Gesturing and Naming : The Use of Functional Knowledge in Object Identification

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Research Article

GESTURING AND NAMING: The Use of Functional Knowledge in Object Identification

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Abstract—*Studies using functional imaging show reliable activation of premotor cortex when observers view manipulable objects. This result has led to the view that knowledge of object function, particularly the actions associated with the typical use of objects, may play a causal role in object identification. To obtain relevant evidence regarding this causal role, we asked subjects to learn gesture-color associations and then attempt to identify objects presented in colors denoting functional gestures that were congruent or incongruent with the objects' use. A strong congruency effect was observed when subjects gestured the use of an object, but not when they named an object. We conclude that our procedure constitutes a sensitive measure of the recruitment and causal role of functional knowledge and that this recruitment is not present during object naming. Preliminary evidence, however, indicates that gestures evoked by the volumetric shape of an object do contribute to object naming.*

Neuropsychological evidence has been taken as support for the claim that recruitment of functional knowledge is a necessary component of the ability to identify certain classes of objects. There are two major sources of such evidence. First, a number of case reports have described selective difficulty in identifying man-made objects relative to biological objects (e.g., Cappa, Frugoni, Pasquali, Perani, & Zorat, 1998; Silveri et al., 1997). The reverse dissociation, difficulty in identifying biological objects and relative preservation of ability to identify nonbiological objects, has also been reported (e.g., Arguin, Bub, & Dudek, 1996; Magnie, Ferreira, Giusiano, & Poncet, 1999). According to Warrington and Shallice (1984), the reason for such a double dissociation is based on a distinction between sensory-semantic knowledge and functional-semantic knowledge. According to this account, identification of biological objects depends more on perceptual details than functional information, whereas the reverse is true for nonbiological objects. In Farah and McClelland's (1991) computational model incorporating this view, semantic features of objects were based on dictionary definitions. These definitions tended to include more functional information for nonbiological objects and more perceptual information for biological objects. Lesions to one or the other type of knowledge in this model produced the double dissociation seen in patients, providing at least an existence proof of the relevance of the distinction between perceptual and functional knowledge in object identification.

One challenge in further examining the role of functional knowledge in object identification is to specify what constitutes functional knowledge. Tversky and Hemenway (1984) suggested that the function of an object is revealed in the way people manually interact with it when carrying out its conventional use. Indeed, the second major source of neuropsychological evidence for the role of functional knowledge in object identification is functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) studies that have demonstrated activation of cortical regions associated with motor action in a variety of object identification tasks. For example, Martin, Wiggs, Ungerleider, and Haxby (1996) found that regions in the left premotor cortex and left middle temporal gyrus (an area believed to be associated with the perception of movement) were selectively activated during naming of tools versus animals. The same areas were activated when subjects named actions elicited by tools (Martin, Haxby, Lalonde, Wiggs, & Ungerleider, 1995) or imagined themselves using the objects (Decety et al., 1994).

A criticism of the argument that functional knowledge (embodied in action schemas) plays a causal role in object identification is that the imaging literature thus far has provided only correlational evidence. Granted, some kind of premotoric representation may be activated in the course of identifying an object, but the nature of this representation remains unclear, and researchers do not yet have evidence on what kinds of premotor representation are causally implicated in identification.

A number of behavioral studies have examined the possible causal role of different kinds of motor actions potentiated during the course of object identification, using interference paradigms that generate incompatibility between a response to a target and another motor action invited by aspects of the display. The rationale for creating such opposition is that if the incompatible motor action is automatically recruited during object identification, subjects will be unable to escape its interfering influence on response production. For example, Tucker and Ellis (1998) presented subjects with photographs of common tools and utensils with handles (e.g., teapot) that were upright or inverted and were positioned with the handle on the right or left. Despite the fact that the task was to classify each object as upright or inverted, responses were faster when the handle was on the same side as the response hand rather than the opposite side. From this stimulus-response-compatibility effect, Tucker and Ellis inferred that objects automatically potentiate habitual actions they afford. These results, however, remain ambiguous with respect to which aspect of the stimulus actually determines the compatibility effect. As is the case with many tools and utensils, the handle of a teapot defines not only the part of the object that is grasped during use, but also the posterior end relative to the observer in a spatial coordinate system established through experience with the object. Many objects (e.g., rowboat) are neither tools nor utensils, but nonetheless maintain the same kind of posterior-anterior asymmetry seen in graspable objects. It is possible that it is this perceived asymmetry, rather than the potentiation of a motor affordance, that underlies the compatibility effect established by Tucker and Ellis. According to this view, objects perceived as strongly asymmetrical along an anterior-posterior dimension would generate response-compatibility effects even though they are not graspable (e.g., airplane).

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Other studies have demonstrated interference effects between a particular action and affordances driven by the structural characteristics of objects. Tucker and Ellis (2001) required subjects to categorize objects as natural or man-made by responding with a particular hand action. Compatibility effects were found when the target object evoked an action different from versus similar to the required response (e.g., clenching the hand to classify a grape as a natural object as opposed to responding with a thumb-and-forefinger pinch). Unfortunately, these results indicate only that interactions between object shape and hand action may occur during responses to objects, but they do not implicate knowledge of object function. Similarly, Pavese and Buxbaum (2002) demonstrated interference in carrying out a motor action to a target (e.g., point or grasp) when distractor objects afforded a related action. In this study, the relatedness between the action to the target and the action to the distractors was defined quite abstractly, such that actions with two very different surface forms (power grasp vs. precision grasp) were considered similar. These interference effects, then, reflect affordances based on general intentions to act but are not directly relevant to questions concerning the role of functional knowledge and specific action schemas in object identification.

For our present purpose, we consider an action as functionally based if it corresponds to the one that people habitually use when interacting with an object so as to carry out its conventional function. We use the posture of the hand during this action as the token for functionally based knowledge (e.g., a poke action when using a calculator). The set of experiments reported here used a procedure designed to indicate whether invoking the mental representation of actions denoting an object's culturally defined usage is a necessary element in its identification. To accomplish this goal, we first trained subjects to pantomime distinct manual actions (Rumiati & Humphreys, 1998), each in response to a particular color. A set of objects was chosen such that each object had a clearly defined manual action (Klatzky, McCloskey, Doherty, Pellegrino, & Smith, 1987) associated with its conventional usage (e.g., pliers—open grasp). During the test phase, an object was presented in a color that was associated either with the same action as the one conventionally applied to that object (congruent condition) or with an unrelated action (incongruent condition). We looked for the presence of congruency effects on response latency either when the subject responded manually to the color of the object or when the subject identified the object. Such effects would be driven by interaction between motor representations from two sources, the color and the object, and therefore would reveal the presence of functional knowledge invoked in the course of object identification.

EXPERIMENT 1

If function-based actions are automatically invoked when a person views an object, as implied by neuroimaging results, then making the gesture associated with the color of an object in our task should be affected by compatibility between that gesture and the conventional action associated with the object. Alternatively, the recruitment of gestural knowledge about an object may depend on the way in which that object is encoded, and passive viewing may not be sufficient to invoke such knowledge. In Experiment 1, subjects responded manually to the color of an object and were told to ignore the object itself. Congruency effects, defined as slower responding when the color-based and object-based gestures conflicted rather than coincided, would imply the automatic activation of functional knowledge engendered by passive viewing. In a neutral condition, subjects responded to a color patch in the absence of any object. The inclusion of this condition provided the potential to determine whether congruency effects were primarily the result of facilitation or interference.

Method

The subjects were 12 undergraduates at the University of Victoria, Canada. Materials consisted of digital photographs of human hands displaying four gestures (pinch, poke, closed grasp, and open grasp) and of eight objects. Our choice of photographs rather than actual objects as the stimulus medium was motivated by our interest in the symbolic representation of actions afforded by object concepts rather than manual actions to physical surfaces (cf. Aglioti, De Souza, & Goodale, 1995). For each gesture, two objects were chosen such that their function-based gesture matched the target gesture (match, needle—pinch; calculator, doorbell—poke; mug, saw—closed grasp; nutcracker, pliers—open grasp). Each photograph of a hand gesture was mounted against four different colored rectangles, and each object was rendered in each of those same four colors and in gray scale. Two variants of each hand gesture were produced, one for right-handed subjects and the other for left-handed subjects. Similarly, two photographs of each object were prepared, one with the object positioned to fit a right hand and the other with the object positioned to fit a left hand. An example of one of the objects in its gray-scale version is shown in Figure 1. As shown in the figure, all displays were superimposed on a black background. Subjects' self-reports of handedness were used to determine the appropriate set of materials for each subject; all stimuli were shown in an orientation that favored the subject's dominant hand. Assignment of color to gesture was counterbalanced across subjects.

All stimuli were displayed centrally on a color computer monitor. In the training phase, subjects were presented with photographs of the four gestures, each mounted on a uniquely colored rectangle. At the start of each trial, the subject used his or her two index fingers to depress two keys mounted on a response box. When the display of the hand gesture appeared, the subject mimicked the gesture by using his or her dominant hand, with the goal of learning which gesture was associated with each color. Each gesture was presented on its colored rectangle four times. Next, the subject was shown a sequence of color rectangles, with each of the four colors appearing 20 times in random

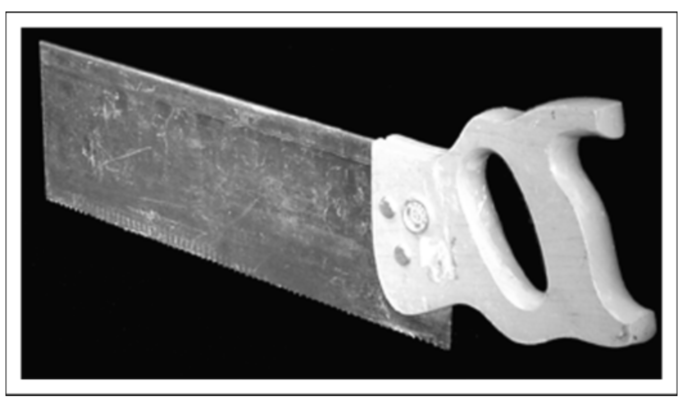

Fig. 1. Example photograph of an object in gray scale oriented for a right-handed subject. The conventional functional gesture associated with this object was a closed grasp.

order. The task was to make the gesture associated with each color, as had been done when hand gestures were pictured on the color rectangles.

In the test phase, subjects were first shown a gray-scale image of each of the eight objects to verify that they could identify each one. Then subjects were presented 72 trials in which a colored stimulus was displayed: a colored rectangle on 24 trials (neutral condition) and a colored object on 48 trials. On all trials, subjects were to gesture in response to the color. They were instructed to make their responses as quickly as possible, but not to lift their response hand from the depressed key until they were ready to initiate the correct gesture. For half of the colored-object trials (congruent condition), the gesture associated with the color and the gesture naturally associated with the object were congruent; for the other half (incongruent condition), the two gestures were incongruent. For incongruent trials, an object appeared once in each of its three possible incongruent colors. Trials from the three conditions were presented in random order. Because there is good evidence that appropriate hand shape is planned prior to reaching (Klatzky, Fikes, & Pellegrino, 1995), response latency was measured from the onset of the display to the key release that occurred as soon as the subject initiated a gestural response to the display. The experimenter monitored each response and classified it as correct, error, or spoil (e.g., the subject hesitated after releasing the key and before starting the gesture).

Results and Discussion

Trials with response latencies less than 250 ms were classified as spoiled. In addition, correct response latencies longer than 3,000 ms were classified as outliers. This cutoff was established so that no more than 0.5% of observations would be excluded (Ulrich & Miller, 1994). Application of the upper latency limit resulted in the exclusion of 0.1% of correct responses.

Mean response latency and error and spoil percentages for each condition in the test phase are shown in Figure 2. An analysis of variance (ANOVA) using a Type I error rate of .05 (as in all experiments reported here) was computed for the response-latency data and revealed a significant effect of condition, $F(2, 22) = 5.07$, $MSE = 2{,}132$. Orthogonal contrasts indicated that response latency was shorter in the neutral condition than in the congruent and incongruent conditions combined, $F(1, 22) = 10.12$, which did not differ from each other, $F < 1$. The power of this test to detect a difference between the congruent and incongruent conditions equal to that found in Experiment 2 (discussed later) was estimated to be larger than .90. ANOVAs applied to the error and to the spoil data found no significant effects, Fs < 1.

The difference between the neutral condition and the conditions in which an object appeared implies that the presence of an object was sufficiently distracting to slow the generation of action in response to the color. This distraction appeared to be independent of functional gestures in that no congruency effect was observed. We therefore concluded that the use of a color rectangle as a neutral condition would not be valid, and so we did not include that condition in later experiments.

The lack of a congruency effect suggests that passively viewing an object is not sufficient to invoke gestural knowledge associated with the object's function. Alternatively, our paradigm may be insensitive to the conflict between gestures associated with a color and with an object. In Experiment 2, we addressed this issue by having subjects switch randomly between the tasks of making the gesture associated with the color or with the object. On each trial, subjects were precued as to which task to perform. Castiello (1996) showed that responding to a distractor as well as a target object led to interference in generating a grasping action to the target. By contrast, no such interference was observed when the distractor was ignored. If task switching elicited attention to the object's identity even when subjects were cued to respond to the color, we would observe a congruency effect both when subjects gestured to a color and when they gestured to an object. Alternatively, if gesture was not recruited even if the object was attended (or if our task is incapable of revealing the presence of competing gestural knowledge), then neither task would generate congruency effects.

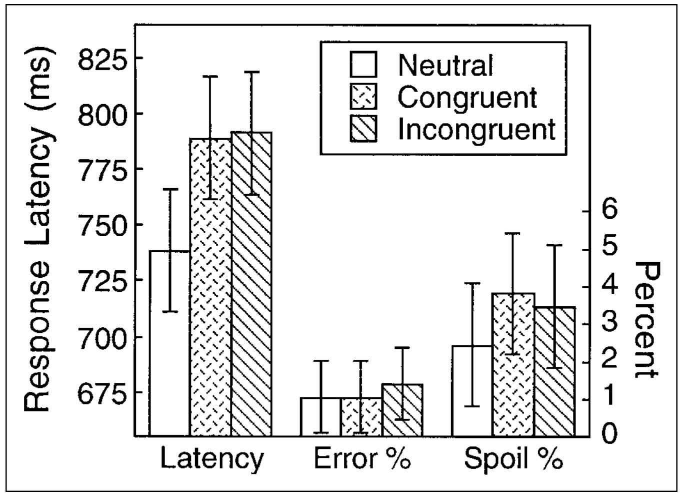

Fig. 2. Mean response latency, error percentage, and spoil percentage as a function of condition in Experiment 1. Subjects responded to colors by making gestures they had learned to associate with the colors. On some trials, the color was carried by an object; each object was associated with a functional gesture that was either congruent or incongruent with the gesture corresponding to the color. On other trials (neutral condition), a colored rectangle was presented without an object. Error bars are 95% within-subjects confidence intervals (Loftus & Masson, 1994).

EXPERIMENT 2

Method

Twenty-eight new subjects were tested. The materials and training phase were the same as in Experiment 1. At the start of each trial in the test phase, subjects were presented a 1-s cue indicating which of two tasks to perform: "gesture to color" or "gesture to object." A picture of a colored object then appeared until the subject responded. Color-driven gestures were those learned during the training phase, and object-driven gestures were those naturally associated with the objects and were reviewed with the subjects at the start of the test phase. Gesture responses were made in the same way as in Experiment 1. The test phase began with 16 practice trials, followed by 96 critical trials. Four trial types occurred equally often among the practice and critical trials, representing a factorial combination of response task (gesture to color vs. object) and color-object congruency (congruent vs. incongruent).

Results and Discussion

Spoiled trials were defined and correct response latencies were trimmed as in Experiment 1. The upper latency boundary was set at 7,000 ms for the color-gesture task (0.3% excluded) and at 6,000 ms for the object-gesture task (0.4% excluded). These large upper limits were dictated by the relatively slow responding brought about by the need on each trial to select between color and object as the critical dimension. In any case, analyses using an upper boundary of 3,000 ms produced the same pattern of results as that reported here.

Figure 3 presents the means for correct response latency and for error and spoil percentages for the color- and object-gesture tasks. ANOVAs applied to the data in the color-gesture task revealed that latencies were significantly longer (183-ms difference), $F(1, 27) = 14.04$, $MSE = 33{,}293$, and errors were more likely (7.0% difference), $F(1, 27) = 22.12$, $MSE = 30.85$, in the incongruent condition than in the congruent condition. No effect was found in the spoil-percentage measure, $F < 1$. The same pattern of results was obtained for the object-gesture task, with significant congruency effects seen in the latency (85-ms difference), $F(1, 27) = 6.42$, $MSE = 15{,}736$, and the error measure (4.0% difference), $F(1, 27) = 6.80$, $MSE = 33.16$, but not in the spoil measure, $F < 1.4$. The finding of congruency effects for both stimulus dimensions validates our use of this paradigm as a means of revealing the recruitment of functional knowledge through interactions between competing sources of gestural representations driven by an object and its color.

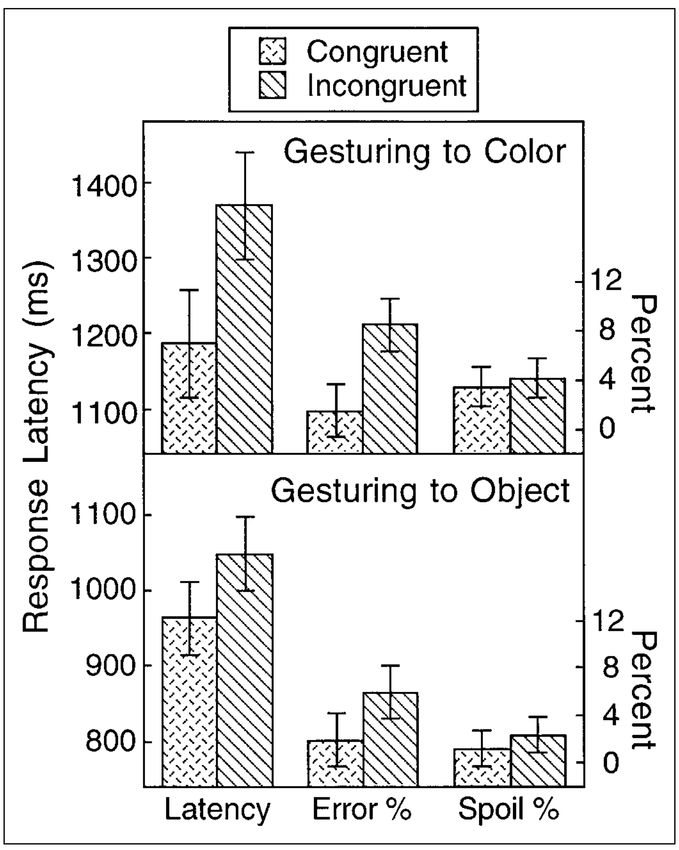

Fig. 3. Mean response latency, error percentage, and spoil percentage for gestural responses to colors and to objects as a function of color-object congruency in Experiment 2. The gesture that subjects learned to associate with each color was either congruent or incongruent with the functional gesture naturally associated with the object that carried the color in the stimulus display. Error bars are 95% within-subjects confidence intervals.

EXPERIMENT 3

Experiment 2 demonstrated that the color-gesture training provided to our subjects is sufficient to interfere with the recruitment of functional knowledge associated with an object when a subject is induced to attend to both color and object dimensions. In Experiment 3, our interest was in whether subjects process the function of an object when required to name it rather than gesture its use. Such functional knowledge may be causally implicated in object identification or may be recruited incidentally with no causal role. If functional knowledge is a necessary component of object naming, then under conditions of task switching between gesturing to color and naming an object, a color-congruency effect should be observed in the naming task. Alternatively, no congruency effect should occur in the naming task if recruitment of functional knowledge during object identification is only incidental, although a congruency effect should still be observed in the color-gesture task.

Method

Twenty-four new subjects were tested. The materials and procedure were the same as in Experiment 2, except that in the test phase the two tasks were to either gesture to the color or name the object. A voice-operated relay was used to detect vocal responses. Trials with failed or artifactual triggering of the voice-operated relay were classified as spoiled.

Results and Discussion

Correct response latencies were trimmed as in Experiment 2, using upper boundaries of 4,000 ms for the color-gesture task (0.2% excluded) and 3,000 ms for the naming task (0.1% excluded). Mean correct response latency and error and spoil percentages for both tasks are shown in Figure 4. An ANOVA was computed for each measure to determine whether a congruency effect was present. For the color-gesture task, latency was reliably slower in the incongruent condition than in the congruent condition, by 64 ms, $F(1, 23) = 5.43$, $MSE = 8{,}951$; no such effect was seen for object naming, $F < 1.3$. No congruency effect was obtained for either task on error or spoil measures, Fs < 1.

Despite never having gestured to the objects themselves in the context of the experiment, subjects showed a reliable influence of the functional gesture associated with an object on their gestural responses to color. Precuing task sets appears to have directed attention toward features of the objects that automatically evoke gestures associated with functional knowledge. In the color-gesture task, these gesture representations interacted with the gestures associated with colors. There is no evidence in this experiment, however, that automatic evocation of functional knowledge has an impact on object naming.

We have thus far examined the contribution of only one class of gestural knowledge to naming—the gestures associated with an object's conventional use. Another important, but distinct, class of gestures has to do with affordances associated with volumetric properties of objects. Many objects, including artifacts, have shapes that invite

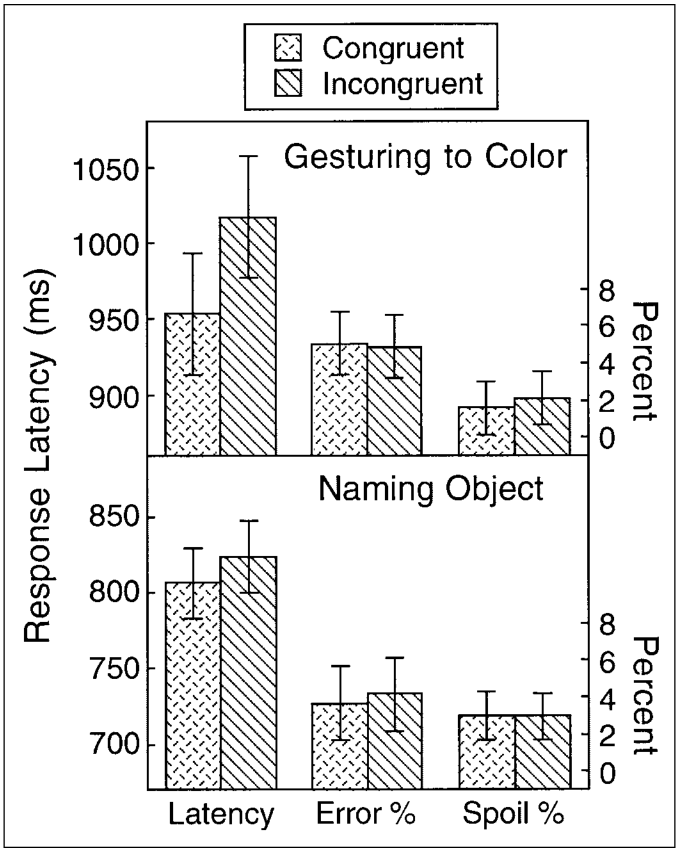

Fig. 4. Mean response latency, error percentage, and spoil percentage for gestural responses to colors and naming responses to objects as a function of color-object congruency in Experiment 3. The gesture that subjects learned to associate with each color was either congruent or incongruent with the functional gesture naturally associated with the object that carried the color in the stimulus display. Error bars are 95% within-subjects confidence intervals.

particular ways of grasping them, quite independently of their conventional use (e.g., picking up a calculator with an open grasp, rather than poking its keys). This type of motoric representation may well be invoked at some stage of object naming as a necessary part of identification. Indeed, we do not know whether a volumetrically based representation for action, as opposed to functional knowledge, is responsible for the neuroimaging evidence that motor representations are recruited as part of object identification.

Conceivably, then, naming was unaffected by color-object congruity in Experiment 3 because we examined the effect of knowledge about functional gestures rather than volumetrically based gestural representations on object identification. To test the idea that representations of volumetric gestures may causally interact with object naming, we reexamined the data from Experiment 3. We first identified objects for which the functional gesture was the same as the volumetric gesture. Of the four pairs of objects used in our experiments (one pair for each functional gesture), one met this criterion: match and needle. For both of these items, pinch was both the associated functional gesture and the volumetric gesture. For the remaining three pairs, the volumetric gesture was judged to be quite different from the functional gesture (e.g., for calculator and doorbell, the functional gesture was poke and the volumetric gesture was open grasp). Thus, only for match and needle was our manipulation of color congruency meaningful from the perspective of volumetric representations. If volumetric representations are involved in object naming, we would expect a color-congruency effect to emerge for these two objects, but not for any of the other three object pairs. Figure 5 shows mean naming latency for each object pair in the congruent- and incongruent-color conditions. Naming latency for match and needle showed a reliable 64-ms congruency effect, $F(1, 23) = 6.36$, $MSE = 7{,}805$, whereas none of the other object pairs showed an effect, $F\text{s} < 1$.

CONCLUSION

Passive viewing of an object did not generate functional knowledge in the form of motor representations that could then interact with corresponding representations involved in making a learned gestural response to a color in which the object appeared. Precuing whether to gesture to color or to object yielded parallel congruency effects for the two tasks. More surprisingly, when the task set for objects required naming and not gesturing, functional knowledge derived from objects influenced the act of gesturing to color, but no congruency effect was found in object naming.

Motoric representation of conventional function is not automatically invoked unless attention is directed specifically toward an object. Nor does this kind of representation appear to be causally involved in naming an object. We are skeptical, then, of the claim that the motor activation seen in neuroimaging results during the viewing of objects has to do with conventional functional knowledge. By contrast, we have preliminary evidence that other kinds of gestural knowledge, such as affordances driven by the volumetric properties of object shape, may play an important role in object identification. Thus, the causal relation between the activation of motor representations observed in neuroimaging and object identification may have to do with form rather than function.

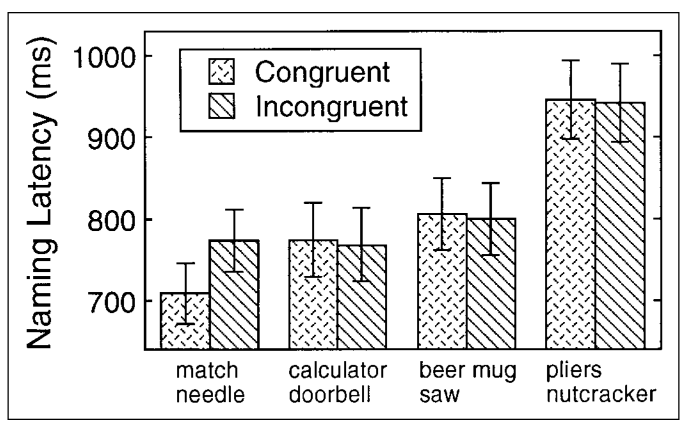

Fig. 5. Mean naming latency for object pairs in Experiment 3. The volumetric gesture plausibly used merely to pick up an object was identical to the functional gesture naturally associated with the object only for the match and needle; thus, only for these two objects was the congruency manipulation relevant to knowledge of volumetric gesture. Error bars are 95% within-subjects confidence intervals.

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