 1, but no effect of narrative structure, $F(1, 52) = .27$, $MSE = 2.47$, power = .08. Scenario type and narrative structure interacted, $F(3, 156) = 1.62$, $MSE = 4.32$, $p < .05$, $R^2 = .07$, power = .7.

To identify the source of the interaction, we compared the two levels of narrative structure (i.e., history first and history last) at each level of scenario type. Only compromised goal produced a significant difference, $F(1, 52) = 6.26$, $MSE = .92$, $p < .05$. A compromised goal had slightly more influence when it occurred at the end of the narrative than at the beginning. In contrast, recency affected neither history, $F(1, 52) = 2.43$, $MSE = 1.49$, $p = .125$, nor physical structure, $F(1, 52) = 1.50$, $MSE = 2.42$, $p = .226$, significantly. Recency also had no effect on the baseline scenarios, $F(1, 52) = .644$, $MSE = .92$, $p = .426$.

When we performed planned comparisons between the different scenario types, the results closely replicated those of Experiment 1. All three compromised scenarios received lower ratings relative to baseline: compromised history, $F(1, 53) = 17.83$, $MSE = 1.13$, $p < .001$; compromised goal, $F(1, 53) = 9.94$, $MSE = 1.07$, $p < .01$; and compromised structure, $F(1, 53) = 79.79$, $MSE = 3.10$, $p < .001$. Most important, compromising physical structure produced lower ratings than compromising either history, $F(1, 53) = 35.61$, $MSE = 3.55$, $p < .001$, or goal, $F(1, 53) = 44.13$, $MSE = 3.19$, $p < .001$.

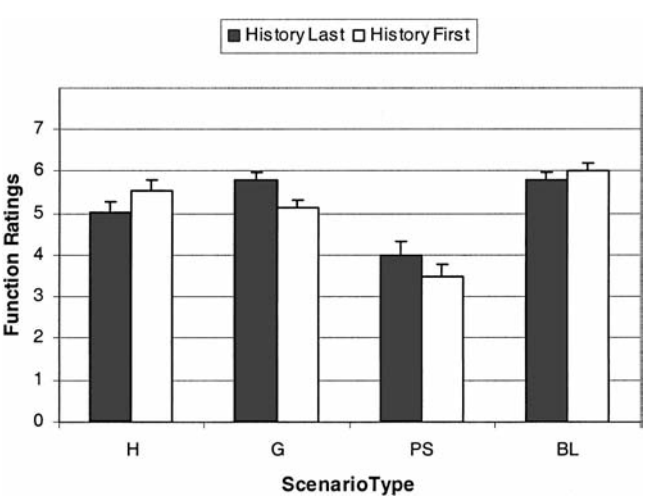

Figure 6. Average function ratings in Experiment 3 for the compromised history (H), compromised goal (G), compromised structure (PS), and baseline (BL) scenarios as a function of different narrative structure (history first vs. history last). Error bars are standard errors.

Discussion

Narrative structure appears to be a relatively minor factor in this paradigm. Although recency had a small significant impact on the importance of goals, it had no significant impact on the importance of history or physical structure. Most important, this modest effect does not change the relative importance of the three causes. As found in Experiment 1, physical structure had the most impact, whereas history and goals had much smaller but nevertheless significant impacts. Regardless of narrative order, history and goals were never the most important causes.[4]

Experiment 4

A second methodological issue concerns the relative strength of the four compromise manipulations. Perhaps physical structure and agent action produced the largest effects in Experiments 1 and 3 because their manipulations were strongest, thereby underestimating the effects of history and goal, which might have had weaker manipulations.

To assess this possibility, we presented each manipulation explicitly to participants in the context of a full baseline scenario and asked them to rate how strong a manipulation they thought it was. For example, participants read a baseline scenario and rated how much more intentional the object's creation could have been. Participants then read a compromised history scenario and rated how much more accidental the object's creation could have been. Whereas the history component was supposed to be as intentional as possible in the baseline scenario, it was supposed to be as accidental as possible in the compromised history scenario. These judgments indicated how well the two scenarios achieved their respective goals. Analogous strength measures were collected for the agent goal, agent action, and physical structure manipulations.

A difference score computed from each pair of ratings provided a measure of manipulation strength (as explained later). If the findings in Experiments 1 and 3 resulted from agent action and physical structure having stronger manipulations than history and agent goal, manipulation strength should correlate with the size of these differences. If manipulation strength was not a factor, some other pattern should appear.

Method

Design and participants. The experiment used a 4 × 2 design, with the four scenario types and baseline versus compromised judgment fully crossed within participants. Participants were 18 Emory undergraduates (11 women, 7 men) participating for course credit. Participants read 12 critical pairs of complete scenarios (four for each of three objects), rated the adequate version of a scenario component in each pair, and then rated its compromised version, each in the larger context of a complete scenario.

[4] A potential worry might be that participants in the history-last condition read the components out of order, reading history first, so that the scenario made more sense to them. However, the modest effect of narrative structure argues against this interpretation. If participants had read the components in the same order for both narratives, no effect of narrative order should have occurred.

Materials. For each of the three objects in the previous experiments (mop, whistle, pencil), four pairs of complete scenarios were constructed. For each pair, a baseline scenario appeared at the top of the page, and a compromised scenario appeared below, both describing the same object (e.g., a mop). In both scenarios, text about one and the same component was underlined, where the component was history, agent goal, agent action, or physical structure. In the baseline scenario, the underlined text described the component in its adequate form. In the compromised scenario, the underlined text described the same component in its compromised form. The other three components in both scenarios were uncompromised.

Participants provided two ratings on each page. When the underlined component was the object's history, participants first rated whether history in the baseline scenario could have been any more intentional and second rated whether history in the compromised scenario could have been any more accidental. Analogously, when the underlined component was the agent's goal, participants rated whether the goal could have been any more intentional or accidental. When the underlined component was the object's physical structure, participants first rated whether physical structure in the baseline scenario could have been any more efficient and second rated whether physical structure in the compromised scenario could have been any more inefficient. Analogously, when the underlined component was the agent's action, participants rated whether the action could have been any more efficient or inefficient. Participants used a scale ranging from 1 (*It could not have been made any more X*) to 7 (*It could have been a lot more X*), with *X* being intentional or accidental, efficient or inefficient.

Three orders of the 12 pages were constructed and were assigned randomly to participants. Each order contained three blocks, each presenting the four objects once. No component was ever the same between consecutive pages, nor was any object ever the same, except once by necessity of the design.

Procedure. After reading instructions that described the pairs of scenarios and the two rating measures, participants rated three practice examples having the same scenarios as the practice trials in Experiment 1 for whether the main character's behavior could have been made any more annoying. Participants then rated the 12 critical pairs of scenarios.

Results

For each pair of scenarios, manipulation strength was defined as 15 – B – C, where B was the baseline rating and C was the compromised rating. The boundary cases for history illustrate how this measure works. If the baseline scenario were maximally intentional (rating = 1), and if the compromised history scenario were maximally accidental (rating = 1), manipulation strength would achieve its maximum of 13 (i.e., 15 – 1 – 1). Conversely, if the baseline scenario were minimally intentional (rating = 7), and if the compromised history scenario were minimally accidental (rating = 7), manipulation strength would achieve its minimum of 1 (i.e., 15 – 7 – 7 = 1). Thus the score ranged from 1 to 13, increasing as manipulation strength increased.

Figure 7 presents manipulation strength scores averaged across participants and objects, along with the two individual ratings that went into them. In a one-way ANOVA, scenario had a significant effect on manipulation strength $F(3, 51) = 10.35$, $MSE = 1.37$, $p < .001$, $R^2 = .38$, power = .998. One planned comparison assessed the prediction (not ours) that the history manipulation was weaker than the other manipulations. The opposite, however, occurred. Participants viewed the history manipulation as stronger than the other three, $F(1, 17) = 16.60$, $MSE = 2.13$, $p < .001$. A second planned comparison then assessed the prediction (again not ours) that the two distant manipulations (history, goal) were weaker than the two immediate manipulations (agent action, physical structure). Again, however, the opposite occurred. Participants viewed the intentional manipulations as stronger than the other two, $F(1, 17) = 11.48$ $MSE = 2.34$, $p < .01$. As Figure 7 illustrates, manipulation strength decreased across history, agent goal, agent action, and physical structure.

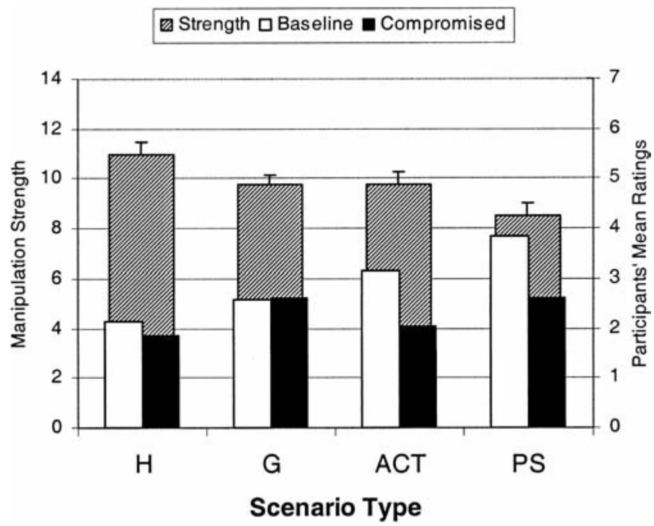

Figure 7. From Experiment 4, average ratings of efficiency and adequacy for the baseline scenario and average ratings of inefficiency and inadequacy for the compromised scenarios used to manipulate history (H), agent goal (G), agent action (ACT), and physical structure (PS). Lower values on the right ordinate indicate increasing inefficiency and inadequacy for the baseline and compromised scenarios. Overall manipulation strengths for the components are shown in the background and result from combining the baseline and compromised measures (i.e., 15 – baseline − compromised). Higher values on the left ordinate indicate stronger manipulations. Error bars are standard errors.

Discussion

These results do not support the conclusion that manipulation strength was responsible for the dominance of agent action and physical structure over history and agent goal in Experiments 1 and 3. To the contrary, agent action and physical structure had the strongest effects in those experiments, despite having weaker manipulations. Conversely, factors with stronger manipulations—history and goal—had weaker effects. This finding strengthens the conclusion that people view immediate causes as more central to function than distant causes.

Experiment 5

As summarized in Figure 1C, we made three assumptions about the underlying causal structure of function: (a) Objects have histories that cause their physical structure, (b) agents have goals that cause their actions, and (c) physical structure and agent action jointly cause a functional outcome. Across Experiments 1, 2, and 3, we used this causal model to derive predictions that the data supported. Nevertheless, independent corroboration of this model is desirable. Experiment 5 addressed this methodological issue. Participants drew causal links from each scenario component to other components that they thought were causal effects of it. From these data, we reconstructed the causal models that participants perceived in the scenarios.

Method

Materials, design, and participants. For each of the three objects used in the previous studies (mop, pencil, whistle), the baseline scenario was divided into its components (history, goal, agent action, physical structure). Outcomes were added (from the causal rating question) so that a final effect was available for the other four components to cause. Each component was presented in a text box, with the five boxes positioned randomly in a circle. In this arrangement, participants could understand each component as an individual event but could also understand the scenario as a functioning whole. The texts for the components were somewhat altered from their forms in Appendix A so that participants could not rely on temporal or grammatical cues to infer causal structure. Grammatical cues were minimized by wording all five components in the past tense. Referential cues were minimized by using only definite reference. Temporal cues were minimized by the random arrangement of components in a circle. Nevertheless, each component was individually comprehensible, and all five were comprehensible as forming a coherent system. Appendix B presents the revised components.

Participants received three pages, one each for the mop, pencil, and whistle. Three versions of the materials were constructed that counterbalanced the order of the objects and the arrangement of their five components in a circle. Participants were 45 Emory undergraduates (37 women, 8 men) participating for course credit or pay, assigned randomly to the three materials versions.

Procedure. Participants were instructed to first read the five components on a page and to understand the system they formed. Participants were then asked to draw an arrow between each pair of components that formed a causal relation, from the cause component to the effect component. The instructions stressed four points in the context of more detailed instructions and examples: First, a causal relation from *X* to *Y* meant that *Y* could have occurred as a result of *X* occurring. If *X* had not occurred, then *Y* might not have occurred, unless some other cause, such as *Z*, had occurred. Second, a causal relation could either mean than an action caused an outcome or that some state of the world enabled an outcome to occur. A causal outcome did not have to result from an action but could also result from an enabling state. Third, a causal relation between two things had to be direct, not indirect. Thus, if *X* caused *Y*, and if *Y* caused *Z*, it was not necessary to draw an indirect causal relation from *X* to *Z*. Fourth, a component did not have to have just one causal relation going into it or out of it. It could also have zero causal relations associated with it or more than one.

Results

Across participants, the total frequency of links from one component to each of the other four components was counted for each object. This produced a 5 × 5 matrix containing directional connections between all possible pairs of components in both directions. The average number of links drawn by a participant for each object was 3.64 (minimum = 2, maximum = 5, SD = .73).

To weed out spurious links, we adopted the following criterion. For each object, we computed the standard deviation across the frequencies of the 25 cells in its summary matrix. All frequencies less than 3 standard deviations below the maximum frequency in the summary matrix were then removed. For the mop, the maximum was 42 and the matrix standard deviation was 12.3, setting the cutoff at 5.09. For the pencil, the maximum was 43 and the matrix standard deviation was 12.4, setting the cutoff at 5.79. For the whistle, the maximum was 45 and the matrix standard deviation was 12.97, setting the cutoff at 6.08.

After removing spurious links, we integrated the results across the three objects by adding the three object matrices together. To further ensure that links in this final matrix were robust, we dropped a link if it did not appear in the individual matrices for at least two of the three objects. The causal model in Figure 8 depicts the links that survived to make it into the final matrix, where each causal relation shown in the model reflects a link in the final matrix. The thickness of each arrow reflects its strength across participants and objects, namely, the percentage of times it was mentioned out of 135 opportunities (i.e., 45 participants × 3 objects).

As can be seen, the resulting causal model in Figure 8 bears a clear resemblance to Figure 1C. Links exist from history to physical structure and from physical structure to outcome. In addition, links exist from agent goal to agent action and from agent action to outcome. One further link, not in Figure 1C, goes from physical structure to agent action, consistent with the idea the physical structure affords the potential for action (Gibson, 1950, 1979). Notably, physical structure and agent action are associated with the most links, making them most central in the causal model (Sloman et al., 1998).

Discussion

Overall, the results are consistent with the causal model presented earlier in Figure 1C. HIPE's integration of history and affordance theories appears to capture the underlying causal structure that participants perceived in the scenarios used for Experiments 1, 2, and 3. Most important, our assumptions about immediate versus distant causes appear correct. Whereas participants perceived agent action and physical structure as directly causing functional outcomes, they did not perceive history and agent goal as doing so. Even though a stronger relation existed between history and physical structure than between physical structure and outcome, physical structure nevertheless had more impact on judgments of function in Experiments 1 and 3. Even though the

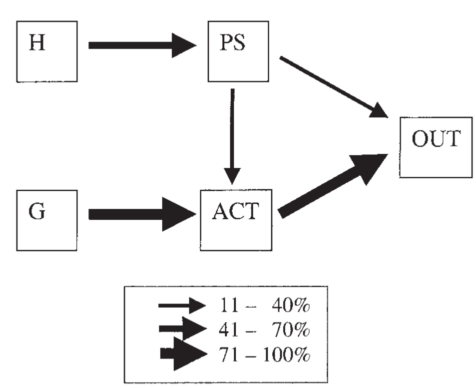

Figure 8. From Experiment 5, the causal model across participants and scenarios showing significant causal relations between history (H), agent goal (G), agent action (ACT), physical structure (PS), and outcome (OUT). Arrow width reflects the percentage of the time that a causal link was produced across participants and scenarios, with the minimum percentage for each width shown.

relations between agent goal and agent action and between agent action and outcome were equally strong, agent action nevertheless had more impact on function judgments. Causal proximity, not causal strength, appears most important in producing functional outcomes.

Experiment 6

As Experiments 1, 2, and 3 demonstrated, learning that an object has a compromised history or agent goal does not diminish its perceived functionality very much. Conversely, learning that an object has a compromised physical structure or agent action diminishes its perceived functionality considerably, even when history and agent goal are adequate. These results suggest that immediate causes are more central to function than distant causes, consistent with the HIPE theory.

However, these findings conflict with studies in which intentional history has been found to be more central to function than physical structure and agent action (Gelman & Bloom, 2000; Gutheil et al., 2004; Matan & Carey, 2001). The causal model that underlies HIPE's predictions (Figure 1C) offers an account of these conflicting results. In these other studies, central components of HIPE's causal model were omitted. In particular, one of the immediate causes was omitted, while the distant causes remained present. As a result, a distant cause, such as history, had a much larger opportunity than usual to affect outcomes via causal updating. If this account is correct, then a distant cause like history does not typically have large effects when immediate causes are present. It can, however, have large effects when an immediate cause is missing.

To see this, consider the specific absences of immediate causes in previous studies that have reported large history effects. In Gelman and Bloom (2000), participants saw an object and received either an accidental (compromised) or intentional (adequate) history for it. Although physical structure was present, agent action was not mentioned, such that an immediate cause was missing. For example, participants were shown a paper hat and told that it was created either accidentally or intentionally. Actions on the hat were not described, however, so no information about this immediate cause was conveyed. Given just this information, the object's perceived function was much higher when it was created intentionally than when it was created accidentally.

In Matan and Carey (2001), participants learned about someone intentionally creating an object to serve one function but later learned that an opportunistic agent used the object for a different function. Participants perceived the original (historically important) function as more central to the object than the later opportunistic function. Although agent action was described, physical structure was left deliberately ambiguous. For example, an object was described as created to be a teapot but was used as a watering can instead, with minimal information about physical structure given.

In Gutheil et al. (2004), participants were asked to name and count the number of each object type in a display of physical objects (e.g., three plastic forks, along with various other objects). After participants counted the objects initially, various transformations on the objects were performed, such as coloring them with a marker. Participants then named and counted the objects again. Finally, one of the plastic forks was crushed, followed by another cycle of naming and counting. Notably, most adults continued to consider the crushed fork a "fork," stating that there were still three forks present. Again, however, important aspects of HIPE's causal chain were absent, including agent action and agent goal.[5]

In the three lines of work just described, the history manipulation had large effects on naming, thereby supporting intentional views. According to HIPE, however, these findings reflect the causal updating principle. As we just saw, participants received scenarios that omitted an immediate cause, thereby providing substantial opportunity for causal updating. When history was intentional, participants may have inferred that a missing immediate cause was adequate. When history was accidental, they may have inferred that a missing immediate cause was compromised. As a result, the difference between intentional and accidental history may have been much larger than if both immediate causes had been present.

To test these predictions, we adapted the scenarios from our previous experiments to implement the types of scenarios presented in Gelman and Bloom (2000), Gutheil et al. (2004), and Matan and Carey (2001). To implement the scenarios in Gelman and Bloom (2000) and Gutheil et al. (2004), we deleted all mention of action in what we call the *missing action scenarios* (history, agent goal, and physical structure remained present).[6] To implement Matan and Carey's scenarios, we deleted all mention of physical structure in what we call the *missing structure scenarios* (history, agent goal, and agent action remained present). Finally, the complete scenarios presented all four components (i.e., history, agent goal, agent action, and physical structure).

Only history was compromised in this experiment. Every other component was always adequate. This manipulation of intentional versus accidental history was crossed with scenario completeness, leading to the following predictions. First, we should continue to see a small effect of compromising history on the complete scenarios. As Experiments 1, 2, and 3 demonstrated, when both immediate causes are specified, accidental history should produce a slight decrement in function relative to intentional history. Second, when either agent action or physical structure is missing, compromising history should produce a significantly larger effect.

[5] Task demands may have also been operative. The referential communication literature shows that when a speaker refers to an object with a specific term, listeners adopt the term as a temporary naming convention (e.g., Clark & Wilkes-Gibbs, 1986; Krauss & Glucksberg, 1977). In Gutheil et al.'s experiments, the experimenter regularly used "fork" while referring to the critical objects on multiple occasions before the critical trial, providing potential for a naming convention to develop. Furthermore, the counting task requires a unit of counting (i.e., a sortal), such that participants may have viewed "fork" as a counting unit, rather than thinking more deeply about whether the crushed fork remained a category member. It would have been interesting to have explicitly probed participants' preference for whether the crushed fork "was" once a fork versus whether it still "is" a fork. Finally, the crushed fork remained in the context of two other intact forks, which may have produced a contextual bias to call it a "fork," given the sortal demands of the counting task.

[6] Unlike Gutheil et al.'s (2004) experiments, we included agent goals. Nevertheless, if our prediction is correct, the absence of agent actions should be sufficient to increase the history effect significantly. Presumably, excluding agent goals along with agent actions would increase history's effect even more.

Because participants lack complete information about an immediate cause, history has larger effects through causal updating. Should this pattern occur, it would resolve the discrepancy between our results and those of other researchers. History can be central but primarily when incomplete information about immediate causes increases causal updating.

On the basis of HIPE's causal structure in Figure 1C, it might appear that compromising history should have no impact when agent action is missing. Because history has no causal path to agent action, it should not produce any causal updating for it. Experiment 5, however, found that participants perceive a causal link between physical structure and agent action that is not present in Figure 1C (see Figure 8). Because this causal path allows history to influence action, compromising history could affect functional outcomes when agent action is missing. Furthermore, because the causal path for agent action was more salient than the causal path for physical structure in Experiment 5, this could amplify indirect interactions between history and a missing agent action.

Given that object naming was the measure assessed in Gelman and Bloom (2000) and Matan and Carey (2001), we examined it here as well (i.e., function and cause ratings were not included). As these and many other researchers have demonstrated (and as we demonstrated earlier), object naming is highly sensitive to perceived function.

Method

Design and participants. The experiment used a 3 × 2 mixed design, with scenario completeness as a between-participants factor and adequate versus compromised history as a within-participants factor. Participants were 36 Emory undergraduates (26 women, 10 men) participating for course credit or pay, with participants assigned randomly to missing structure, missing action, or complete scenarios. Participants read six critical scenarios and performed name ratings only.

Materials. In the adequate history condition, the complete scenarios were identical to the baseline scenarios of Experiment 1 (i.e., all four components were adequate). For the missing structure and missing action scenarios in the adequate history condition, the structure or the action, respectively, was removed from the complete baseline scenario. In the compromised history condition, the complete scenarios, the missing structure scenarios, the and missing action scenarios were the same as those in the adequate history condition, except that history was compromised.

As in previous experiments, two of the objects were the mop and the whistle. The pencil was not included, however, because its function could not be conveyed clearly once its physical structure was removed in the missing structure condition. Thus a new object better suited for this manipulation was used instead, namely, a comb. Its materials are shown in Appendix A.

We constructed six sequences of six scenarios. In each sequence, the three objects were presented once with adequate history and once with compromised history, for a total of six scenarios. Within a given sequence, the same object did not occur consecutively, and scenarios alternated between adequate and compromised history. Across the six sequences, the order of the objects was counterbalanced, along with whether their history was adequate or compromised. The six counterbalanced sequences were distributed equally over the complete, missing structure, and missing action conditions.

Procedure. The procedure was the same as that in Experiment 1.

Results

Figure 9 presents the average ratings across participants and objects from a Scenario Completeness × History ANOVA. The overall analysis revealed main effects of both completeness, $F(2, 33) = 3.92$, $MSE = 1.62$, $p < .05$, $R^2 = .19$, power = .67, and history, $F(1, 33) = 41.30$, $MSE = .91$, $p < .001$, $R^2 = .56$, power = 1. Name ratings were higher for complete than for incomplete scenarios and were also higher for adequate history scenarios than for compromised history scenarios. Most important, scenario completeness and history interacted, $F(2, 33) = 3.48$, $MSE = .91$, $p < .05$, $R^2 = .17$, power = .61. As predicted, history's effect was largest when information about the immediate causes was incomplete. As in previous experiments, when the immediate causes were fully described, history's effect was small but remained present.

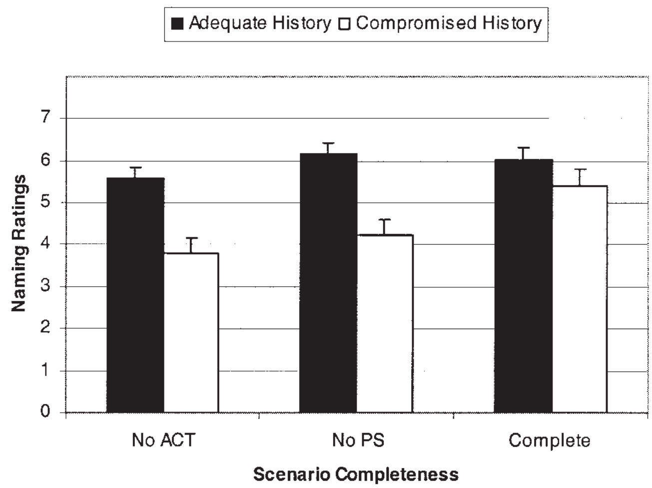

Figure 9. Average naming ratings in Experiment 6 for scenarios lacking a description of agent action (No ACT), for scenarios lacking physical structure (No PS), and for complete scenarios (Complete) as a function of adequate versus compromised history. Error bars are standard errors.

To examine the interaction, we assessed the difference between adequate and compromised history for each of the three completeness conditions. For the two incomplete conditions, the history effect was significant: missing action, $F(1, 11) = 19.75$, $MSE = .96$, $p < .001$, $R^2 = .64$, power = .98; missing structure, $F(1, 11) = 19.39$, $MSE = 1.17$, $p < .001$, $R^2 = .64$, power = .98. For the complete scenario condition, however, the history effect was only marginally significant, $F(1, 11) = 3.77$, $MSE = .59$, $p = .078$, $R^2 = .26$, power = .43. In addition, the two incomplete scenarios did not differ in the size of the history effect, $F(1, 33) = .09$, $MSE = 1.82$, but each exhibited a larger history effect than the complete scenarios: missing action versus complete, $F(1, 33) = 4.49$, $MSE = 1.82$, $p < .05$; missing structure versus complete, $F(1, 33) = 5.86$, $MSE = 1.82$, $p < .05$.

Discussion

As predicted, the absence of an immediate cause amplified the history effect. When both immediate causes were present, the history effect was relatively small, as in Experiments 1, 2, and 3. When an immediate cause was missing, however, the history effect was significantly larger, as in Gelman and Bloom (2000), Gutheil et al. (2004), and Matan and Carey (2001). This pattern is consistent with HIPE's earlier predictions. When both immediate causes are present, they dominate causal reasoning about functional outcomes. History has a small effect through causal updating, because the immediate causes are somewhat ambiguous. Conversely, when an immediate cause is absent, much more potential for causal updating exists, such that varying history has a larger effect. Compromised history produces increased causal updating not only for missing physical structure, but also for missing agent action. As discussed earlier, the latter effect may reflect a causal link from physical structure to agent action and also the greater salience of the causal path for agent action than for physical structure (Figure 8).

Most important, history does not normally have as large an effect on function as previous work has suggested. Instead, immediate causes typically dominate reasoning about function, unless one of them is missing.

Experiment 7

Experiment 6 created conditions that increased the opportunity for causal updating. Experiment 7 created conditions that decreased the opportunity. If causal updating is indeed occurring, then it should be possible to create conditions that both increase and decrease it.

As we have suggested throughout this article, the descriptions of physical structure and agent action in the scenarios were somewhat ambiguous. Because of this ambiguity, history and agent goal were able to have minor effects via causal updating. If this account is correct, then it should be possible to reduce causal updating by decreasing the ambiguity of physical structure and agent action. When these immediate causes are described more precisely, less opportunity should exist for the distant causes to produce causal updating. When history varies from adequate to compromised, its impact on functional outcomes should be less than when the immediate causes are more ambiguous.

To assess this possibility, Experiment 7 manipulated whether the descriptions of agent action and physical structure were vague or detailed. The vague descriptions were the same descriptions of agent action and physical structure used in previous experiments. The detailed descriptions were modified to make it clear that the critical objects readily afforded their associated functions. If the original history effect indeed reflected causal updating, it should diminish as the descriptions of physical structure and action become better specified. Again naming ratings were used, because previous studies that found strong history effects used this measure. Function ratings were also used to see if detailed descriptions further affected people's conceptual understanding of function.

Method

Design and participants. The experiment used a 2 × 2 × 2 mixed design, with vague versus detailed descriptions and adequate versus compromised history as within-participant factors and naming versus function ratings as a between-participants factor. Participants were 48 Emory undergraduates (31 women, 17 men) participating for course credit or pay, with 24 assigned randomly to each rating condition. Participants read eight critical scenarios and performed either name or function ratings only.

Materials. All four objects from the previous experiments were used (mop, whistle, pencil, comb). All four components were presented in each scenario (history, agent goal, agent action, physical structure). In the vague description condition, the previous versions of the agent action and physical structure components were used (Appendix A). In the detailed description condition, more detailed versions of these two components were used instead (Appendix C). Both conditions used the original history and agent goal descriptions from previous experiments (Appendix A).

Each list contained two blocks. All four scenarios in a block were either adequate history scenarios or compromised history scenarios, with half the participants receiving each type of block first. Thus, participants were not aware of the history manipulation during the first block, thereby minimizing demand. If a learning effect was observed across blocks, we could only analyze the first block and throw out the second, treating history as a between-participants factor.

The first block contained the four objects in one random order; the second block contained the same four objects in a different random order. In a given list, two objects had vague descriptions in both blocks, and two had detailed descriptions in both (i.e., each object was studied once with adequate history and once with compromised history). To minimize demand, a given participant did not see the same object in both its vague and detailed versions but did receive both vague and detailed descriptions across the four objects. In counterbalanced versions of the scenarios, the assignment of vague versus detailed description alternated across objects.

Thus the materials consisted of eight lists that resulted from crossing (a) the two object orders used for the two blocks, (b) the two assignments of vague versus detailed descriptions to the four objects, and (c) whether participants received adequate history scenarios or compromised history scenarios first. The eight lists were distributed equally across the two rating conditions.

Procedure. The procedure was the same as that in Experiment 1.

Results

To assess whether learning affected performance across the two history blocks, a Block × History × Description Detail × Rating ANOVA was performed. Block did not have a main effect, $F(1, 46) = .99$, $MSE = 1.40$, power = .16, nor did it interact with history, $F(1, 46) = .26$, $MSE = 2.86$, power = .08, or with description detail, $F(1, 46) = .31$, $MSE = 1.01$, power = .09. In addition, there was no three-way interaction between these factors, $F(1, 46) = .66$, $MSE = 3.34$, power = .13. As a result, keeping history as a within-participant manipulation appeared justified.

Figure 10 presents the average ratings across participants and objects from a History × Description Detail × Rating ANOVA. Rating had a main effect, with function ratings being higher than name ratings, $F(1, 46) = 12.07$, $MSE = 3.23$, $p < .001$, $R^2 = .21$, power = .925. Rating did not enter into any two- or three-way interactions. Because the same pattern occurred for both measures, the following analyses collapse across them.

History and description detail both had main effects. As in previous experiments, adequate history scenarios were rated higher than compromised history scenarios, $F(1, 47) = 36.45$, $MSE = 2.25$, $p < .001$, $R^2 = .44$, power = 1. Consistent with the finding from Experiment 1 that history is particularly important for naming, history had a marginally larger effect on naming ratings than it did on function ratings, $F(1, 46) = 3.04$, $MSE = 2.16$, $p = .088$, $R^2 = .062$, power = .40.

As predicted, detailed scenarios were rated higher than vague ones, $F(1, 47) = 6.56$, $MSE = 1$, $p < .05$, $R^2 = .12$, power = .709. Increasing the specificity of the immediate causes appeared to reduce causal updating. Most important, history and description detail interacted, $F(1, 47) = 14.38$, $MSE = .29$, $p < .001$, $R^2 = .23$, power = .96. This interaction was significant individually for the function ratings, $F(1, 23) = 7.88$, $MSE = .26$, $p < .01$, $R^2 =$

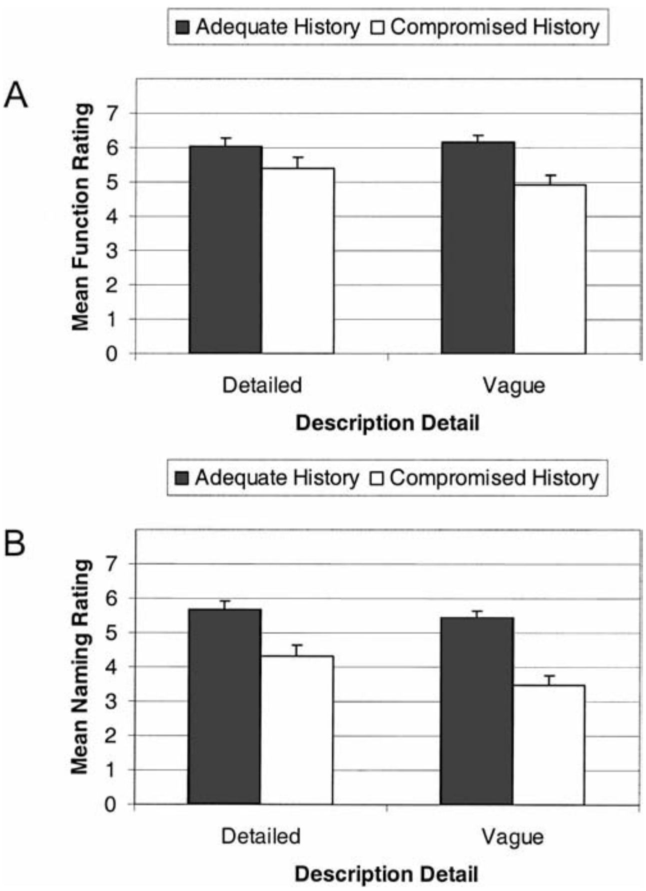

Figure 10. Average function (Panel A) and naming (Panel B) ratings in Experiment 7 for detailed versus vague scenarios as a function of adequate versus compromised history. Error bars are standard errors.

.26, power =.77, and for the naming ratings, $F(1, 23) = 6.40$, $MSE = .34$, $p < .05$, $R^2 = .22$, power = .68. Across both rating conditions, detailed descriptions reduced the size of the history effect significantly, relative to vague descriptions.

Discussion

These findings confirm HIPE's prediction that the specificity of the immediate causes modulates the potential for causal updating. When the original descriptions of physical structure and agent action were used, the small history effect obtained in Experiments 1, 2, 3, and 6 was again obtained. However, when these descriptions were made more detailed, the history effect became even smaller. As the immediate causes became better specified, they had more control over inferred functional outcomes, such that less opportunity for causal updating existed.

Together, Experiments 6 and 7 show that it is possible to modulate causal updating in either direction. When the immediate causes are highly ambiguous, large amounts of causal updating can occur (Experiment 6). Distant causes, such as history, can have large effects, as observed in previous research. Conversely, as the immediate causes become increasingly well specified, they dominate functional reasoning, thereby minimizing causal updating (Experiment 7). Under these conditions, the effects of distant causes become increasingly small.

General Discussion

We first review the implications of these results for theories of functional reasoning, including affordance theories, intentional theories, and the HIPE theory. We then review implications of these results for different measures of function. Finally, we explore further aspects of causal reasoning that bear on the interpretation of our findings.

Causal Proximity and Causal Updating in Functional Reasoning

We began with the issue of whether affordances or intentions underlie people's functional reasoning. According to affordance theorists, the physical structure of an object and an agent's action determine an object's functionality. According to intentional theorists, an object's functionality primarily reflects what the object's designer intended it to be. The experiments reported here could be taken as offering more support for affordance theories than for intentional theories. Across experiments, the affordance causes—physical structure and agent action—had more impact on people's functional reasoning than did the intentional causes—history and agent goal. Nevertheless, the intentional causes consistently had small effects, which became larger when affordance causes were missing. Such effects pose problems for affordance theories, which typically do not assume explicitly that intentions enter into functional reasoning. Nevertheless, the affordance causes had considerably more impact, which poses problems for intentional theories. A more serious problem for intentional theories is that intentional history was not necessary for assigning names to objects. As long as physical structure and agent action were both adequate, participants were comfortable applying category names to objects, even when those objects had been created accidentally.

The HIPE theory offers an alternative account of functional reasoning (Barsalou et al., in press; Chaigneau & Barsalou, in press). According to HIPE, people construct causal models dynamically to reason about function. Furthermore, when descriptions of affordance and intentional causes are present simultaneously, people incorporate both into causal models, as in Figure 1C. Most important, HIPE assumes that principles of causal reasoning underlie functional reasoning.

In particular, HIPE proposes that the principles of causal proximity and causal updating are central. According to the causal proximity principle, immediate causes, such as physical structure and agent action, dominate functional reasoning because they bear on functional outcomes directly. When physical structure and agent action are specified fully, they are sufficient to determine functional outcomes. Under these conditions, distant causes, such as history and agent goal, have little effect. Thus, physical structure and agent action do not dominate because they are affordance causes per se. Instead they dominate because they bear directly on functional outcomes in causal models.

When an immediate cause is ambiguous or missing, however, the distant causes indirectly affect functional outcomes. According to the causal updating principle, the distant causes influence the forms of immediate causes that are not fully specified. Because the descriptions of physical structure and agent action were typically brief and somewhat ambiguous in the experiments here, they offered potential for modest causal updating. As a result, the distant causes produced small effects on functional judgments across experiments.

A variety of other effects across experiments also supported the presence of causal updating. When both distant causes were manipulated simultaneously (Experiment 2), causal updating showed a cumulative effect. Compromising both distant causes simultaneously had more impact on functional outcomes than when only one was compromised, consistent with the prediction that they each influenced an immediate cause. When an immediate cause was missing (Experiment 6), the greatest potential for causal updating existed. Under these conditions, history had a much larger effect on functional outcomes than usual, given its unconstrained potential to shape the missing cause. Conversely, when the descriptions of the immediate causes were made more specific (Experiment 7), less potential for causal updating existed. Under these conditions, history's effect became significantly smaller than usual.

Three control experiments ruled out alternative interpretations and verified key assumptions. Experiment 3 demonstrated that narrative order played little role in these experiments. One very small recency benefit appeared for information about the agent's goal. In general, though, participants appeared to integrate the causes from different presentation orders into the same underlying causal model, such that the immediate causes dominated under different narrative orders.

Experiment 4 showed that differences in manipulation strength were not responsible for the immediate causes having more impact. To the contrary, the manipulations were generally stronger for the distant causes than for the immediate ones. Nevertheless, the immediate causes had greater impact, further supporting the causal proximity principle.

Finally, Experiment 5 verified that participants constructed causal models like Figure 1C while comprehending the scenarios in these experiments. According to this scaling study, participants viewed physical structure and agent action as the only two immediate causes of function. They further viewed history and agent goal as distant causes that determine physical structure and agent action, respectively. Thus, participants perceived the causal structure that underlies HIPE's predictions.

Measuring Function

Across experiments, three measures of object knowledge were assessed: function, causality, and naming judgments. All three showed the same general pattern; namely, the immediate causes dominated the distant causes. Nevertheless, other more specific patterns emerged as well. First, function and causality judgments behaved the same. In Experiments 1 and 2, the ordering of compromised causes for causality judgments was identical to the ordering for function judgments. The equivalence of function and causality ratings supports HIPE's central assumption that causal models underlie people's conception of function. As people reason about the function of an object, they appear to assemble a causal understanding of the relevant entities and events. As a result, function judgments closely follow causal judgments.

Naming judgments exhibited three departures of interest. First, history had more impact on naming than on function and causality (Experiments 1 and 7). Second, physical structure dominated agent action in naming, whereas agent action dominated physical structure in causality and function judgments (Experiment 1). Third, agent goal did not have a significant effect on naming but did have one on function and causality (Experiment 1). These three results suggest that naming judgments focused participants' attention on the causal path in Figure 1C that runs from history to physical structure to outcome. When participants judged the appropriateness of a name, they appeared to place more importance on history and physical structure than when they judged function and causality.

At least two factors could underlie this emphasis. First, people may focus on an object's physical structure so that they can establish whether it is sufficient to support later action associated with a named category. Assigning a category name to an object may more reflect its *potential* to be used for a particular function than its actual use. If so, physical structure could be more important for naming than for judging causality and function. Alternatively, history may be particularly important for naming because it determines an object's physical structure. As intentional theorists suggest, the intention to create an object for a particular purpose constrains its physical form (e.g., Bloom, 1996, 1998). Because history causes physical structure, and because physical structure is central for assessing functional potential, these two causal factors may play central roles in naming.

Finally, the stimuli in the experiments here were texts, and the responses were ratings. An important issue is whether these results generalize to interactions with physical stimuli. In related work, Chaigneau, Barsalou, and Zamani (2004) asked participants to predict the functions of physical objects. As found here, the immediate causes in Figure 1C—physical structure and agent action—were again central for functional reasoning. Developmental work using physical objects has similarly found that physical structure and agent action are central to function (e.g., Kemler-Nelson, 1995; Kemler-Nelson, Frankenfield, et al., 2000; Kemler-Nelson, Russell, et al., 2000). Together, these findings suggest that the results reported here generalize.

Alternative Accounts

We first explore the implications of our results for independent and interactive cue models of causality. We then explore the possible role of the similarity heuristic in our experiments.

Independent and interactive cue models of causality. Although it is tempting to explain our results with a simple independent cue model, it is not satisfactory. Consider an associative implementation of an independent cue model, namely, a simple linear network having scenario components as inputs and functional outcomes as outputs. For our mop scenarios, the inputs would include the adequate and compromised forms of physical structure, agent action, agent goal, and history. Although these eight inputs constitute a small subset of the knowledge that people have for mops, they are sufficient for this example. Similarly, the outputs for the mop would include various functional outcomes that could occur while using it. Each input form of a scenario component is connected to every possible outcome, with the sign and strength of each connection reflecting whether its scenario component activates or inhibits its functional outcome and how strongly. Thus, when a particular scenario is encountered, the particular forms of physical structure, agent action, agent goal, and history present converge on the functional outcome most strongly associated to them as a group. This particular outcome then becomes the inferred outcome for the scenario.

One problem for this account is its assumption that each potential cause operates independently of the other causes. Experiments 6 and 7 offer examples of interactions between causes that this model cannot explain. In Experiment 6, the presence or absence of an immediate cause modulated the size of the history effect. In Experiment 7, the vagueness or specificity of an immediate cause similarly modulated history. To explain these results, some means of implementing interactions between causes is necessary. A simple independent causes model will not work.

An obvious way to implement interactions is to add a layer of hidden units between the input and output layer. The hidden units could conjoin particular combinations of causes, such that a given cause's influence on outcomes is modulated by the presence or absence of other causes. For example, a compromised history cause could have small impact when both immediate causes are present but have more impact when one is absent. Thus, more complex models explain interactions by adding a layer of representation that captures relations between input causes.

Another problem arises, however, for both independent cue models and their interactive relatives. Frequently in causal reasoning, people represent causal states that do not currently reside in long-term memory. Consider the scenarios used in the experiments here. In many cases, the compromised forms of scenario components were highly novel (e.g., accidentally creating a mop, a mop having plastic bags on the end). Even some of the adequate scenario components may have been novel as well (e.g., intentionally creating a mop using a stick and some rags). Furthermore, many of the inferred functional outcomes may have also been novel (e.g., accidentally wiping up a spill by dragging a mop through it).

Problematically, independent and interactive cue models tend to assume that all relevant causal states are prestored in memory. Mechanisms typically do not exist for creating new causal states on the fly. Clearly, though, people readily construct such states during causal reasoning. The ability to do so offers obvious utility in reasoning about the attainment of novel goals (e.g., how to clean up a spill when a commercially produced mop is not available).

The ability to construct novel representations is typically associated with more symbolic accounts of cognition, such as those that use classic representation languages in artificial intelligence (e.g., Chandrasekaran & Josephson, 2000; Forbus, 1993). This capability also exists in simulation-based accounts of symbolic processing (e.g., via the productive simulation mechanisms in Barsalou, 1999, 2003a). Regardless of how symbolic functioning is implemented, it is clear that novel causal states are constructed ubiquitously in human reasoning. Nevertheless, it is also highly likely that probabilistic and associative processes play central roles as well. Thus, models that combine all these mechanisms will probably be necessary to explain causal reasoning (cf. Sloman & Rips, 1998).

The similarity heuristic. Another relatively superficial, noncausal form of reasoning could have also played a role in our experiments. When participants were inferring functional outcomes, they could have assessed the similarity of the experimental scenarios to typical scenarios stored in memory (Kahneman & Tversky, 1972). For example, when participants received the baseline mop scenario, they could have compared it with a typical mop scenario acquired either from mopping floors oneself or from watching others. Participants may have then assessed the similarity of the baseline scenario to the typical scenario, thereby assessing whether the former was representative of the latter. To the extent that it was, participants may have inferred that the baseline scenario was likely to have a positive functional outcome. Alternatively, when participants received the compromised action scenario, the accidental mopping action may have differed enough from the typical mopping action that a negative outcome seemed likely.

Assessing similarity in this manner requires no causal reasoning. Instead, relatively superficial similarity judgments guide inference. Findings from Rehder (1999) suggest that similarity does indeed enter into causal judgments. While assessing causal relations during categorization, Rehder found that noncausal features influenced performance. Even though a causal relation fully defined category membership, participants nevertheless used similarity in their judgments as well.

Similarity offers a post hoc explanation of various results in our experiments. Whenever a scenario component was compromised (e.g., Experiment 1), it could have decreased the scenario's similarity relative to the typical functional situation. Rather than reasoning causally, participants could have simply noted this drop in similarity and lowered their ratings accordingly. Similarly, when two scenario components were compromised (Experiment 2), this could have decreased similarity further, such that participants lowered their ratings still more.

Other findings from these experiments are more difficult for the similarity account to explain. For example, why did some scenario components affect functional outcomes more than others? Why were physical structure and agent action more important than history and agent goal? As the literature on similarity has shown, background theories typically specify which features are relevant to similarity and the weights that they receive (e.g., Kim & Ahn, 2002). Notably, causal structures are widely viewed as underlying these functions. Features become important in similarity because they have a central status in causal networks (e.g., Sloman et al., 1998). It follows that any greater weight attributed to physical structure and agent action, relative to history and agent goal, is likely to have reflected causal reasoning of the sort proposed here. If participants used similarity, causal reasoning probably played a role in determining the feature weights.

Further problems for the similarity account are the interactions between causes in Experiments 6 and 7, where history's impact was modulated by the status of physical structure and agent action. Similar to feature weighting, theorists have argued that background theories establish relations between features during similarity judgments (e.g., Markman & Gentner, 1997). Again, these relations are often assumed to reflect underlying causal relations. Thus, interactions between feature weights during similarity judgments are also likely to have reflected causal reasoning.

As these examples illustrate—and much additional literature as well—causal reasoning plays a central role throughout the processing of similarity. It is unlikely that participants adopted a similarity strategy that included no underlying causal reasoning at some point in its history. Both Kahneman and Tversky (1972) and Rehder and Burnett (in press) reached related conclusions about the roles of causal reasoning in similarity.

So, how might a superficial similarity heuristic nevertheless enter into the functional reasoning process? We suspect that the similarity heuristic interacts with whether functional reasoning is superficial or deep. To be more specific, we assume that people perform much relatively deep processing of causal relations in the world (although see Rozenblit & Keil, 2002). As common artifacts are encountered repeatedly, especially during development, people explore the underlying causal mechanisms to understand their functions. As a result, causal models become established in memory to represent these understandings. Even after extensive learning, if these objects are encountered in novel conditions, further causal reasoning may be necessary to understand variants on their typical functions (e.g., the compromised scenarios in our experiments).

Conversely, we assume that established causal models in long-term memory can be processed superficially. Once a causal model becomes established, people may be able to retrieve content from it without processing the underlying causal relations. Under these conditions, people simply note the similarity between a current artifact and superficially retrieved features from a causal model. As a result, superficial similarity enters into judgments of function.

An important thing to note, however, is that the superficial use of information from causal models may primarily occur for highly familiar scenarios under speeded conditions. Because our experiments used novel scenarios and because participants were under no time pressure, it is likely that they performed extensive causal reasoning to reach their judgments. Nevertheless, some superficial processing of similarity may have occurred automatically and played a role in their judgments as well.

Conclusion

Previous research on function has often pitted affordances against intentions. Our findings suggest that this mutually exclusive approach is too simplistic. Function appears to be a complex relational construct that includes both affordance and intentional causes. Furthermore, the relative importance of these causes appears to reflect properties of causal reasoning, rather than properties of affordances and intentions per se. Important properties of causal reasoning appear to include the distinction between immediate versus distant causes in causal models, the inclusion versus omission of immediate causes, the vagueness of immediate causes, and so forth. Factors like these may go a long way toward explaining the relative importance of affordances and intentions in functional reasoning.

References

Ahn, W. (1998). Why are different features central for natural kinds and artifacts? The role of causal status in determining feature centrality. *Cognition, 69,* 135–178.

Ahn, W., & Bailenson, J. (1996). Causal attribution as a search for underlying mechanisms: An explanation of the conjunction fallacy and the discounting principle. *Cognitive Psychology, 31,* 82–123.

Ahn, W., & Kalish, C. W. (2000). The role of mechanism beliefs in causal reasoning. In F. Keil & R. Wilson (Eds.), *Explanation and cognition* (pp. 199–225). Cambridge, MA: MIT Press.

Ahn, W., Kalish, C. W., Medin, D. L., & Gelman, S. A. (1995). The role of covariation versus mechanism information in causal attribution. *Cognition, 54,* 299–352.

Barsalou, L. W. (1987). The instability of graded structure: Implications for the nature of concepts. In U. Neisser (Ed.), *Concepts and conceptual development: Ecological and intellectual factors in categorization* (pp. 101–140). Cambridge, England: Cambridge University Press.

Barsalou, L. W. (1999). Perceptual symbol systems. *Behavioral and Brain Sciences, 22,* 577–660.

Barsalou, L. W. (2003a). Abstraction in perceptual symbol systems. *Philosophical Transactions of the Royal Society of London: Biological Sciences, 358,* 1177–1187.

Barsalou, L. W. (2003b). Situated simulation in the human conceptual system. *Language and Cognitive Processes, 18,* 513–562.

Barsalou, L. W., Sloman, S. A, & Chaigneau, S. E. (in press). The HIPE theory of function. In L. Carlson & E. van der Zee (Eds.), *Representing functional features for language and space: Insights from perception, categorization and development*. Oxford, England: Oxford University Press.

Barton, M. E., & Komatsu, L. K. (1989). Defining features of natural kinds and artifacts. *Journal of Psycholinguistic Research, 18,* 433–447.

Bloom, P. (1996). Intention, history, and artifact concepts. *Cognition, 60,* 1–29.

Bloom, P. (1998). Theories of artifact categorization. *Cognition, 66,* 87–93.

Chaigneau, S. E. (2002). *Studies in the conceptual structure of object function*. Unpublished doctoral dissertation, Emory University, Atlanta, GA.

Chaigneau, S. E., & Barsalou, L. W. (in press). The role of function in categorization. *Theoria et Historia Scientiarum*.

Chaigneau, S. E., Barsalou, L. W., & Zamani, M. (2004). *Function as a multimodal relational construct*. Manuscript in preparation.

Chandrasekaran, B., & Josephson, J. R. (2000). Function in device representation. *Engineering With Computers, 16,* 162–177.

Chao L. L., & Martin A. (2000). Representation of manipulable man-made objects in the dorsal stream. *Neuroimage, 12,* 478–484.

Cheng, P. W. (1997). From covariation to causation: A causal power theory. *Psychological Review, 104,* 367–405.

Cheng, P. W., & Novick, L. R. (1992). Covariation in natural causal induction. *Psychological Review, 99,* 365–382.

Clark, H. H., & Wilkes-Gibbs, D. (1986). Referring as a collaborative process. *Cognition, 22,* 1–39.

Cree, G. S., & McRae, K. (2003). Analyzing the factors underlying the structure and computation of the meaning of chipmunk, cherry, chisel, cheese, and cello (and many other such concrete nouns). *Journal of Experimental Psychology: General, 132,* 163–201.

Diesendruck, G., Markson, L., & Bloom, P. (2003). Children's reliance on creator's intent in extending names for artifacts. *Psychological Science, 14,* 164–168.

Farrar, M. J., Raney, G. E., & Boyer, M. E. (1992). Knowledge, concepts, and inferences in childhood. *Child Development, 63,* 673–691.

Fincher-Kiefer, R. (2001). Perceptual components of situation models. *Memory and Cognition, 29,* 336–343.

Forbus, K. (1993). Qualitative process theory: Twelve years after. *Artificial Intelligence, 59,* 115–123.

Gelman, S. A. (1988). The development of induction within natural kind and artifact categories. *Cognitive Psychology, 20,* 65–95.

Gelman, S. A., & Bloom, P. (2000). Young children are sensitive to how an object was created when deciding what to name it. *Cognition, 76,* 91–103.

Gentner, D. (1978). What looks like a jiggy but acts like a zimbo? A study of early word meaning using artificial objects. *Papers and Reports on Child Language Development, 15,* 1–6.

Gentner, D., & Rattermann, M. J. (1991). Language and the career of similarity. In S. Gelman & J. Byrnes (Eds.), *Perspectives on language* *and thought: Interrelations in development* (pp. 225–277). New York: Cambridge University Press.

Gibson, J. J. (1950). *The perception of the visual world*. Boston: Houghton Mifflin.

Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston: Houghton Mifflin.

Glenberg, A. M., & Kaschak, M. P. (2002). Grounding language in action. *Psychonomic Bulletin & Review, 9,* 558–569.

Glenberg, A. M., & Robertson, D. A. (2000). Symbol grounding and meaning: A comparison of high-dimensional and embodied theories of meaning. *Journal of Memory and Language, 43,* 379–401.

Glymour, C. (2001). *The mind's arrows: Bayes nets and graphical causal models in psychology*. Cambridge, MA: MIT Press.

Gutheil, G., Bloom, P., Valderrama, N., & Freedman, R. (2004). The role of historical intuitions in children's and adult's naming of artifacts. *Cognition, 91,* 23–42.

Hauk, O., Johnsrude, I., & Pulvermüller, F. (2004). Somatopic representation of action words in human motor and premotor cortex. *Neuron, 41,* 301–307.

Heit, E., & Rubinstein, J. (1994). Similarity and property effects in inductive reasoning. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 20,* 411–422.

Kahneman, D., & Tversky, A. (1972). Subjective probability: A judgment of representativeness. *Cognitive Psychology, 3,* 430–454.

Kaschak, M. P., & Glenberg, A. M. (2000). Constructing meaning: The role of affordances and grammatical constructions in sentence comprehension. *Journal of Memory and Language, 43,* 508–529.

Keil, F. C. (1989). *Concepts, kinds, and cognitive development*. Cambridge, MA: MIT Press.

Kellenbach, M. L., Brett, M., & Patterson, K. (2003). Actions speak louder than functions: The importance of manipulability and action in tool representation. *Journal of Cognitive Neuroscience, 15,* 30–46.

Kemler-Nelson, D. G. (1995). Principle-based inferences in young children's categorization: Revisiting the impact of function on the naming of artifacts. *Cognitive Development, 10,* 347–380.

Kemler-Nelson, D. G., Frankenfield, A., Morris, C., & Blair, E. (2000). Young children's use of functional information to categorize artifacts: Three factors that matter. *Cognition, 77,* 133–168.

Kemler-Nelson, D. G., Russell, R., Duke, N., & Jones, K. (2000). Two-year-olds name artifacts by their functions. *Child Development, 71,* 1271–1288.

Kim, N., & Ahn, W. (2002). Clinical psychologists' theory-based representations of mental disorders predict their diagnostic reasoning and memory. *Journal of Experimental Psychology: General, 131,* 451–476.

Krauss, R. M., & Glucksberg, S. (1977). Social and nonsocial speech. *Scientific American, 236,* 100–105.

Landau, B., Smith, L. B., & Jones, S. S. (1998). Object shape, object function, and object name. *Journal of Memory and Language, 38,* 1–27.

Madole, K. L., & Oakes, L. M. (in press). Infants' attention to and use of functional properties in categorization. In L. Carlson & E. van der Zee (Eds.), *Functional features in language and space: Insights from perception, categorization, and development*. Oxford, England: Oxford University Press.

Malt, B. C., & Johnson, E. C. (1992). Do artifact concepts have cores? *Journal of Memory and Language, 31,* 195–217.

Malt, B. C., & Sloman, S. A. (in press). Artifact concepts are artifactual. In E. Margolis & S. Laurence (Eds.), *Creations of the mind: Essays on artifacts and their representation*. Oxford, England: Oxford University Press.

Markman, A. B., & Gentner, D. (1997). The effects of alignability on memory. *Psychological Science, 8,* 363–367.

Martin, A. (2001). Functional neuroimaging of semantic memory. In R. Cabeza & A. Kingstone (Eds.), *Handbook of functional neuroimaging of cognition* (pp. 153–186). Cambridge, MA: MIT Press.

Matan, A., & Carey, S. (2001). Developmental changes within the core of artifact concepts. *Cognition, 78,* 1–26.

Medin, D. L., Lynch, E. B., Coley, J. D., & Atran, S. (1997). Categorization and reasoning among tree experts: Do all roads lead to Rome? *Cognitive Psychology, 32,* 49–96.

Pearl, J. (2000). *Causality: Models, reasoning, and inference.* Cambridge, UK: Cambridge University Press.

Prasada, S. (1999). Names for things and stuff: An Aristotelian perspective. In R. Jackendoff, P. Bloom, & K. Wynn (Eds.), *Language, logic, and concepts: Essays in honor of John Macnamara* (pp. 119–146). Cambridge, MA: MIT Press.

Putnam, H. (1975). The meaning of "meaning." In H. Putnam (Ed.), *Mind, language and reality. Philosophical papers* (Vol. 2, pp. 215–271). Cambridge, UK: Cambridge University Press.

Rehder, B. (1999). A causal model theory of categorization. In *Proceedings of the 21st annual meeting of the Cognitive Science Society* (pp. 595–600). Mahwah, NJ: Erlbaum.

Rehder, B., & Burnett, R. C. (in press). Inferring unobserved category features with causal knowledge. *Cognitive Psychology*.

Richardson, D. C., Spivey, M. J., Barsalou, L. W., & McRae, K. (2003). Spatial representations activated during real-time comprehension of verbs. *Cognitive Science, 27,* 767–780.

Rips, L. J. (1989). Similarity, typicality, and categorization. In S. Vosniadou & A. Ortony (Eds.), *Similarity and analogical reasoning* (pp. 21–59). New York: Cambridge University Press.

Ross, B. H., & Murphy, G. L. (1999). Food for thought: Cross-classification and category organization in a complex real-world domain. *Cognitive Psychology, 38,* 495–553.

Rozenblit, L., & Keil, F. (2002). The misunderstood limits of folk science: An illusion of explanatory depth. *Cognitive Science, 26,* 521–562.

Shanks, D. R. (1991). On similarities between causal judgments in experienced and described situations. *Psychological Science, 2,* 341–350.

Sloman, S. A., & Lagnado, D. (2004). Causal invariance in reasoning and learning. In B. Ross (Ed.), *The psychology of learning and motivation* (Vol. 44, pp. 287–325). San Diego, CA: Academic Press.

Sloman, S. A., Love, B., & Ahn, W. (1998). Feature centrality and conceptual coherence. *Cognitive Science, 22,* 189–228.

Sloman, S. A., & Malt, B. C. (2003). Artifacts are not ascribed essences, nor are they treated as belonging to kinds. *Language and Cognitive Processes, 18,* 563–582.

Sloman, S. A., & Rips, L. J. (1998). Similarity as an explanatory construct. *Cognition, 65,* 87–101.

Smith, L. B. (1999). Children's noun learning: How general learning processes make specialized learning mechanisms. In B. MacWhinney (Ed.), *The emergence of language* (pp. 277–303). Mahwah, NJ: Erlbaum.

Smith, L. B., Jones, S. S., & Landau, B. (1996). Naming in young children: A dumb attentional mechanism? *Cognition, 60,* 143–171.

Spellman, B. A. (1997). Crediting causality. *Journal of Experimental Psychology: General, 126,* 323–348.

Spivey, M., Tyler, M., Richardson, D., & Young, E. (2000). Eye movements during comprehension of spoken scene descriptions. In *Proceedings of the 22nd annual conference of the Cognitive Science Society* (pp. 487–492). Mahwah, NJ: Erlbaum.

Stanfield, R. A., & Zwaan, R. A. (2001). The effect of implied orientation derived from verbal context on picture recognition. *Psychological Science, 12,* 153–156.

Tomikawa, S. A., & Dodd, D. H. (1980). Early word meanings: Perceptually or functionally based. *Child Development, 51,* 1103–1109.

Tversky, B. (1989). Parts, partonomies, and taxonomies. *Developmental Psychology, 25,* 983–995.

Waldmann, M. R. (1996). Knowledge-based causal induction. In D. R. Shanks, K. J. Holyoak, & D. L. Medin (Eds.), *The psychology of*

learning and motivation: Causal learning (pp. 47–88). San Diego, CA: Academic Press.
Waldmann, M. R., & Holyoak, K. J. (1992). Predictive and diagnostic learning within causal models: Asymmetries in cue competition. *Journal of Experimental Psychology: General, 121,* 222–236.
Warrington, E. K., & Shallice, T. (1984). Category specific semantic impairments. *Brain, 107,* 829–854.
Wimsatt, W. C. (1972). Teleological and logical structure of function statements. *Studies in History and Philosophy of Science, 3,* 1–80.
Wright, L. (1973). Functions. *Philosophical Review, 82,* 139–168.
Zwaan, R. A., Stanfield, R. A., & Yaxley, R. H. (2002). Language comprehenders mentally represent the shapes of objects. *Psychological Science, 13,* 168–171.

Appendix A

Core Materials for the Scenarios in Experiments 1, 2, 3, 4, 6, and 7

Appendix A presents baseline and compromised scenarios for the mop, pencil, whistle, and comb used across most experiments. Participants read the scenarios as unbroken narratives. For clarity, however, we present them here broken up into separate components for history, physical structure, goal, and agent action. In the actual scenarios, the components were strung together to form a continuous text in the order shown here, except for Experiments 3 and 7, where additional orders were used as well. See Figure 2 for an example.

In the baseline scenarios, components for history, physical structure, goal, and agent action were shown, all uncompromised. In a compromised scenario, one or more compromised components replaced their noncompromised counterparts in the text, again strung together continuously. The names below for the components were not shown in any of the scenarios (i.e., history, goal, physical structure, action). The baseline components are shown first, followed by their compromised counterparts. The three rating questions used in all experiments are shown at the end.

Mop Baseline Scenario

History

One day Jane wanted to wipe up a water spill on the kitchen floor, but she didn't have anything to do it with. So she decided to make something. She looked around the house for things that would allow her to make an object for wiping up a water spill on the kitchen floor. She gathered all the materials and made it. When she finished, she left it in the kitchen so she could use it later.

Physical Structure

The object consisted of a bundle of thick cloth attached to a 4-foot long stick.

Goal

Later that day, John was looking for something to wipe up a water spill on the kitchen floor. He saw the object that Jane had made and thought that it would be good for wiping up a water spill on the kitchen floor.

Action

He grabbed the object with the bundle of thick cloth pointing downward and pressed it against the water spill.

Mop Compromised Components

History

One day Jane was cleaning the attic. She picked up a bunch of useless things and put them all inside a big cardboard box. Because the box was overflowing, she used a long stick to shove things down. As she did this, something became attached to the stick. Then, Jane carried the box downstairs. She didn't notice that as she did this, the stick and the thing that was attached to it fell together, as a single object, to the floor.

Physical Structure

The object consisted of a bundle of plastic bags attached to a 4-foot long stick.

Goal

Later that day, John was in the kitchen looking for something to eat. He was distracted as he looked for something and inadvertently grabbed the object that Jane had left in the kitchen.

Action

He grabbed the object with the bundle of thick cloth pointing upward instead of downward, and pressed the bare wood end against the water spill.

(Note that to keep scenarios consistent, when physical structure was compromised by introducing "a bundle of plastic bags" in its description, the action component also referred to the plastic bags rather than to "a bundle of thick cloth.")

Pencil Baseline Scenario

History

One day Jane wanted to draw lines on a white sheet of paper, but she didn't have anything to do it with. So she decided to make something. She looked around the house for things that would allow her to make an object for drawing lines on a white sheet of paper. She gathered all the materials and made it. When she finished, she left it on a table so she could use it later.

Physical Structure

The object consisted of a slender wooden stick, approximately 3 inches in length, which had been lightly burned.

Goal

Later that day, John was looking for something to draw lines on a white sheet of paper. He saw the object that Jane had made and thought that it would be good for drawing lines on a white sheet of paper.

Action

He grabbed the object and pressed its tip against the white sheet of paper while moving his hand in different directions.

Pencil Compromised Components

History

One day Jane noticed that the fireplace needed to be cleaned. She piled up the ashes, half-burned logs, and sticks and carefully transferred everything into an ash bucket. She didn't notice that as she did this, one object fell on the floor.

Physical Structure

The object consisted of a slender wooden stick, approximately 3 inches in length, that had been polished with sandpaper.

Goal

Later that day, John was sitting at the table while eating his lunch. He was distracted as he munched and inadvertently grabbed the object that Jane had left on the table.

Action

He grabbed the object and waved it in front of the white piece of paper without ever touching it.

Whistle Baseline Scenario

History

One day Jane wanted to call her dog (who was out in the garden and was trained to answer to a high-pitch sound), but she didn't have anything to do it with. So she decided to make something. She looked around the house for things that would allow her to make an object for calling her dog. She gathered all the materials and made it. When she finished, she left it on a table so she could use it later.

Physical Structure

The object was a conical sea shell that now had its tip broken.

Goal

Later that day, John was looking for something to call his dog with. He saw the object that Jane had made and thought that it would be good for calling his dog.

Action

He grabbed the object, put its tip in his mouth, and blew.

Whistle Compromised Components

History

One day Jane wanted to clean up her desk. She reviewed different documents and objects that were on her desk and began to put all unwanted items in a cardboard box. Because she wasn't careful when throwing objects into the box, the tip of one of the objects she discarded broke.

Physical Structure

The object was a conical sea shell that now had its tip broken and replaced with a solid piece of plastic resin that completely blocked the opening.

Goal

Later that day, John was searching on the table for something to play with. He was distracted as he looked for something and inadvertently grabbed the sea shell.

Action

He grabbed the object, put his mouth near the wider opening, and whispered his dog's name.

Comb Baseline Scenario (Experiments 6 and 7 Only)

History

One day Jane wanted to comb her hair, but she didn't have anything to do it with. So she decided to make something. She looked around the house for things that would allow her to make an object for combing her hair. She gathered all the materials and made it. When she finished, she left it on a table so she could use it later.

Physical Structure

It was a toothed object of about 8 inches in length.

Goal

Later that day, John was looking for something to comb his hair with. He saw the object that Jane had left on the table and thought that it would be good for combing his hair.

Action

He grabbed the object and pulled it through his hair.

Comb Compromised Components

Because history was the only component ever compromised for the comb, compromised versions of physical structure, goal, and action are not shown.

History

One day Jane wanted to do something with a bunch of plastic scrap she had. She wanted to put it somewhere so that she could inspect it later, but she didn't know where to put it. So, she decided to put it temporarily in the oven. Because she didn't notice that her oven was on, when she retrieved the scrap, some of it had melted. She left everything on a table so that it would cool down.

Rating Questions

Causal Question

"How likely would it be that, as a result of the events described above, John *X*?" Depending on the scenario, *X* was "wiped up the water spill," "drew lines on the white piece of paper," or "called his dog."

Function Question

"How well does this scenario illustrate the function of a *X*?" Depending on the scenario, *X* was "mop," "charcoal pencil," "whistle," or "comb."

Naming Question

"Is it appropriate to call this object a *X*?" Depending on the scenario, *X* was "mop," "charcoal pencil," "whistle," or "comb."

(*Appendixes continue*)

Appendix B

Materials for Experiment 5

This appendix presents the content of the text boxes presented to participants that they were to connect causally. Outcomes were included so that a final effect was available for the other four components to cause. The names below for the components were not shown in any of the scenarios (i.e., history, goal, physical structure, action, outcome).

Mop

History

Some unknown person designed and constructed the object for the purpose of cleaning up liquid spills.

Physical Structure

The object's physical structure consisted of several cloth rags that had been attached intentionally to one end of the long stick.

Goal

Person *X* wanted to clean up the water spill.

Action

Person *X* found the object, pressed the end with the rags against the water on the floor, and moved the object back and forth repeatedly.

Outcome

The object absorbed the water.

Pencil

History

Some unknown person designed and constructed the object for the purpose of drawing on paper.

Physical Structure

The object's physical structure consisted of the 3-inch slender wooden stick that had been intentionally burnt lightly on one end.

Goal

Person Y wanted to draw lines on the white piece of paper.

Action

Person *Y* found the object, pressed the end with charcoal against the sheet of paper, and moved the object in different directions.

Outcome

Black lines appeared on the sheet of paper.

Whistle

History

Some unknown person designed and constructed the object for the purpose of calling dogs.

Physical Structure

The object's physical structure consisted of the conical sea shell whose tip had been intentionally broken off, revealing the thin edge inside.

Goal

Person *Z* wanted to call her dog, who was some distance away.

Action

Person *Z* found the object, put the broken end to her lips, and blew into the object smoothly.

Outcome

The high-pitched sound came out of the object.

Appendix C

Additional Materials Used in Experiment 7

In Experiment 7, the components for physical structure and action were sometimes presented in more detailed forms. The detailed versions of these two components are shown here for all objects. With the exception of physical structure for comb, all vague descriptions for physical structure and action were the same as in Appendix A. To increase the readability of the comb scenarios, however, their vague description of physical structure in Appendix A was revised slightly. This new vague description and the corresponding detailed description both appear here for comb.

Mop

Physical Structure

The object consisted of 12 rags of long thick cloth all firmly attached to the end of a 4-foot-long stick.

Action

He grabbed the object, pointing the rags downward, and rubbed them repeatedly against the water spill.

Pencil

Physical Structure

The object consisted of a slender wooden stick, approximately 3 inches in length, lightly burnt at the tip.

Action

He grabbed the object and pressed its burnt tip against a white sheet of paper, while moving it systematically across the sheet.

Whistle

Physical Structure

The object was a conical sea shell that now had just the tip of it broken off, exposing a thin edge on its inside.

Action

He grabbed the object, put its tip carefully between his lips, and blew smoothly.

Comb

Vague Physical Structure

Part of the melted plastic scrap had formed a toothed object, of about 8 inches in length.

Detailed Physical Structure

Part of the melted plastic scrap had formed an 8-inch object with 30 equally spaced thin teeth, parallel and close together.

Action

He grabbed the object and pulled its teeth repeatedly and systematically through his hair.

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