

The Constituents of Action Representation Evoked
When Identifying Manipulable Objects

by

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B.A., University of Victoria, 2012

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of the Requirements for the Degree of

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in the Department of Psychology

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Supervisory Committee

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Abstract

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We examined the effects of keeping hand actions in working memory on the speed of naming handled objects. The features of the hand action and objects' handle matched or mismatched on two dimensions: alignment (left vs. right), orientation (horizontal vs. vertical). For objects presented in their canonical upright position, the speed of naming was only slower when the actions were partially incongruent with the target object. For rotated objects, the effect was reversed. The pattern of results suggests that the identification system is more sensitive to the functional goal (i.e. the end state) of the rotated object in evoking action representations than the actions evoked by the depicted view (i.e. the beginning state). The findings, overall, strongly support the notion that action representations play a functional role in object identification.

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General Introduction

Increasing evidence from neurological (e.g. Rizzolatti, Camarda, Fogassi, Gentilucci, Pupino, & Matelli, 1988; Chao & Martin 2000; Mecklinger, Gruenewald, Weiskopf, & Doeller., 2004; Raos, Umiltà, Murata, Fogassi, & Gallese, 2006) and behavioral research (e.g. Helbig, Graf, & Kiefer, 2006; Helbig, Steinwender, Graf, & Kiefer, 2010; Campanella, & Shallice, 2011; Pecher, 2013; Pecher, de Klerk, Klever, Post, van Reenen, & Vonk, 2013; Tousignant & Pexman, 2012; Myung, Blumstein, & Sedivy, 2006; Witt, Kemmerer, Linkenauger, & Culham, 2010) suggests that the action representations associated with manipulable objects are closely linked to their meaning. Single-unit recording studies in macaque monkeys have shown that grasping-related neurons in the rostral part of the ventral premotor cortex (canonical F5 neurons) respond to the visual presentation of graspable objects, even when grasping movement was not required (Rizzolatti et al. 1988; Raos et al. 2006). In humans, Chao and Martin (2000) found a selective activation of the left posterior parietal and left ventral premotor cortices by having participants passively view pictures of manipulable objects such as a hammer. No such activation occurs when people viewed non-manipulable objects such as a dog, a house, or a human face. In behavioural studies, Helbig et al. (2010) had participants view 1-2 second video clips of grasping actions before the participants must identify a manipulable object. They found that observing grasp actions congruent with the target object's function facilitated superior object naming accuracy.

Many of the behavioral studies used common manipulable objects (e.g. beer mug, frying pan, hammer, etc.) to investigate how attention to these objects can elicit mental representations of action in the motor system. These studies provide a wide range of descriptions of action

representation which have been repeatedly claimed to play a functional role in object recognition. Unfortunately, a vagueness in how action representation is currently defined within and across these studies have also created many inconsistencies in the metric used to investigate this phenomena. In turn, resultant claims drawn from these studies are often uninformative as to the exact nature of action representations, and the precise role they play in the identification process. Through a series of experiments performed in our lab, we aim to provide a clearer insight into the relationship between action representation and object identification. We present, in this paper, studies that provide strong evidence in support of action representations playing a functional role in the visual identification of manipulable objects.

In a recent study, Bub, Masson and Lin (2013) successfully showed that keeping hand actions in working memory had a strong influence on a person's ability to identify handled objects. Action representations in the study were operationally defined as the hand and grasp posture induced by the location (left/right) and orientation (horizontal/vertical) of the object's handle. The study revealed a counter-intuitive yet sensible finding: partial overlap between features of hand actions kept in working memory and those induced by the object's handle required time-consuming resolution of the conflict generated by the non-overlapping features. According to the influential theory of event coding (TEC) by Hommel (2004; Hommel, Musseler, Aschersleben, & Prinz, 2001; see Bub, Masson, & Lin, 2013 for brief review), performance was impaired only when feature overlap is partial because the non-overlapping features between the action and the object creates a conflict in the feature integration process for object naming. For example, suppose a participant was asked to keep a horizontal left-handed action in working memory before naming a beer mug (vertical orientation) with its handle facing the left. According to TEC, the motor system would initially activate and bind the "LEFT" and

“HORIZONTAL” features for the hand action. When the participant prepares to name the object, the perceptual system mediating identification would similarly attempt to activate and bind the corresponding features: “LEFT” and “VERTICAL.” As the cognitive system activates its corresponding features for object naming, the overlapping “LEFT” feature shared with the hand action also evokes the “HORIZONTAL” feature that was bound to the hand action. A conflict arises between the “VERTICAL” feature of the object and the “HORIZONTAL” feature of the hand action; thus, naming is delayed to resolve this non-overlapping feature conflict. The finding suggested that the mental representations evoked during object identification includes a representation of action that is quite specific; it includes the hand and grasp posture induced by the location and orientation of the object’s handle.

One major limitation of the study, however, was that the experimental design could not discern whether action representation was evoked by the depicted view of the object (e.g. an object’s depicted view is based only on its form in a particular orientation rather than the canonical form), and/or the functional properties of the object. As Cho and Proctor (2010) have articulated through a series of experiments, a grasp affordance effect need not be caused by the action representation evoked by the functional properties of manipulable objects. The authors argued that the effect was instead an object-based Simon effect induced by the object’s handle directing spatial attention to the left or right area in the visual field; the same effect was achieved using irregular objects with which similarly biased spatial attention. Analogously, if action representation is evoked only by the depicted visual presentation of the handle, then one may argue that action representation may not necessarily play a functional role in the identification process per se. Instead, the partial incongruency interference effect on naming may be caused by conflict in the visuospatial system and not conflict in the motor system. Due to this confound, it

remains inconclusive whether action representations play a functional role in object identification.

Some evidence does, however, suggest that the functional properties of an object play a subtle but nonetheless crucial role in evoking action representations. As demonstrated in Masson, Bub, and Breuer (2011), one way to examine the relationship between action representation and the functional properties of handled objects was to rotate the object 90 degrees from its upright position (e.g. a beer mug rotated 90 degrees on its side so that its handle pointed upward and affords a horizontal grasp instead of a vertical grasp). The study found that rotated objects effectively primed hand actions that were fully congruent with the object in its rotated form. Full congruency refers to when the rotated object affords a hand action that is commensurate (left-handed vs. right-handed) and matching the wrist orientation (horizontal vs. vertical) with the hand action in working memory. Commensurability was defined by the left-right dimension of the afforded action for rotated objects whereas alignment was defined by the left-right dimension for upright objects (see **figure 1**). The constraint of commensurability implies that rotated objects evoke action representations only when they afford the potential to be readily positioned for functional action, even though the actual hand action evoked still conforms to the depicted visual presentation of the object. For example, when a beer mug with its handle facing the left is rotated on its side (left commensurate and horizontally oriented), this new version of the beer mug only evokes a left-handed horizontal hand action, which is fully congruent with the object's afforded hand action in terms of commensurability and orientation congruency. It does not evoke a right-handed horizontal grasp (incommensurate) or a left-handed vertical grasp (incongruent orientation). It is intriguing as to why only a fully congruent (left-handed horizontal) hand action would be evoked in planning a reach and grasp action for the above-mentioned beer mug (left

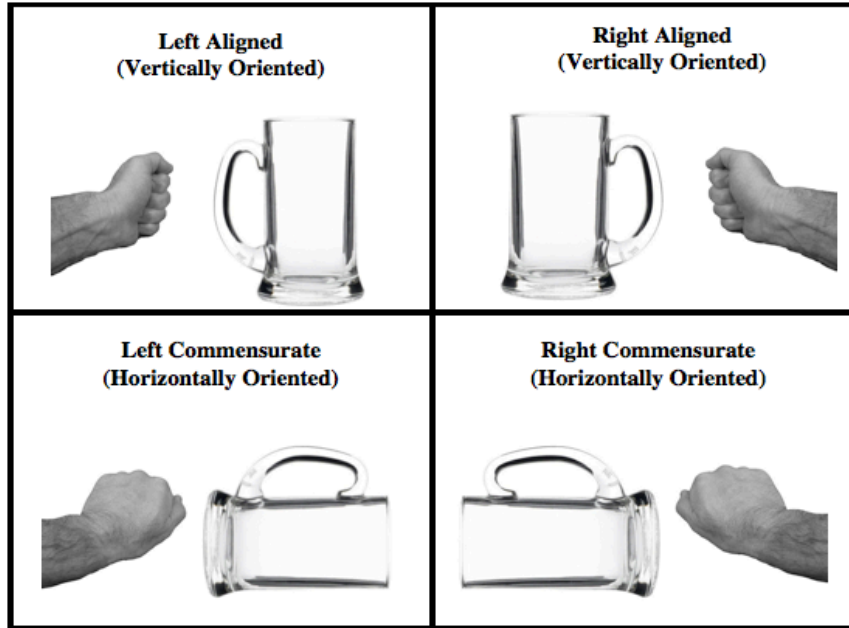


Figure 1. Examples of alignment congruency and commensurability. Objects and hand actions in this figure are all fully congruent with each other.

commensurate and horizontally oriented). Suppose that an object's functional properties do not play a role in evoking action representation when planning a reaching and grasping action (a la Cho and Proctor), then a left-handed and a right-handed horizontal action should both be primed by the rotated object. A rotated object, solely based on its depicted view, cannot indicate the left-right dimension unless the functional properties are taken into account. The fact that a left-handed, not a right-handed, action is evoked in the example suggests that the functional properties of the object play a role in planning a reach and grasp action. Surprisingly though, the functional properties do not select the appropriate hand action based on the object's canonical form. For example, if the functional properties based on the canonical form are the sole determinants of the object's action representation, one might expect a left commensurate rotated beer mug (i.e. a beer mug with its handle facing the left rotated 90 degrees on in its side) to evoke a *vertical* left handed action instead of a horizontal left-handed action because the vertical

hand action would be the proper reach and grasp action for the beer mug in its functional end state. However, this was not the case. The rotated object only primed a hand action that fully matched the object's afforded action in terms of orientation and commensurability based on the object's depicted view. The specificity of this constraint in the priming effect hints at the subtlety of the motor system in planning a reach and grasp action for an object. The motor system begins by calculating the hand action based on the hand's beginning state (i.e. the representation determined by the depicted view of the object) which is readily available for a proximal action. However, the motor system still requires information regarding the hand's end state (i.e. the representation determined by the object's functional purpose) during the planning process because the object will ultimately need to be rotated back to its canonical upright position for its intended purpose. When planning to reach and grasp an object, an action representation is evoked by the depicted visual form taking into account the object's function.

Following this line of reasoning, the question we are most interested in is whether action representations also play a functional role in object naming. Exactly how would the beginning state and end state of a rotated object influence the evocation of action representation during the identification process? Although we would expect action representation to play a functional role in object naming, we would not expect the two states to influence object identification in exactly the same manner as they did in planning a reach and grasp action. It would not be expected that the beginning state of a rotated object would have much of an influence on the identification process because the beginning state, by itself, has no association with the functional properties or the object's conceptual knowledge. It is more likely that the object's end state would have a much greater influence on the identification process because an object in its end state correctly indicates its intended functional purpose. For example, a rotated beer mug must be returned to its

canonical upright position in order to be used for its intended purpose (i.e. to drink from the beer mug). Because the end state has a more direct association with an object's conceptual representation, we would expect the participants to name a rotated object by only consulting a representation of the object's functional properties and not the representation evoked by the object's depicted view. If this is true, then we would expect to see a pattern of effects that shows a rotated object named as if it has already been rotated back to its canonical upright position (i.e. its end state). The main goal of the two experiments outlined in this paper were designed to investigate whether the action representation evoked via identifying an object includes the functional properties of the object by examining the influence of the beginning state and end state on object naming.

Experiment 1

Experiment 1 is a replication of Bub, Masson & Lin's (2013) study with two notable changes. The aforementioned study only presented objects in their canonical upright form and Experiment 1 includes both upright and rotated versions of the objects. The second difference is that the current study also included a special type of object which we referred to as acanonical objects. Acanonical objects do not have an obvious canonical upright form (e.g. flashlight). They are atypical because they do not indicate a clear distinction between the beginning state and end state. It is possible that when naming acanonical objects, the action representation can only be evoked based on the depicted view of the objects because the beginning state is also likely to be the functional end state as well. Due to their ambiguous nature, acanonical objects will be analyzed separately from the typically canonical horizontal and vertical objects. The purpose of Experiment 1 is to examine the role of an object's beginning state and end state in evoking action representation when naming a handled object.

Experiment 1 Method

Subjects. Thirty undergraduate students at the University of Victoria participated in the experiment for extra credit in a psychology course.

Materials. Four unique pantomimes associated with handled objects were selected (see **Figure 2**). Each pantomime had four tokens produced by factorially combining wrist rotation (horizontal and vertical) and hand used (left hand and right hand). A set of 16 grayscale digital photographs of pantomimes was selected. These photographs were used to cue target pantomimes.

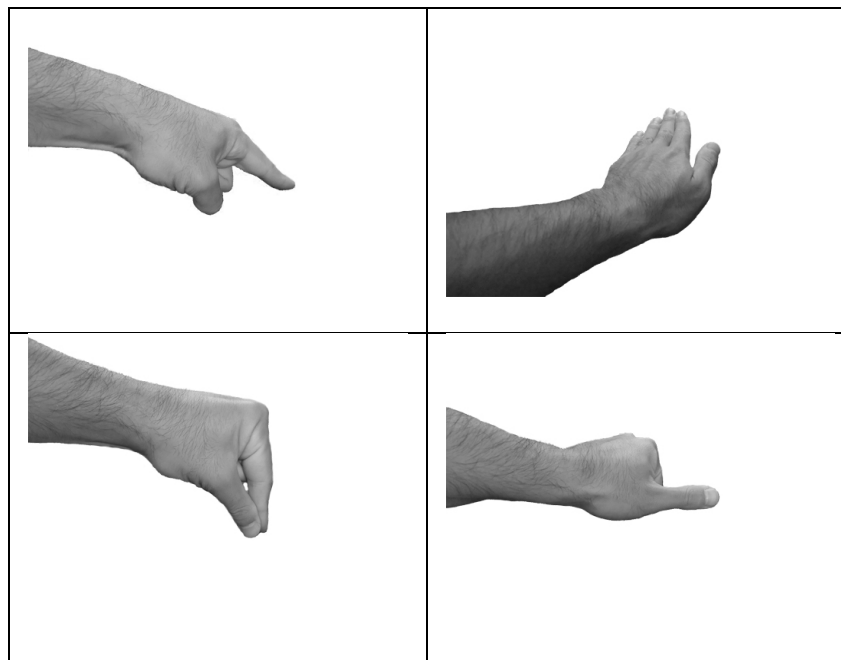


Figure 2. (Left-handed Horizontal) Pantomimes Used in the Experiment.

Twenty-four handled (see **Table 1**) objects with four visual variations were selected (96 unique objects). Objects only invited a power grasp, which is a full-palm grasp involving all five fingers. A set of eight objects had vertical handles inviting a vertical grasp in their canonical upright position (e.g. beer mug). Another eight objects had horizontal handles in their canonical

upright position inviting a horizontal grasp (e.g. frying pan). A third set of eight objects had no obvious canonical upright position (i.e. flashlight); we referred to these objects as “acanonical.” For analysis purposes, we also arbitrarily labeled the acanonical objects as having vertical handles inviting a vertical grasp in their canonical upright position. All objects had both a left-hand version (handle of the object facing the left side) and a right-hand version (handle of the object facing the right side). All object had both a canonical upright version and rotated version where the objects were rotated 90 degrees. A total set of 384 grayscale digital photographs of handled objects were selected. All objects and pantomimes were scaled to 12.7cm by 12.7 cm (5 inches by 5 inches) when displayed on a computer monitor viewed from 50 cm.

Table 1. Names of Objects Used in the Experiment

Horizontally oriented handle
frying pan, iron, kettle, knife, pizzacutter, saucepan, strainer, vacuum
Vertically oriented handle
beer mug, coffee mug, garden sprayer, measuring cup, megaphone, pitcher, teapot, watergun
Acanonically oriented handle
flashlight, hairbrush, hammer, hatchet, saw, sickle, toothbrush, wrench

Design. A 2 x 2 x 2 factorial repeated measures design was used to determine the effects of hand alignment congruency with object handle alignment (left vs. right), wrist rotation congruency with object handle orientation (horizontal vs. vertical), and rotation (upright vs. rotated) on the speed of identifying manipulable objects. Acanonical objects are analyzed separately from the typically upright horizontal and vertical objects. In all of the analyses, the alignment and orientation of all of objects (typical and acanonical) are determined based on the

object's depicted view but not necessarily their canonical upright view; for upright objects, however, the canonical upright position is the same as their depicted view.

Procedure. Instructions and stimuli were presented on a color monitor controlled by an Apple Mac Pro desktop computer. In the first training session, pictures of hands were shown and participant mimicked horizontal and vertical gestures once per hand in the left and right versions (16 trials in total). In the second training session, both the horizontal and vertical objects were shown in their left-hand version (96 trials in total). Participants were asked to name the objects out loud. The two training sessions were intended to ensure that the participants were familiar with the objects and pantomimes and could identify them from the photographs. In the testing session, participants viewed a sequence of 2 hand gestures and then were shown an object which they were asked to name as quickly as possible. After naming the object, a signal appeared on the screen 25% of the time informing the participant to mimic the hand gestures shown before the object. The signal was intended to prevent participants from passively naming the objects while ignoring the pantomimes. It also ensured that participants paid attention to and remembered the pantomimes without being required to act out the pantomimes every single trial.

Participants viewed 96 objects in three blocks (288 critical trials). In each block, objects and pantomimes were split into 16 conditions (2 handle alignment x 2 handle orientation x 2 hand alignment x 2 hand orientation). Each block contained all 96 unique objects and they were randomly assigned to the 16 conditions. Within each block, each condition contained two unique objects of each type (6 unique objects per condition). The visual presentation of the pantomimes and objects were decided based upon the condition to which they were assigned. If a horizontal object was assigned to a vertical handle orientation, then the object was rotated and vice versa.

The alignment of rotated object was decided based on the object's commensurability (the alignment of the handle when it is rotated back to its canonical upright position).

Within each block, the four hand types were paired with each other with no repeated hand types. This provided us with 6 unique hand type combinations when the order of the hand types was not accounted for. Since there were 6 object tokens per condition, each condition would have an unique object randomly paired with a hand type combination. The pairing between unique objects and hand type combinations varied across each block.

Experiment 1 Results

Acanonical objects only. A 2 x 2 x 2 repeated measures analysis of variance (ANOVA) revealed a main effect of alignment congruency, $F(1, 29) = 10.77, p < .05$. Participants were slower at naming the target object when the hand actions matched the alignment of the object than when they are misaligned (see **figure 3**). The analysis did not reveal any other significant main effects or interactions.

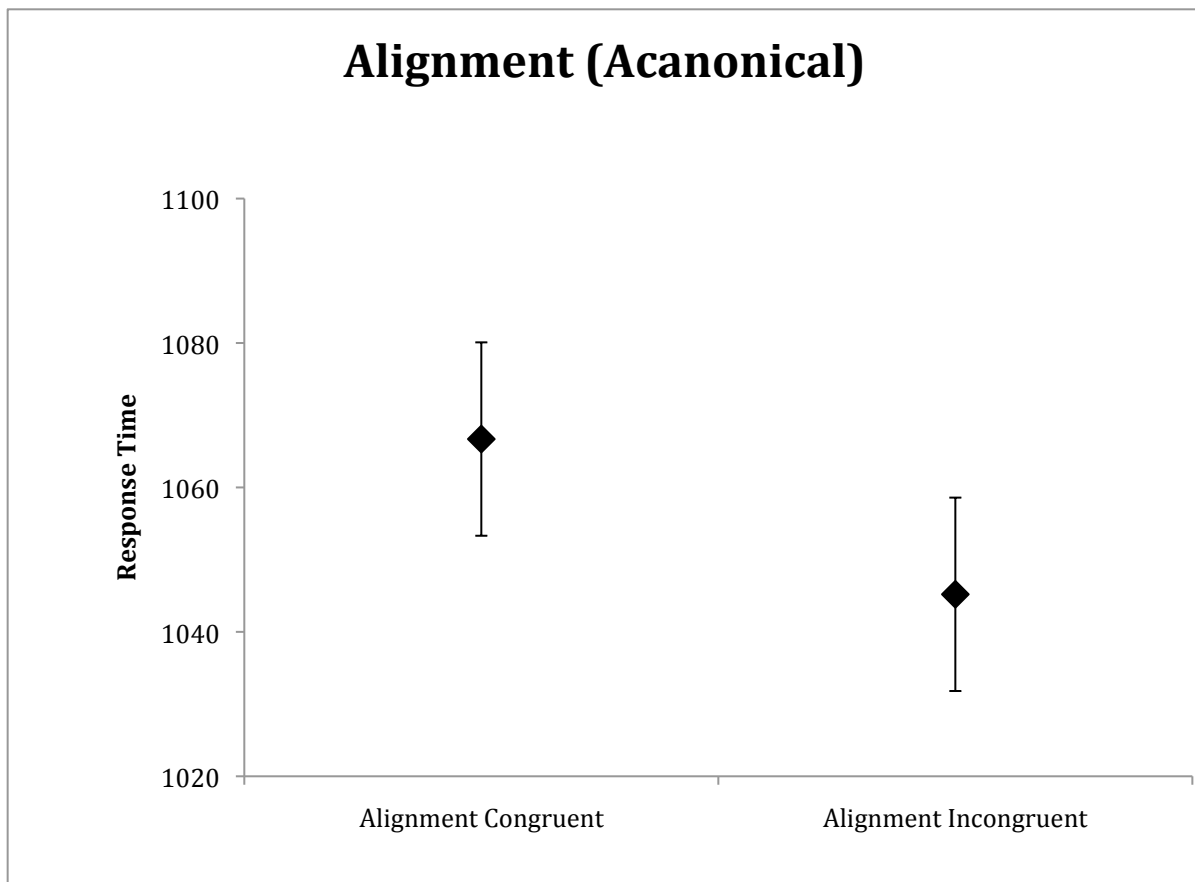


Figure 3 Response (in milliseconds) for naming acanonical objects when the alignment of the hand action is aligned with the object's handle. The error bars represent 95% confidence intervals.

Typical objects only. A 2 x 2 x 2 repeated measures ANOVA revealed a 3 way interaction between rotation, alignment congruency and orientation congruency, $F(1, 29) =$

14.97, $p < .001$. To examine the nature of the 3-way interaction (and the partial incongruency effect, a la Bub Masson and Lin, more directly), two subsets were created from the rotation variable (i.e. upright & rotated) and the subsets were analyzed separately. For upright objects, the analysis revealed an interaction between alignment and orientation congruencies, $F(1, 29) = 4.58$, $p < .05$. Participants were slower at naming the target object when the hand actions matched only one feature of the target object than when the hand actions completely matched or completely mismatched the target object (see **figure 4**). For rotated objects, the analysis also revealed an interaction between alignment and orientation congruencies, $F(1, 29) = 5.74$, $p < .05$. The pattern was reversed for the rotated objects. Participants were faster at naming the target object when the hand actions matched only one feature of the target object than when the hand actions completely matched or completely mismatched the target object (see **figure 5**).

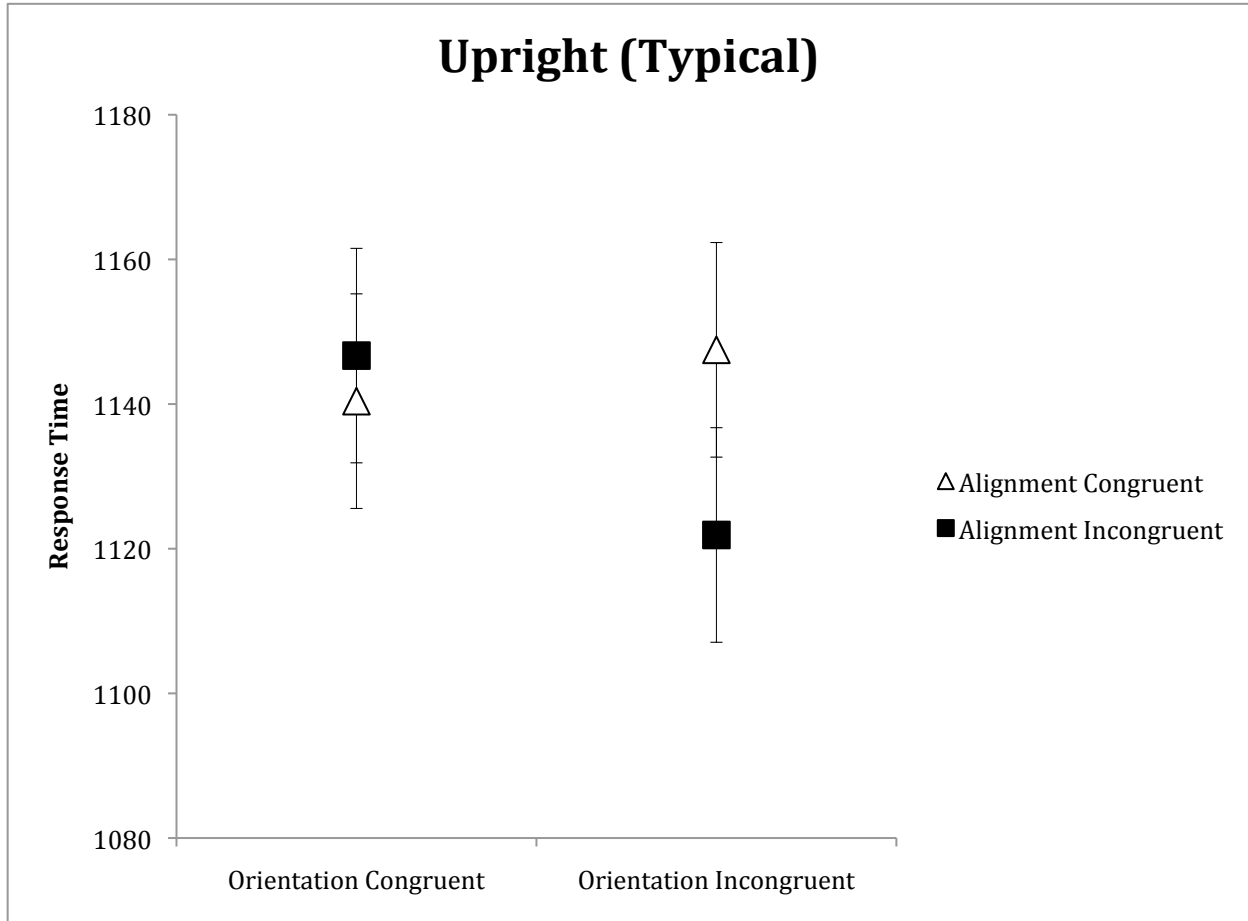


Figure 4. Response time (in milliseconds) for naming typical objects in the canonical upright position when the hand actions are fully congruent, fully incongruent, or partially incongruent with the target object. The error bars represent 95% confidence intervals.

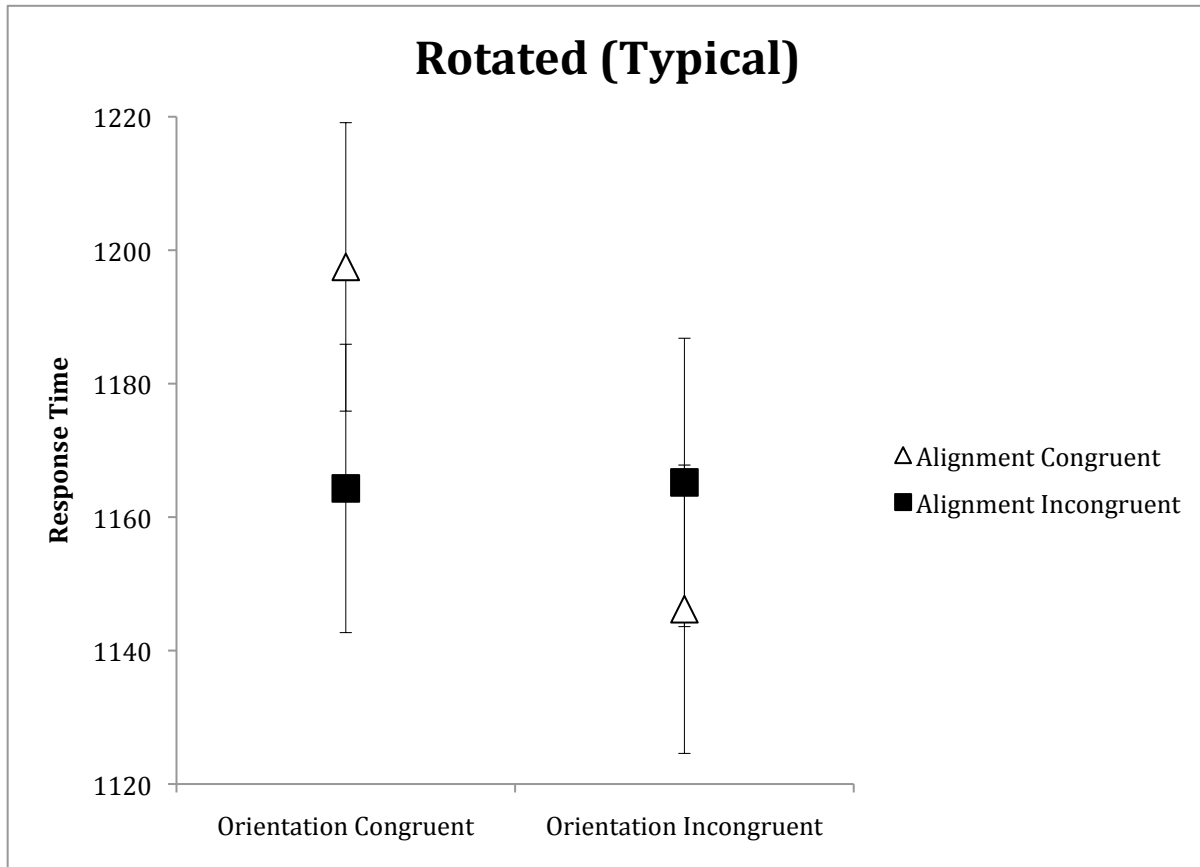


Figure 5. Response time (in milliseconds) for naming typical objects in their rotated position when the hand actions are fully congruent, fully incongruent, or partially incongruent with the target object. The error bars represent 95% confidence intervals.

Post-hoc quintile analysis of typical objects

A post-hoc quintile analysis was conducted, by splitting the response time data into five quintiles from fastest 20% of the responses (Q1) to the slowest 20% of the responses (Q5), to examine how the strength of the partial incongruency interference effect for naming upright objects and the reversal of the effect for naming rotated objects varied depending on how quickly the participants named the objects. The effect sizes at each quintile were calculated for the partial incongruency interference effect pattern for naming upright objects and the reverse of the effect for naming rotated objects. For upright objects, the delta plot (see **figure 6**) revealed the partial

incongruency interference effect pattern was present only at Q2. For rotated objects, the delta plot revealed the reverse of the effect pattern was present from Q1 to Q4.

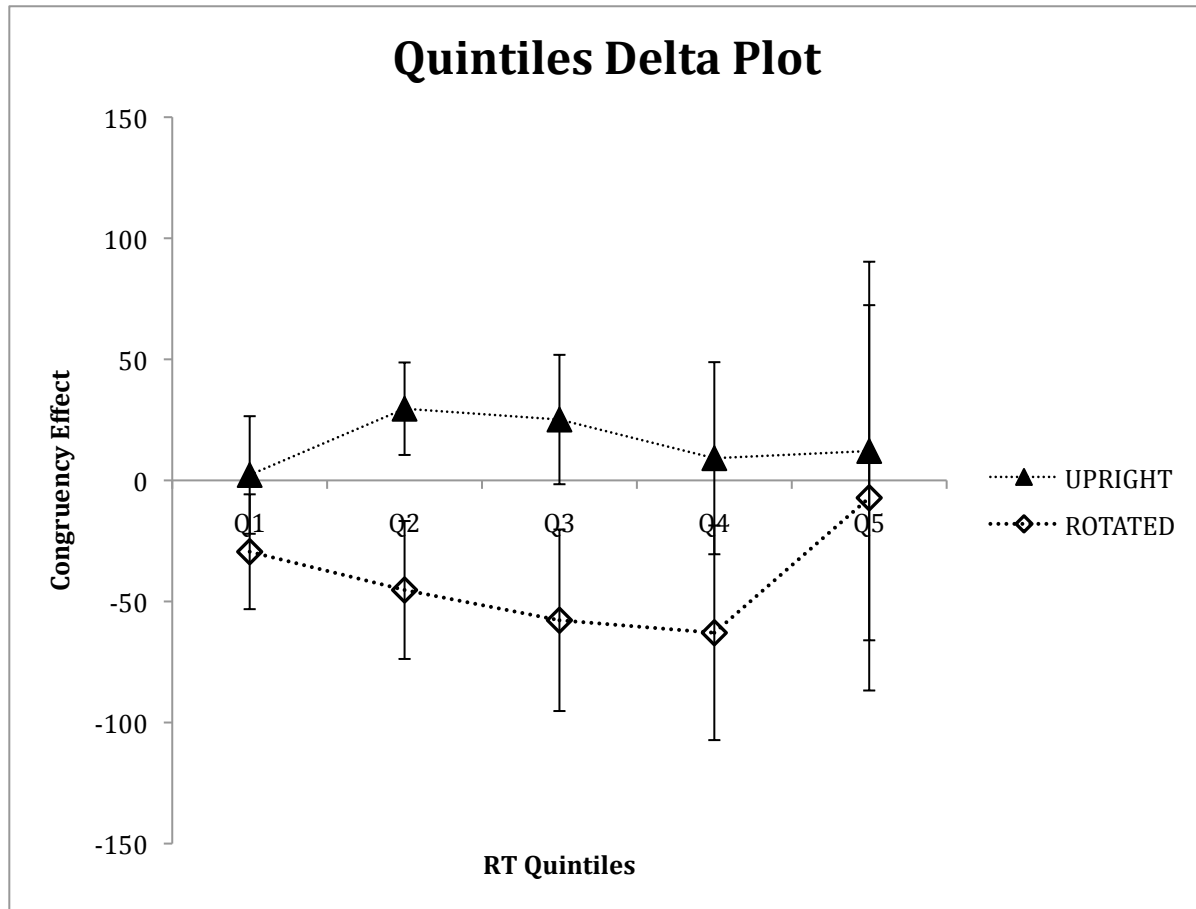


Figure 6. Delta plot (in milliseconds) for the partial incongruency effect in naming upright objects and the reverse of the effect in naming rotated objects. The error bars represent 95% confidence intervals.

Experiment 1 Discussion

Acanonical objects. The orientation of acanonical objects did not seem to play a significant role in evoking action representation when naming acanonical objects. The alignment of the handle, on the other hand, did have an influence on naming this type of object. If we assume that this type of object is being named solely based on its depicted view, because the beginning state and end state are undistinguishable, then the result is perhaps not too surprising. Since acanonical objects do not have an obvious canonical upright position, the orientation of the handle would be irrelevant to the functional properties of the object. An alignment effect was observed because, as previously discussed in Cho and Proctor's (2010) study, consulting only the depicted view would result in an alignment effect. The object's handle would serve as a spatial bias towards one side of the visual field depending on where the handle is protruding out of the object's body. This is, however, only a speculative claim. A refined experiment is required to differentiate the acanonical object's beginning state and end state in order to provide greater insight to the precise nature of action representation evoked when naming this type of object.

Typical Objects. For upright objects, we were able to replicate the partial incongruency interference effect observed in Bub, Masson & Lin (2013). However, the effect was weaker than what we had expected. For naming rotated objects, we also found a reversal of the partial incongruency effect pattern but once again, it was not as distinctive as the effect pattern observed in Bub, Masson & Lin; an overall orientation congruency effect on naming rotated objects was also present. We suspected that we did not observe our expected pattern of effects due to the inclusion of acanonical objects in the stimulus set. Fortunately, a post-hoc quintile analysis was able to reveal how the strength of the partial incongruency interference effect for naming upright

objects and the reversal of the effect for naming rotated objects varied depending on how quickly the participants named the objects. The interaction pattern and reverse pattern were strongest in the second and third fastest quintiles for both upright and rotated objects. This suggested that perhaps if we excluded the acanonical objects from the experiment and encouraged the participants to respond more quickly, we may have found a more distinctive partial incongruency interference effect for the upright objects and the reverse pattern for rotated objects. Thus a second experiment (Experiment 2) was carried out, by excluding the acanonical object and decreasing the viewing time for the objects, to obtain stronger evidence for the distinctive partial incongruency effect pattern and the reverse pattern.

Experiment 2

Experiment 2 was a replication of Experiment 1 with two notable differences. Because the results of Experiment 1 might have been affected by the inclusion of acanonical objects, these objects were excluded from Experiment 2. The second difference in Experiment 2 was that participants only had 150 ms to view the object before it was replaced by a mask; this would presumably encourage the participants to name the objects faster. The quintile analyses in Experiment 1 suggested that faster responses were more efficient in eliciting the partial incongruency interference effect for upright objects and the reverse pattern for rotated objects. If we were able to observe these two patterns in Experiment 2, they would provide stronger support for the notion that the object identification system evokes action representations based on the functional end state of the object.

Experiment 2 Method

Subjects. A new group of thirty undergraduate students at the University of Victoria participated in the experiment for extra credit in a psychology course.

Materials. The same sets of pantomimes and objects were used as in Experiment 1 with the exception of acanonical objects from the stimulus set.

Design. The same 2 x 2 x 2 repeated measures within-subject deisign was used as experiment 1.

Procedure. The procedure remained the same as experiment 1 except with two differences. The target object appeared for only 150ms before being replaced by a 12.7 cm x 12.7 cm distorted image to prevent further processing the target object. The second difference was the assignment of stimuli to conditions because the acanonical objects were removed.

Participants viewed 64 objects in four blocks (256 critical trials). In each block, objects and pantomimes were split into the same 16 conditions (2 handle alignment x 2 handle orientation x 2 hand alignment x 2 hand orientation). Each block contained all 64 unique objects and they are randomly assigned to the 16 conditions. Within each block, each condition contains four unique objects of each type (8 unique objects per condition).

Within each block, the four hand types were paired with each other with no repeated hand types. This provided us with 6 unique hand type combinations. Since there were 6 object tokens per condition, each condition would have an unique object randomly paired up with a hand type combination. The pairing between unique objects and hand type combinations varied across each block.

Experiment 2 Results

A 2 x 2 x 2 repeated measures ANOVA revealed a 3 way interaction between rotation, alignment congruency and orientation congruency, $F(1, 29) = 21.44, p < .001$. To examine the nature of the 3-way interaction, the same subsets were created as Experiment 1. For upright objects, the analysis revealed an interaction between alignment and orientation congruencies, $F(1, 29) = 15.96, p < .001$. Participants were slower at naming the target object when the hand actions matched only one feature of the target object than when the hand actions completely matched or completely mismatched the target object (see **figure 7**). For rotated objects, the analysis also revealed an interaction between alignment and orientation congruencies, $F(1, 29) = 10.43, p < .001$. The pattern was reversed for the rotated objects. Participants were faster at naming the target object when the hand actions matched only one feature of the target object than when the hand actions completely matched or completely mismatched the target object (see **figure 8**).

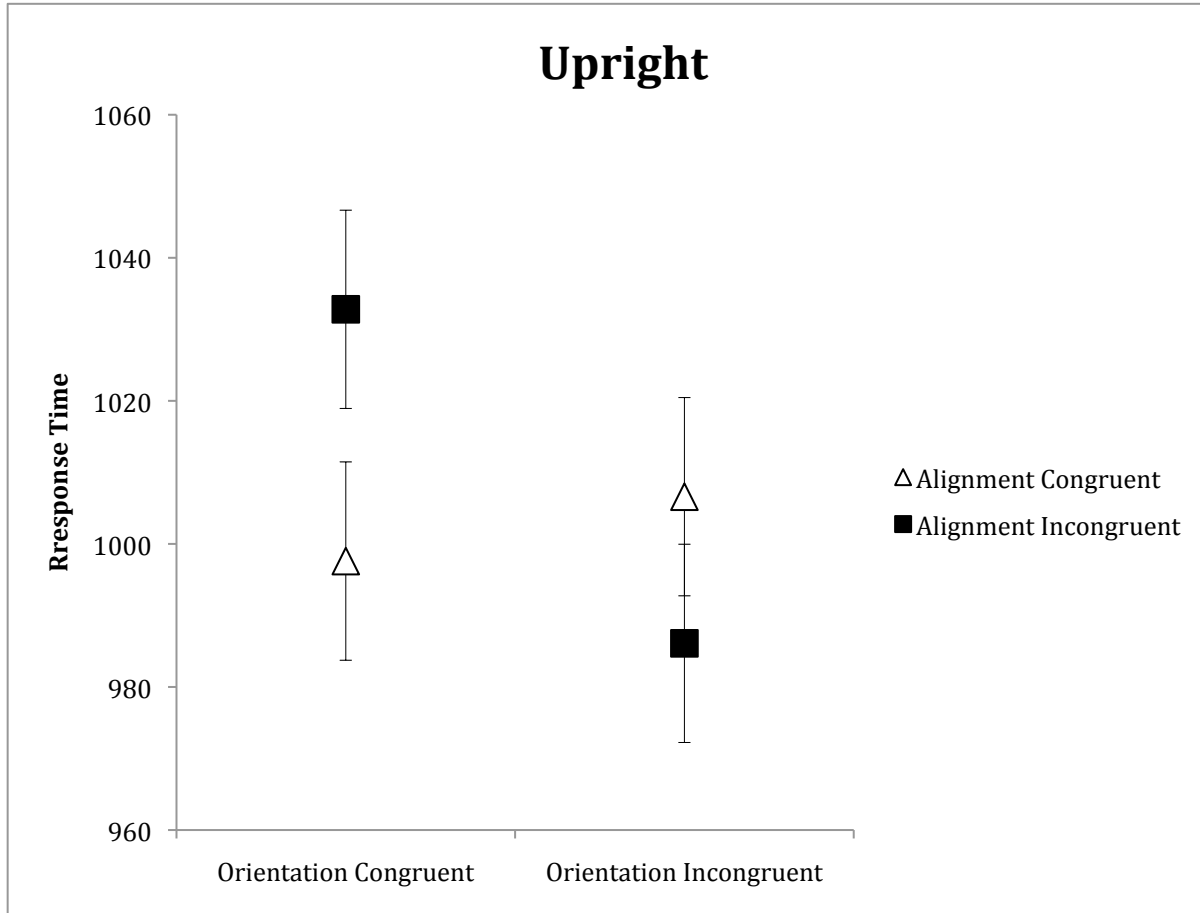


Figure 7. Response time (in milliseconds) for naming typical objects in the canonical upright position when the hand actions are fully congruent, fully incongruent, or partially incongruent with the target object. The objects only appear for 150 ms before it is replaced by a masked stimuli. The error bars represent 95% confidence intervals.

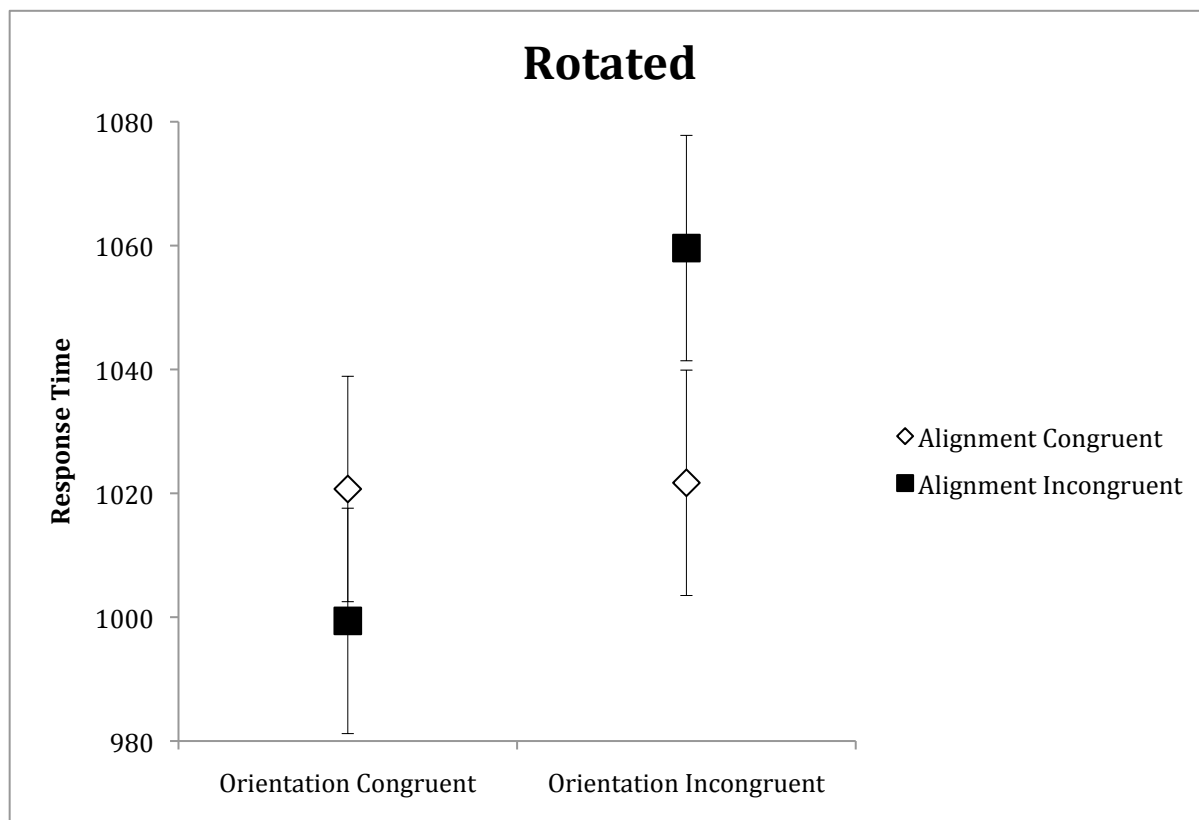


Figure 8. Response time (in milliseconds) for naming typical objects in the rotated position when the hand actions are fully congruent, fully incongruent, or partially incongruent with the target object. The objects only appear for 150 ms before it is replaced by a masked stimuli. The error bars represent 95% confidence intervals.

Post-hoc mixed factors analysis

Due to the similarity in the pattern of results observed in both studies, a post-hoc mixed factors ANOVA was performed to investigate whether the 3-way interaction observed in the two experiments were significantly different from each other. The within-subjects variables were the same as the previous experiments (i.e. rotation, alignment congruency, and orientation congruency). The between-subjects variable is the duration of time the object appeared on the screen (150ms or until response). The mixed factor ANOVA did not reveal a significant 4-way interaction between duration, rotation, alignment congruency and orientation congruency. This null result suggested that decreasing the object viewing time to 150ms did not alter the partial

incongruency interference effect for naming upright object or the reverse of the effect for naming rotated objects.

Post-hoc repeated measures analysis (Experiment 1 & 2 combined)

The two datasets were combined together ($n = 60$) and analyzed as a within-subject repeated-measures design. The $2 \times 2 \times 2$ repeated measures ANOVA revealed a 3 way interaction between rotation, alignment congruency and orientation congruency, $F(1, 59) = 36.47, p < .001$. To examine the precise nature of the 3-way interaction, the same subsets were created as experiment 1 and 2. For upright objects, the ANOVA analysis revealed an interaction between alignment congruency and orientation congruency, $F(1, 59) = 18.31, p < .001$. Participants were slower at naming the target object when the hand actions matched only one feature of the target object than when the hand actions completely matched or completely mismatched the target object (see **figure 9**). For rotated objects, the analysis also revealed an interaction between alignment and orientation congruencies, $F(1, 59) = 15.56, p < .001$. The pattern reversed for the rotated objects. Participants were faster at naming the target object when the hand actions matched only one feature of the target object than when the hand actions completely matched or completely mismatched the target object (**figure 10**).

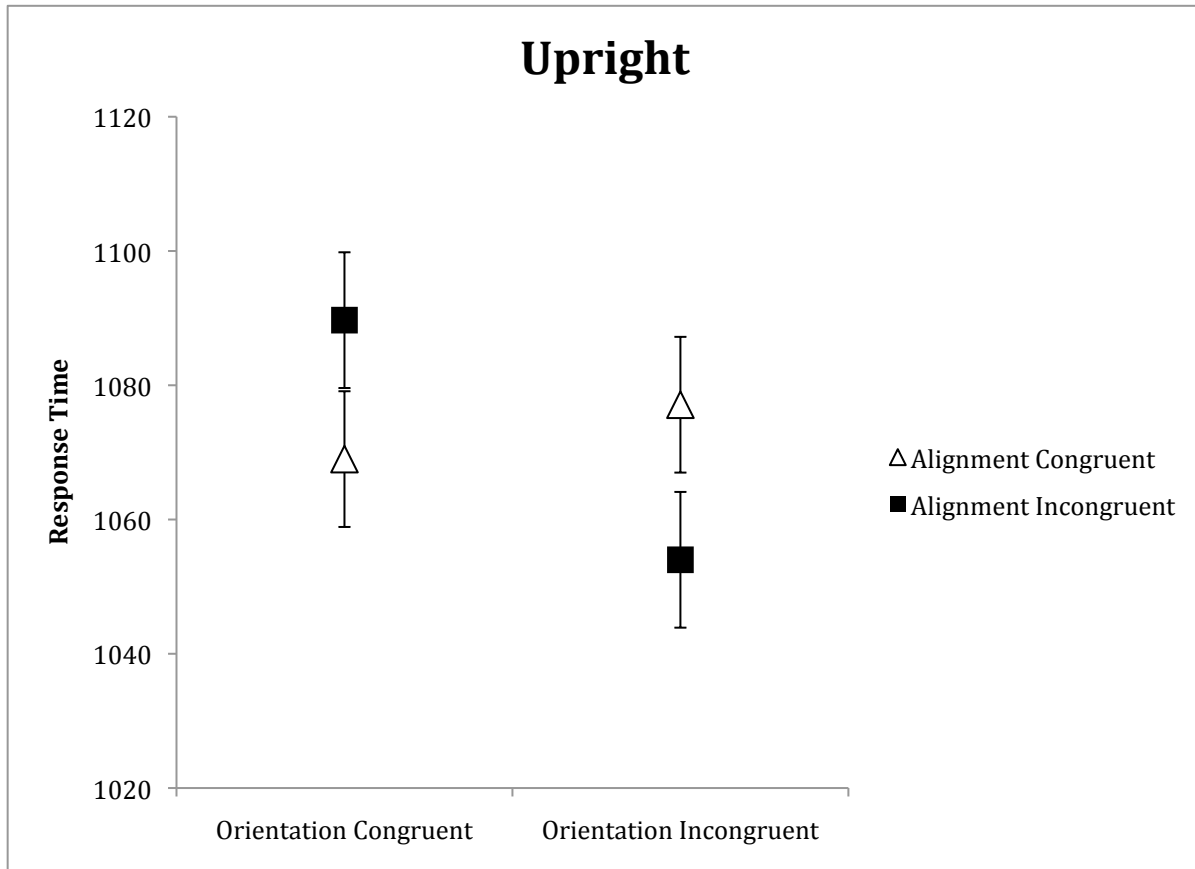


Figure 9. Response time (in milliseconds) for naming typical objects in the canonical upright position when the hand actions are fully congruent, fully incongruent, or partially incongruent with the target object. This dataset combined the data from both Experiment 1 and 2. The error bars represent 95% confidence intervals.

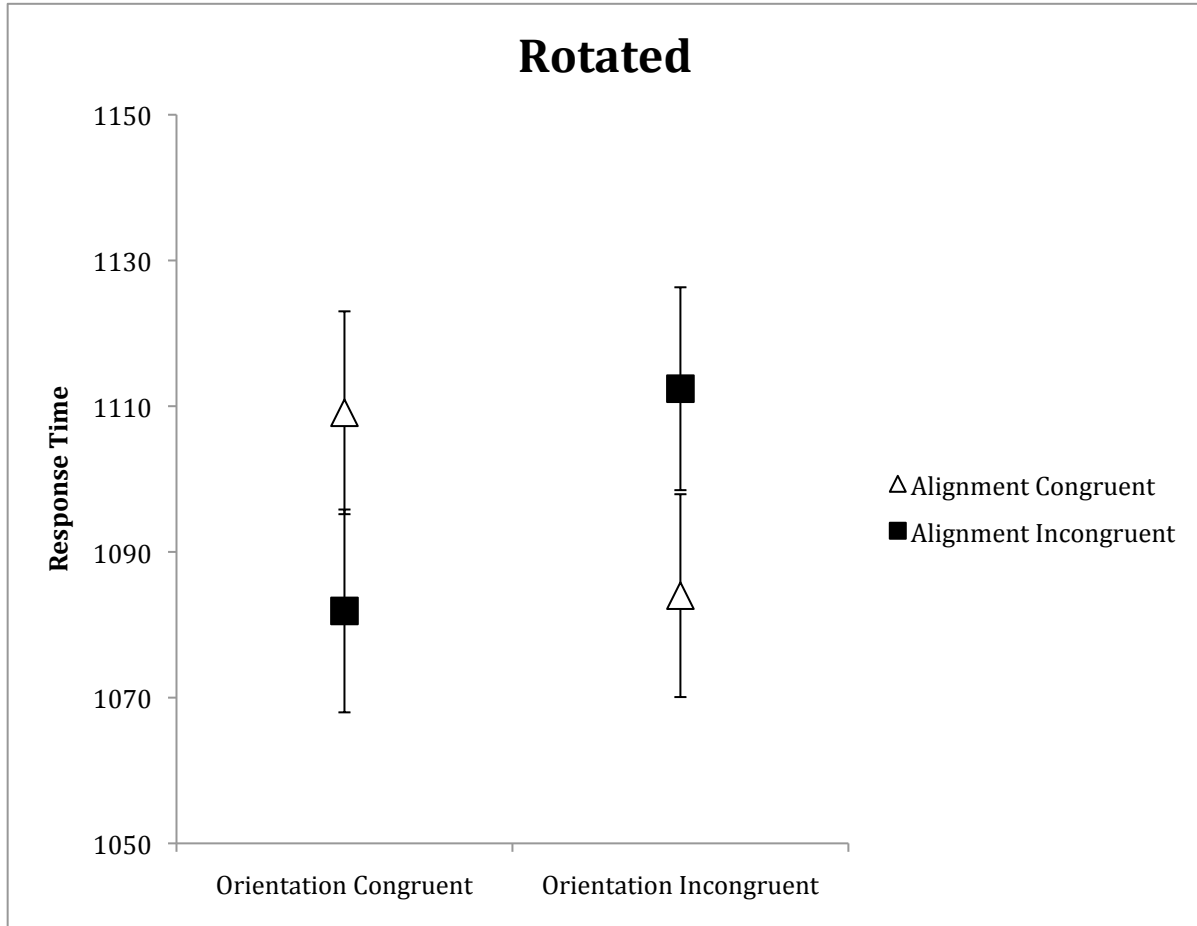


Figure 10. Response time (in milliseconds) for naming typical objects in the rotated position when the hand actions are fully congruent, fully incongruent, or partially incongruent with the target object. This dataset combined the data from both Experiment 1 and 2. The error bars represent 95% confidence intervals.

Experiment 2 Discussion

As expected, excluding the acanonical objects and decreasing the viewing time of the target object revealed a much more distinctive partial incongruency interference effect for naming upright objects and a reverse pattern for naming rotated objects. Analyzing the two datasets using a within-subject repeated measures design provided a clearer pattern of effects as well. Taking the findings together, they provide strong evidence for the notion that action representation plays a functional role in object identification. The functional end state plays a much greater role than the beginning state in evoking action representations when identifying handled objects.

General Discussion

Naming a rotated object evokes action representation solely based on the end state of the object and not the beginning state. The object's beginning state and end state play different roles in evoking action representation when naming objects and planning a reach and grasp action. When naming an object, the beginning state, by itself, provides no relevant information regarding the functional properties of the object. Evoking an action representation based on the depicted view would not aid the identification process. The end state, however, would most certainly be associated with the functional properties because the functional properties are directly related to the conceptual knowledge of the object.

Automaticity. Interestingly, if action representations are a part of an object's conceptual representation, it would imply that identifying an object may indeed automatically evoke action representations as claimed in past studies. For example, Campanella and Shallice (2011) have proposed that action representation is a semantic feature critical to defining object properties. They showed that the presence of objects sharing the same function with a target object interferes significantly with its identification. This interference effect is stronger when the objects shared similarity in terms of the way they are used than if they shared only visual similarity. The authors argued that to access the conceptual knowledge of an object, one must consult the object's functional properties which in turn evokes the action representation associated with the object. The strength of the argument, however, depends on whether evoking action representations is a necessary condition for identifying handled objects. Although the findings from our studies do support this view, we are unable to make a definitive claim based on the evidence in this particular paper. Due to the way the experiments were designed, we cannot

infer whether action representations were automatically evoked or evoked as a result of our task conditions. Action representations might have been evoked as a consequence of keeping hand actions in working memory prior to naming the objects. Holding hand actions in working memory might have biased the identification system to rely on motor representations when naming objects. Therefore, a different experimental design is required to examine the automaticity of evoking action representation in object identification.

Motor vs. Spatial. It is questionable whether the hand actions were kept in working memory as actions or static hand postures. If the hand actions are being kept in working memory as static hand postures, then they might have been coded as visuospatial features as Cho and Proctor (2010) suggested. A proponent of a disembodied account may argue that if the effects we have observed were merely due to conflicts between visuospatial features, then it is not clear whether the motor system was ever involved in the identification process at all. This is a plausible but probably unlikely alternative account to our current interpretation of the findings because it is extremely difficult for the visuospatial account to explain the fact that the rotated objects were identified based on their functional end state and not their depicted view. The fact that the end state of the rotated object, not the beginning state, had an influence on naming strongly suggests the object's functional properties evoked an action representation instead of a visuospatial representation. Furthermore, because hands are fundamentally a part of the human body, one would reasonably assume that keeping hand postures in working memory would still require involvement of the motor system. Unless the hands were coded as abstract stimuli such as arrows, numbers or colours, the representations evoked in our experiments were more likely to be action representations than visuospatial representations. An interesting follow-up for our study would be to replicate our experiment using abstract stimuli (irrespective to the human

body) that can also indicate the left, right, horizontal, vertical dimensions much like the hands and see if the same pattern of effects persists.

Priming vs. Interference. The nature of the effects observed in Masson, Bub and Breuer (2011) and Bub, Masson, Lin (2013) are inherently different. The fact that object primes actions and action interferes with object naming suggests that there may be two different processes for evoking action representations depending on the context. When we compared the strength of the partial incongruency interference effect across the quintiles, we saw that the effect was generally stronger in faster quintiles than the slower quintiles. The object priming effect on performing hand actions lasts for only about 300ms before it disappears. The hand action interference effect lasts longer than a full second. A critical investigation is needed to examine whether the hand action interference effect switches to a priming effect if we shortened the delay between when the hand actions are presented and when the participants have to name the objects.

Regardless of the results of these prospective studies, the evidence presented in this paper revealed an extremely subtle interplay between the motor system, the visual system and the object's conceptual representation in evoking action representations. When naming handled objects, action representations are precisely evoked in accordance with the functional properties of the object.

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