Getting a Handle on Meaning: Planned Hand Actions' Influence on the Identification of Handled Objects

By

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B.Sc., University of Victoria, 2020

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Abstract

We confirm that under certain conditions, constituents of motor actions afforded by handled objects play a role in their identification. Subjects held in working memory action plans specifying both the laterality of the hand to be used (left or right) and a wrist orientation (vertical or horizontal). Speeded object identification was impaired when a pictured object matched the action on only one of these two categorical dimensions (e.g., a frying pan with its handle facing left, an action plan involving the right hand and horizontal wrist orientation), relative to when the object matched the action on both dimensions or neither dimension. This phenomenon only occurred for a semantic task (i.e., naming) and significantly weakened when the handled object was named following the naming of a non-handled object. These results imply that, when maintaining the features of planned actions in working memory, identification of the object leads to conflict between components of the action plan and features of the grasp action afforded by the depicted object. When bound to a matching feature, the discrepant features cannot be easily disregarded, and conflict with the features of the target object resulted in delayed identification. Naming a non-handled object first weakens the pragmatic processing generated by attending to the features of the action plans, resulting in less conflict when only one feature matched between the action plan and action afforded by the handled object.

Table of Contents

List of Figures

List of Tables

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Introduction

There is considerable debate on the possible role that action representations play in the identification of manipulable objects. Of special interest here is the nature of the representations recruited to identify an object, like a frying pan, with the handle lateralized to one or the other side of the base. We will use the term "manipulable object" to refer to this large class of objects (i.e., objects with handles). A widely held claim is that we identify this type of object not only by consulting a representation of its shape but also of the grasp posture best suited to lift and use the object (e.g. Tucker & Ellis, 1998). A frying pan with the handle on the left, for example, would evoke the representation of a left-handed grasp action. Assume that the laterality of the grasp posture elicited by the object is a feature of its perceptual identity. A secondary motor task assigned to the left or right hand might require this feature and render it temporarily unavailable or less accessible for a conceptual task like naming the depicted object. Performance would then be slower and less accurate when the handle is aligned rather than misaligned with the corresponding hand.

Witt, Kemmerer, Linkenauger, & Culham (2010) relied on this idea to assess the possibility that motor features play a role in naming objects. Participants squeezed a foam ball in one hand while naming pictures of tools and animals. Naming was slower when the handle was facing towards rather than away from the hand holding the ball. Since there was no compatibility effect in the naming of animals, Witt et al. (2010) concluded motor simulation has a functional role in tool identification. Unfortunately, subsequent attempts to reproduce this outcome have not been successful. Saccone, Thomas & Nicholls (2021) in a series of experiments, failed to observe any effect on naming pictures of objects like a frying pan, when the handle was oriented towards or away from the hand involved in a secondary motor task (squeezing a ball or continuously moving the fingers in and out of a fist posture). Additional results inconsistent with the notion that lateralized motor representations play a role in identifying objects with the handle oriented to the left or right of the base were reported by Matheson, White & McMullen (2014).

In view of these negative results, Witt, Kemmerer, Linkenauger & Culham (2020) reanalyzed their original data, noting that the statistical outcomes depended on the choice of data-cleaning procedures. In the original experiment, outlier reaction times slower than 4000 ms were excluded, yielding statistically reliable effects. When another and less arbitrary exclusion criterion was adopted (1.5 times the interquartile range) the critical effect was no longer apparent.

It is worthwhile making explicit the tacit assumptions motivating the approach that ultimately yielded null results by Saccone et al. (2021) and by Witt et al. (2020), as a reasonable test of the claim that motor representations play a role in identifying objects with the handle affording a left versus right-handed grasp action. The task of repeatedly squeezing a ball simply requires the iterative production of a stereotyped motor program. The failure to observe any reliable effect of this secondary task on naming graspable objects excludes only one possibility; that there is no effect on naming when the left or right hand is assigned a task that involves a single movement repeatedly executed.

This thesis deals with an altogether different possibility: that the constituents of a planned action in working memory have a potent effect on the naming of the graspable object. Previous work by Bub, Masson & Lin (2013) has demonstrated just such an effect; in brief, the naming of graspable objects with the handle on the left or right of the base was slowed by more than 70 ms on average when the action afforded by the object differed by a single feature from the stored representation of an action sequence held in working memory. The framework underlying this remarkable outcome will shortly be reviewed in more detail.

This thesis is organized as follows. First, the rationale behind the idea that features of actions in working memory could have an impact on naming manipulable objects will be presented, relying on a theoretical framework adapted from previous work on the binding of features in visuomotor tasks (Hommel, 2004). According to principles derived from the Theory of Event Coding (Hommel, 1998), the temporary binding of features in working memory generates interference on subsequent perceptual and motor tasks. By analogy, the same constraint might apply to the naming of graspable objects if actions are recruited as part of their identification.

Given the very large effect observed by Bub et al. (2013), questions arise as to the replicability of the original result, especially in the context of the disappointing failure to reproduce effects previously taken as evidence that lateralized actions can affect the naming of graspable objects. Experiment 1 provides a clear replication of the original results; features of action plans in working memory do indeed have a substantial impact on the naming of manipulable objects.

Next, a theoretical framework is introduced that provides a deeper understanding of the task context responsible for the effect on naming of stored action plans, drawing on a distinction proposed by Jeannerod & Jacob (2005) between semantic and pragmatic modes of representing an object. A pragmatic mode of processing is needed to prepare and maintain an action sequence in working memory. The persistence of this mode of processing accounts for the effect of the action sequence on naming a manipulable object, a task that in other contexts would entail only a semantic mode of processing. A prediction derived from this account is tested and confirmed in Experiment 2.

Finally, the question arises as to whether the impact of stored motor features on naming requires access to semantic properties of the object, or whether a task that only involves perceptual coding is also affected by action plans. Experiment 3 will establish that no comparable effect of motor features in working memory occurs when speeded responses depend only on access to the perceptual properties of the object.

Bound action features in working memory interfere with the planning of other actions

Evidence suggests that components of a grasp action, such as the hand selected, the trajectory of the movement and the position of the fingers on the goal object, are determined by a number of different cortical systems (Jeannerod, 1997). Imagine the sequential production of two actions, both involving the left hand. The first requires that the index and middle fingers are extended, and the second requires an extension of the thumb while the remaining fingers are curled inwards. According to Stoet & Hommel (1999) this action sequence leads to what they refer to as a “binding problem”, akin to the problem facing the visual system when for example, the fruit on a cherry tree must be coded as red and round while the leaves are green and elliptical (D. Allport & Chmiel, 1985; Park & Kanwisher, 1994). As pointed out by Stoet & Hommel (1999): “…how does the system “know” that it is the red object that is round and the green object that is elliptical?” (Page 1626). Likewise, in preparing a sequence of actions, these authors note that “…combining two or more actions that have different features and thus require alternative movement parameters creates a very similar problem as is presumably present in the perception of multiple objects” (page 1626). The solution requires a mechanism that integrates features such as the laterality and position of the fingers when preparing a grasp posture (or the colour and shape of an object in the visual domain) into a coherent representation (see for example, Damasio, 1989; Singer, 1990).

Features integrated for a prepared action can interfere with the production of additional actions, as long as the current plan remains active in working memory (Hommel, 2004). The standard pattern of effects is as follows: Repetition of all task-relevant features between the designated visuomotor task and the contents of working memory yields performance that is no better than conditions in which no feature repeats. A cost occurs, however, when some but not other features of a just integrated event file are repeated, a phenomenon referred to as a “partial repetition cost”.

To understand this outcome, consider a target object that affords a grasp action with the right hand and the wrist oriented vertically (e.g. a beer mug with the handle on the right). Imagine that an action plan is maintained in working memory that includes the features {left hand} and {vertical wrist orientation}. These features are integrated as part of an active motor plan, so that retrieving one necessarily entails retrieval of other bound features. A partial match between the components of the grasp action afforded by the target object and the contents of working memory will induce retrieval of the entire stored action plan by spreading activation. Under suitable task conditions, the mismatched feature - in this instance, hand laterality - between the grasp posture assigned to the depicted object and the components of an action plan retrieved from working memory will generate interference. As Hommel (2004) notes: “Apparently, activating a wrong file impairs performance more than is helped by having an appropriate event file available. This suggests that feature binding produces PARTIAL-REPETITION COSTS rather than object- specific repetition benefits” (page 496, capitals are Hommel’s).

Bound action features in working memory interfere with the naming of graspable objects.

Bub et al. (2013) applied the above framework to the question of whether bound features of a planned action in working memory exert an effect on naming graspable objects. Participants held two sequentially presented hand postures (with the same laterality and wrist orientation) in working memory before they named a handled object. The rationale behind keeping two hand postures in working memory is two-fold. Firstly, having to remember just a single posture might allow for participants to code it visually instead of as an integrated set of motor features. Keeping two hand postures in working memory is sufficiently difficult for the motor system to be recruited for the memory task. Consistent with this assumption, it has been shown that somatosensory cortex activity increases during working memory tasks depending on the number of hand images to be remembered (Galvez-Pol, Calvo-Merino, Capilla, & Forster, 2018).

Secondly, maintaining the correct sequence of two hand postures in working memory requires the binding of motor features. A left-handed posture with the palm held vertical and the thumb extended, for example, must be kept distinct from the same posture with the index finger and thumb forming a pinch grasp. Once the two hand postures were presented, a handled object of a particular laterality and orientation was shown that participants had to name as quickly as possible. After naming, on 25% of the trials, participants were asked to pantomime the gestures presented in the order that they appeared to ensure the planned hand actions were indeed kept in working memory. Bub et al. (2013) found that when there was a partial overlap of features between the planned hand action and afforded grasp action (i.e., either laterality or orientation matched, not both or neither), participants were approximately 70 milliseconds slower to name the handled object. These results definitively suggest that the features of planned actions affect the naming task.

Experiments

2.1 **Experiment I**

The magnitude of the effect is remarkable and deserves further scrutiny. Accordingly, the first experiment is a test of the replicability of the study by Bub et al. (2013).

2.1.1 **Method**

Participants. 30 participants were recruited for extra credit in their undergraduate psychology courses. Of these participants, 2 were male and three were left-handed. The average age of participants was 20.80 years (standard deviation ± 2.85 years). The University of Victoria Human Research Ethics Board approved all experiments presented in this thesis.

Materials. There were three different instances of each of 32 object types (e.g., 3 different teapots, 3 different flashlights; see Table 1 and Figure 2.1.1). The images (base plus handle) were centered at fixation. Each instance had a horizontally mirrored version resulting in a total of 192 digital photographs of common objects with handles. Half of the objects were selected to have a vertical handle (e.g., beer mug) to afford a vertical grasp, and half were selected to have a horizontal handle (e.g., frying pan) to afford a horizontal grasp.

Based on wrist orientation, a vertical and horizontal version of five hand postures (e.g., fist, flat palm, precision grip) were selected and digitally photographed. The resulting 10 photographs were mirrored to create a left-hand and a right-hand version. All images were greyscale and made to be 500 by 500 pixels (or 17.64cm by 17.64cm). Our experiment ran on a Macintosh computer using the SuperLab5 program.

Table 1. Names of Handled Objects used in Experiment I

Horizontally orientated handles	Can opener, Chisel, Flashlight, Frypan, Garden shears, Hand vacuum, Iron, Kettle, Knife, Pliers, Saucepan, Screwdriver, Scrub brush, Spatula, Strainer, Wrench
Vertically orientated handles	Beer mug, Blow dryer, Coffee pot, Coffee mug, Drill, Garden spray, Hairbrush, Hammer, Handsaw, Joystick, Measuring cup, Megaphone, Pitcher, Teapot, Watering can, Water gun

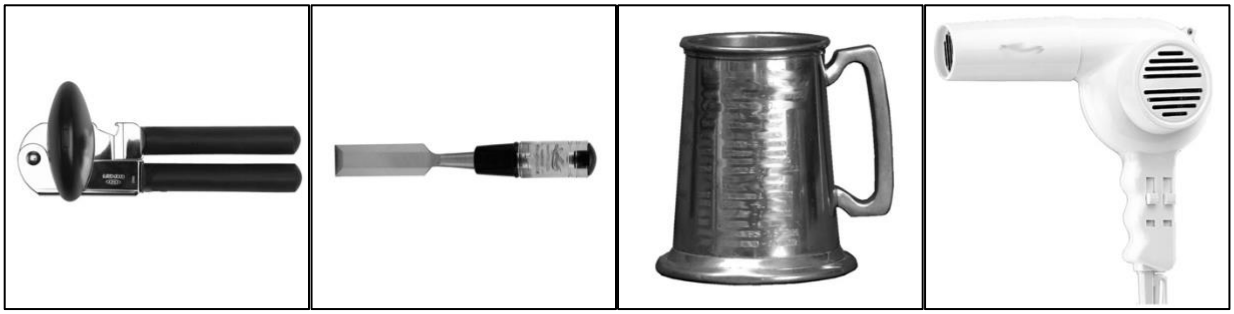

Figure 2.1.1. Example images of right-lateralized horizontally (*left*) and vertically (*right*) orientated handled objects use in Experiment I.

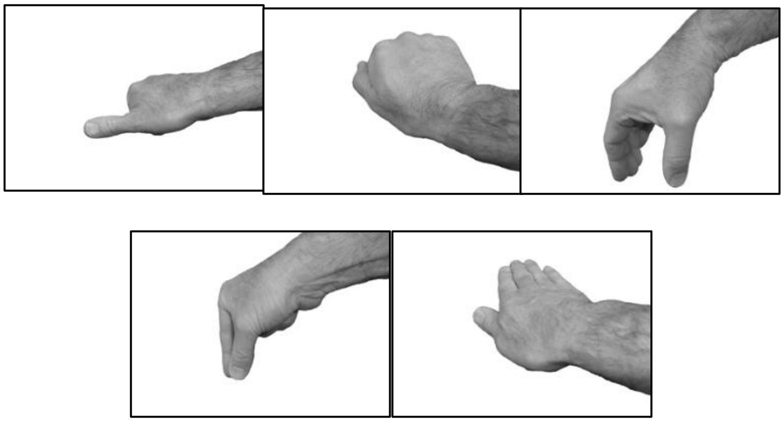

Figure 2.1.2. Right lateralized, horizontally orientated versions of the five hand postures.

Design. Five pairs of hand postures were created. Each single posture was included in two different pairs and two different postures were used in each pair. The pairs were rendered in four different versions defined by the 2x2 factorial combination of laterality (left or right) and orientation (vertical or horizontal). Both hands in each of the 20 pairs had the same alignment and the same orientation with each other. In combination, the hand posture, laterality, and orientation specified a unique hand action that a subject could perform.

A 2x2 factorial repeated measures design was used to determine the effects of orientation congruency (congruent or incongruent) and laterality alignment (aligned or misaligned) between hand postures and the object's handle.

Procedure. Before beginning the experiment, each participant signed a consent form. The experiment was held in a quiet room where participants sat about 50 cm away from the computer monitor.

Using an Apple Mac Pro desktop computer, subjects were individually tested. In the first training phase, they were trained to pantomime each of the five hand postures in each or the four possible versions (right or left and horizontal or vertical) twice, for a total of 40 trials. In the second training phase, subjects were familiarized with the set of 96 object photographs (all instances of the images affording a grasp posture with the same laterality). Each image was individually presented with the name of the pictured object appearing below it. The subject read the name aloud and was instructed on the nature of the object if they were unfamiliar with it. This ensured that participants were familiar with the postures and objects for later testing.

Following the training, a total of 192 trials (two blocks of 96 critical object-naming trials) were presented. In each block, the 16 unique combination of laterality alignment and orientation congruency (2 hand lateralities x 2 hand orientations x 2 handle lateralities x 2 handle orientations) were presented six times. Each block contained all 96 instances objects which were randomly assigned to the 16 conditions. At the start of each trial, a pair of pictured hand postures was sequentially presented, with each posture being shown for 1s. Following a delay of 1s, a fixation cross appeared for 250 ms, which was then replaced by the photograph of a handled object. The object remained in view until a naming response was made by the subject via a headset microphone. This sequence of events is illustrated in Figure 2.1.3. Subjects were instructed to respond as quickly and accurately as possible. The experimenter recorded the accuracy of the response by a key press with the aid of viewing a separate monitor that indicated the object's name. Errors were operationalized as inability to name the object, uttering an incorrect name, and false starts.

On 25% of the trials at random, participants were instructed to reproduce the two hand actions presented at the start of the trial, and they did so by pantomiming the actions. This ensured that subjects attempted to hold the hand actions in working memory while performing the object-naming task. To be deemed correct, subjects had to generate the same hand shape, wrist orientation (horizontal or vertical), laterality of hand (left or right), and order that the sequence presented at the beginning of the trial demonstrated. Small variations in the hand shape did not count as errors, so long as they could be differentiated from the other possible hand shapes. We also recorded if subjects reproduced the postures in the incorrect order, if they were outright incorrect (at least one posture varied in orientation or alignment), or if the trial was spoiled by some experimental error. Subjects maintained the representation of two hand postures (instead of one) to maximize the likelihood that the memory load would influence object-naming performance without overloading their short-term memory. Breaks were provided after every 32 trials.

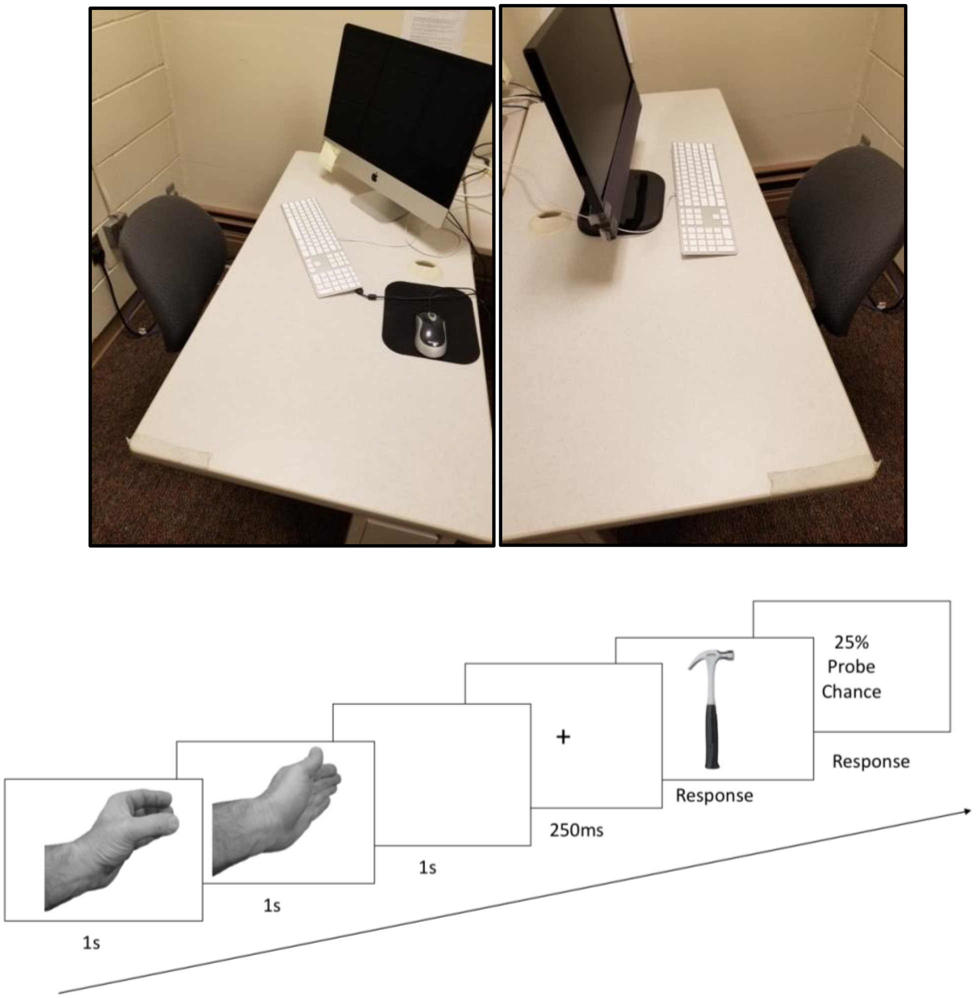

Figure 2.1.3. *Top:* Lab setup for experiments I, II, and III with experimenter on the left and participant on the right. *Bottom*: Example of trial procedure sequencing for Experiment I.

2.1.2 **Results and Discussion**

So that fewer than 0.5% of correct responses would be excluded, response times were deemed to be outliers if they exceeded 2,400 ms or preceded 100 ms in this object-naming task as recommended by Ulrich & Miller (1994). No participants were excluded due to excessive incorrect responses on either the naming task or probe trials.

The mean response time for correct responses in each of 16 conditions was computed for each participant. These conditions were defined by the factorial combination of object laterality, object orientation, and the hand-action laterality and orientating relative to the object (2 × 2 × 2 × 2). Reducing these factors to measures of compatibility between the handle of the object and the hand postures according to the measures of laterality (aligned or misaligned) and orientation (congruent or incongruent), we computed a 2x2 within subject analysis of variance (ANOVA). There was an interaction between congruency of orientation and alignment of laterality (F(1, 29) = 30.68, MSE = 3,882, p < .0001) shown in Figure 2.1.4. Naming was about 63.0 ms slower when the hand postures matched the object's handle on only one feature of orientation and laterality than when they either completely matched or mismatched. This crossover pattern explains why none of the main effects were significant. Clearly, the results fully substantiate the outcome of Bub et al.'s (2013) original study in regards to the crossover pattern in magnitude and form.

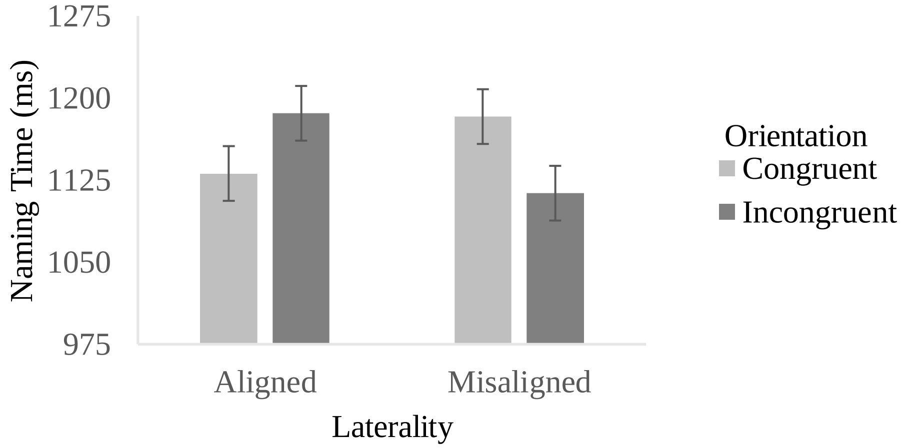

Figure 2.1.4. Mean response times (in milliseconds) for naming handled objects in Experiment I as a function of laterality alignment and orientation congruency. Error bars represent 95% confidence intervals.

For this object-naming task, the average error rate was 4.93%. Using the same 2x2 structure, an ANOVA indicated that the interaction between congruency of orientation and alignment of laterality had a significant effect on the error rate, F(1, 29) = 5.62, MSE = 338.1, p = .03, (Figure 2.1.5). This is the same crossover pattern as found in the naming reaction time data and demonstrates that errors occurred 1.48% less frequently on the faster naming trials where hand posture features completely matched or mismatch the grasp action afforded by the handle.

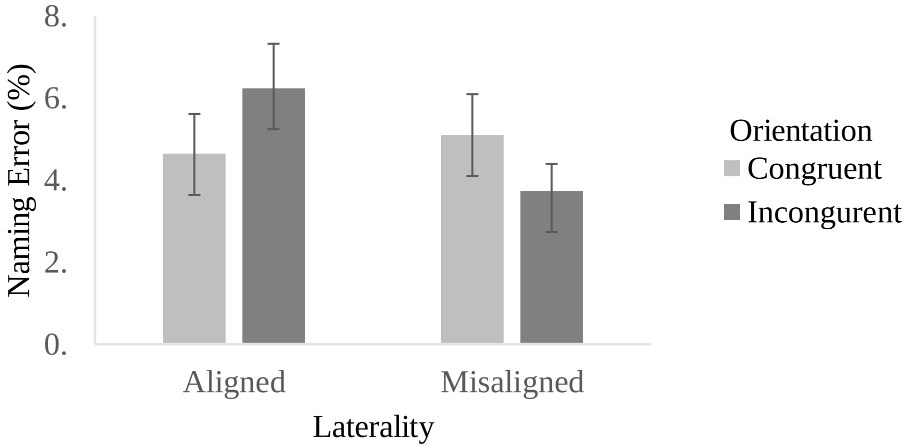

Figure 2.1.5. Mean naming error rate in Experiment I as a function of Laterality Alignment and Orientation Congruency. Error bars represent 95% confidence intervals.

For probe trials, the mean percentage error in the four conditions is shown in Figure 2.1.6. Unlike the results originally reported by Bub et al. (2013), the same crossover interaction pattern was not present in the recall of hand postures (F(1, 29) = 4.51, MSE = 218.9, p = 0.124). The relatively high error rate (48.59% overall) is likely the reason for this; the overall error rate was much higher than that of the original study (Bub et al., 2013). Further, since probe trials were only conducted on 25% of trials, there was a low power to detect any effect.

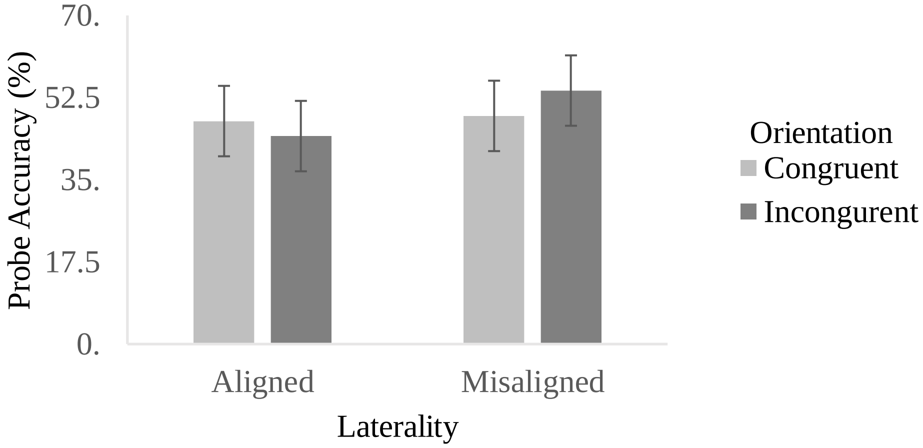

Figure 2.1.6. Mean probe accuracy error rate in Experiment I as a function of laterality alignment and orientation congruency. Error bars represent 95% confidence intervals.

There was however an effect of laterality alignment for the probe trials, F(1, 29) = 4.505, MSE = 191.4, p = 0.04. When the laterality of the hand mismatched the side of the handle, participants were 5.36% less accurate in their recall of the two postures.

2.2 **Experiment II**

The results obtained by Bub et al. (2013) are clearly replicable, indicating that the features of planned actions in working memory are consulted during the naming of graspable objects. The question remains as to the reason for this interference effect. Why does the overlap between features of planned actions in working memory and the actions afforded by the depicted object affect a purely conceptual task like naming? Some ideas on the role that action representations might play in identifying tools have previously been suggested, motivated by evidence from functional imaging that pictures of tools, even passively viewed, elicit cortical activity that encompass left hemisphere regions associated with object motion and manipulation (see Chouinard & Goodale, 2010, for a review). As noted by Martin (2016), any claim that this activation is essential to identifying graspable objects must confront the following puzzle: neuropsychological evidence shows that damage to left posterior parietal cortex can impair the ability to correctly use (or pantomime using) an object, without affecting the ability to identify and name it (Gonzalez Rothi, Ochipa, & Heilman, 1991; Johnson-Frey, 2004; Negri et al., 2007). Clearly, there is no direct causal relationship between object identity and the actions afforded by a depicted object.

Martin suggests two possible solutions to this issue, neither of which appear compelling. The first is that despite the evidence from neuropsychological cases, the conceptual representation of a manipulable object is impoverished or deficient in some way if the representation of the actions afforded by the object is impaired. Without further elaboration, this suggestion offers no insight into the nature of any deficiency in the conceptual representation of an object given impairment to action representations unless, tautologically, we simply assume that the limitation affects the ability to enact or pantomime the object's proper function. The second possibility, according to Martin, is that object naming always includes as an ancillary process, an anticipation of future actions that could be a carried out by means of the object. There is little to distinguish this idea from the alternative suggestion that motor cortical regions become active simply as a by-product of their connectivity to regions associated with their perceptual identity.

In what follows, a different perspective is adopted, built on a distinction between vision-for-perception and vision-for-action. Jeannerod & Jacob (2005) note that to think or reason about visual objects depends on semantic representations and entails access to a fairly abstract conceptual level of representation. To paraphrase these authors, much of the detailed pictorial content of visual percepts must be selectively eliminated to access the content of thoughts and beliefs about objects and their relationships stored in memory. Unlike the semantic processes that determine the ability to think about objects, the representations governing the ability to reach and grasp a visual target appear to have little or no conceptual content (Goodale, Milner, Jakobson, & Carey, 1991). Nonetheless, pragmatic processes - the term used by Jeannerod & Jacob (2005) to denote the neural systems dedicated to vision-for-action - must also include more conceptual levels of representation beyond the mere ability to pick up an object. As these authors note, prior experience is needed to plan or anticipate the consequences and evaluate the feasibility of an action (Rosenbaum & Jorgensen, 1992), to carry out motor imagery tasks (Parsons, 1994), and in cued motor preparation tasks that require attention to and selection of the hand needed to produce a grasp posture (Johnson et al., 2002). Needless to say, conceptual representations are also involved in maintaining the features of two lateralized grasp postures in working memory.

There is in addition, good evidence that in neurologically intact observers, grasp actions afforded by an object are linked to stored knowledge of how we typically interact with the object to carry out its proper function. Creem & Proffitt (2001) found that participants tend to apply a grasp posture suitable for using an object like a hammer even when simply asked to lift and move it. Given a demanding secondary task that interferes with semantic access, however, the grasp posture no longer conformed to the functional properties of the object. More recently, Knights, Smith, & Rossit (2022) have shown that planning to grasp a tool or utensil by the handle automatically evokes activation in anterior temporal regions, a cortical region forming part of the semantic network that represents the functional properties of an object. As these authors suggest, the anterior temporal lobe combines sensorimotor and semantic content to mediate the complex ability of using tools.

What then is the relationship between action representations and semantic processes when manipulable objects are named after registering a sequence of hand postures in working memory? Pragmatic processes are likely to remain active and affect the naming of graspable objects due to task set inertia, a well described phenomenon (Allport, Styles, & Hsieh, 1994; Monsell, 2003; Wylie & Allport, 2000) that occurs when control processes allocated to a prior Task A are triggered by attributes of an object presented for Task B. Here, control processes needed for Task A concern attention to the features of a planned action sequence in working memory, while the attributes of the object in Task B that trigger these control processes are the motor features of a graspable object presented for naming. The postures stored in working memory require attention to the laterality of the hands and their wrist orientation. The persistence of pragmatic processes will allow that these action features are also evoked by the functional properties of the object accessed for naming. Conflict occurs when there is a mismatch between one of these features (the laterality/orientation of the grasp posture associated with the proper function of the object) and a feature of the planned action sequence in working memory.

An interesting prediction occurs in the light of this analysis. The cost of task set inertia is much weaker on the second trial after switching between tasks (Monsell, 2003). It follows that the substantial effect of actions in working memory will be greatly reduced if two objects are presented for naming. The first is an object that affords no grasp action while the second depicts a graspable object. Pragmatic processes should be less active when the second object is presented, yielding a weaker interaction between the contents of working memory and the actions afforded by the object. The effect of the action sequence in working memory on naming will be compared with a control condition in which the first pictured object is graspable while the second object does not afford a grasp action.

2.2.1 **Method**

Participants. Thirty-three subjects completed this experiment to receive extra credit in their undergraduate psychology courses. Fourteen of the subjects were male and six subjects were left-handed. Subjects had an average age of 22.73 years (standard deviation ± 4.56 years).

Materials. The materials used in this experiment were identical to those in the first experiment other than the inclusion of pictures of objects without handles. We added three different instances of 32 non-handled object types (Table 2). Each instance had a horizontally mirrored version resulting in a total of 192 digital photographs of common objects without handles used as critical stimuli.

Table 2. Names of Non-handled Objects used in Experiment II

Acorn, Barrel, Bear, Bed, Bird, Boat, Butterfly, Cat, Chair, Couch, Cow, Dog, Elephant, Fish, Frog, Helicopter, Horse, House, Jacket, Jet, Lamp, Monitor, Mushroom, Pants, Plane, Raft, Robe, Table, T-shirt, Windmill

Design. The design of this experiment was identical to the first, save for the inclusion of naming pictures of objects without handles. Subjects were trained to identify non-handled objects in the same way they were with handled objects. On 50% of trials, they were shown before the handled object, and on the other 50% they were shown after. Trials were further pseudorandomized by randomly pairing non-handled objects with handled such that they were not paired with the same object more than once.

Procedure. The difference in the procedure of this experiment from Experiment I was how the presentation of the pictured objects operated due to the addition of a second pictured object per trial. Regardless of the order of images (handled object first or second), the first object remained in view until a naming response was made by the subject via speaking into a headset microphone. The second object then appeared until a naming response occurred into the microphone (see Figure 2.2.1).

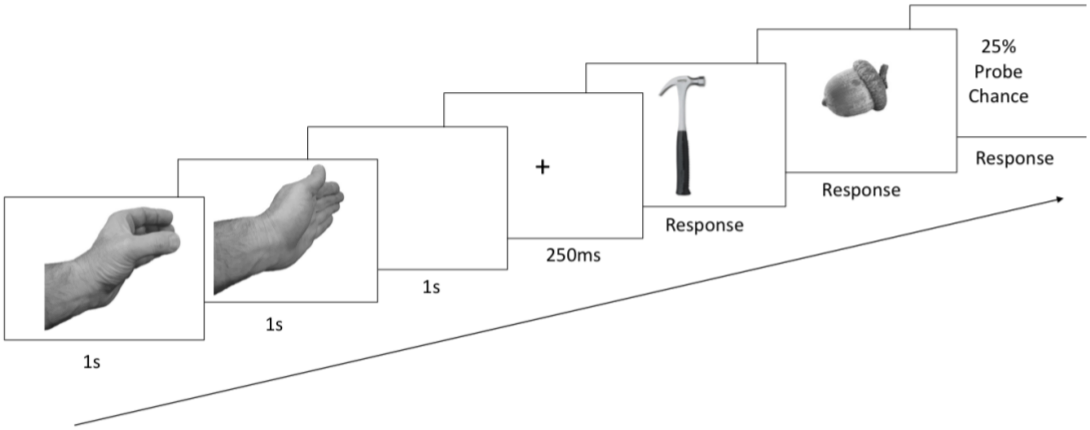

Figure 2.2.1. Example of trial procedure sequencing for Experiment II.

2.2.2 **Results and Discussion.**

Adding the factor of object order, a 2x2x2 within subject ANOVA was computed for when the handled object and the non-handled object. Looking at handled objects, there was a main effect of object order (F(1, 32) = 32.98, MSE = 7796, $p < 0.001$) where participants were 62.4 ms faster if it was presented second. There was also a two-way interaction between orientation congruency and laterality alignment (F(1, 32) = 37.75, MSE = 7472, $p < 0.001$). The same cross-over pattern was present with an average difference of 65.4 ms between the faster conditions (both or neither feature matched) and the slower ones (only one feature matched).

There was also a three-way interaction between orientation, laterality, and the order in which the objects were presented displayed if Figure 2.2.2 ($F(1, 32) = 8.5$, $MSE = 6775$, $p < 0.01$). When handled objects were presented first, there was a 94.9 ms difference between the fast and slow conditions. This is another replication of Bub et al. (2013) since a non-handled object did not intervene between the working memory and naming tasks. In other words, a pragmatic representation is consulted for the semantic task of naming. The only difference between this replication and Bub et al.'s (2013) original result is that the magnitude of the effect of motor features in working memory on naming latency is around 20 ms larger than their 70 ms compatibility effect.

When the handled object was shown after the object without a handle, the compatibility effect was substantially reduced to 22.75 ms. Here, naming a non-handled object first primes the semantic pathway. There is less of an impact for the conditions where features partially overlap, and there is a substantial reduction in the magnitude of the compatibility effect. This is likely because non-handled objects (e.g., a tree) do not afford a specific grasp action so naming the object deemphasizes the consultation of the pragmatic pathway during the naming task. No significant patterns of response errors (4.39%) or probe accuracy (51.67%) were found for any of the effects.

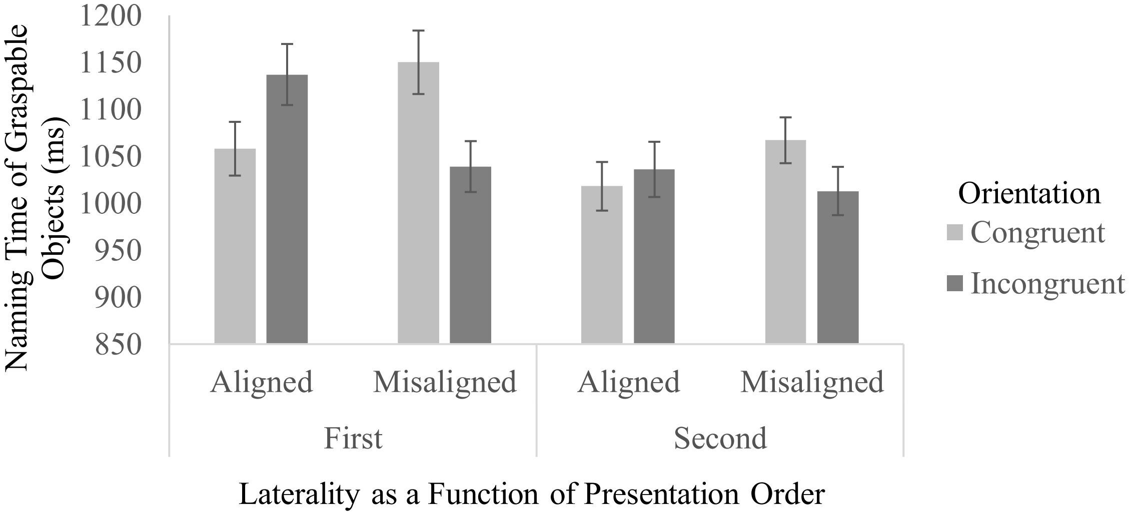

Figure 2.2.2. Mean response time (in milliseconds) for naming handled objects in Experiment II as a function of laterality alignment, orientation congruency, and presentation order. Error bars represent 95% confidence intervals.

In addition to a replication of previous results - when the first item presented for naming depicted a graspable object - there is another outcome worth noting. As can be seen in Figure 2.2.2, naming responses to graspable objects presented second were faster overall than responses to the same objects presented first, but the benefit of occurring second was much larger for objects that shared a single feature (hand or wrist orientation) with the postures in working memory relative to objects that shared neither or both features. This result makes sense if the effects of the bound motor features in working memory on naming a graspable object have weakened after encountering a non-graspable object. A pragmatic task set is no longer strongly active by the time the second item is presented, yielding an especially marked improvement (i.e. a decrease) in naming latencies for graspable objects that share only a single motor feature with a planned action sequence in working memory.

As for non-manipulable objects, participants were 54.2 ms faster to name the object when it was presented after the handled object (F(1, 32) = 17.83, MSE = 10877, $p < 0.0001$). Likewise, looking at the cases not drastically influenced by presentation order (where both or neither features overlap between the graspable object and planned action sequence), manipulable objects were named 32.9 ms faster when presented second (F(1, 32) = 9.31, MSE = 3831, $p = 0.005$). In other words, naming responses are faster and more accurate for the second of two objects, irrespective of whether the object is manipulable or does not afford any grasp action.

2.3 **Experiment III**

We now enquire whether the impact of action features on naming specifically involves retrieval of the semantic properties of the depicted object. There is good evidence that the orientation of an object can be determined by consulting spatial representations without first accessing the object's identity. Turnbull (1997), for example, documented a double dissociation between two neuropsychological cases. The first, who presented with a visuospatial disorder, could correctly name depicted objects but was unable to indicate their upright canonical orientation. A second case with visual object agnosia was unable to name many objects but could accurately indicate their canonical orientation. A similar double dissociation using functional imaging in neurologically intact participants was reported by Valyear, Culham, Sharif, Westwood & Goodale (2006). A region in the temporo-occipital cortex showed a selective increase in activity to changes in the identity of a depicted object but was insensitive to changes in its orientation. By contrast, a region in the parieto-occipital cortex showed a selective increase in activation to changes in object orientation, but was insensitive to changes in object identity.

A reasonable inference is that orientation judgements - in particular whether an object is inverted or appears in its canonical, upright orientation - can often be carried out by consulting structural rather than semantic properties of an image. For example, cues such as the base (i.e., what the object rests upon when placed on a flat surface) versus the opening of a container can directly be used to determine the object's canonical orientation. If the impact of action features in working memory depends on access to a conceptual representation of the object, no such effect should be observed when the task requires upright/inverted judgements rather than naming.

This possibility is especially interesting given the widely held claim that upright/inverted judgments of manipulable objects depicted with their handles on the left or right are automatically influenced by a representation of the hand best suited to lift the object (Tucker & Ellis, 1998). It is often assumed that the components of a grasp action are triggered by structural properties of the depicted object, directly perceived, rather than stored conceptual (i.e. functional) knowledge. Symes, Ellis, & Tucker (2007) referred to this representation as a "pure physical affordance"; that is a grasp action based solely on the position and shape of the handle in the case of an object like a frying pan, without regard to its functional properties.

Notice that this conjecture on the nature of the motor representations evoked by the image of a graspable object is at odds with prior evidence already described, that grasp actions elicited by an object are linked to stored knowledge of how we typically interact with the object (Creem & Proffitt, 2001; Knights et al., 2022). Nevertheless, a prediction worth testing is as follows. Assume, as we have argued, that upright/inverted judgements can be determined on the basis of structural rather than conceptual properties of a depicted object. Accept also the claim that features of a grasp action are directly generated by structural attributes of the object (Tucker & Ellis, 1998). It follows that the same effect of a stored action plan in working memory that occurs on naming latency should also be observed on speeded upright/inverted decisions. The rival possibility is that the impact of a planned action requires access to stored conceptual properties of an object. Moreover, it may not be the case that features of a grasp action are automatically generated during orientation judgements. Accordingly, the potent effect of hand actions in working memory on naming performance should not be replicated when the task is to determine whether the object is upright or inverted.

2.3.1 **Method**

Participants. Thirty-eight subjects completed this experiment to receive extra credit in their undergraduate psychology courses. Six of the subjects were male, and none were left-handed. Subjects had an average age of 19.61 years (standard deviation ± 2.80 years).

Materials. Many of the images used in this experiment were identical to those in the first experiment with a few exceptions. The first difference was that objects that could not easily be identified as upright or inverted due to horizontal symmetry were substituted for those that could (see Table 3; see Figure 2.3.1). Like the replaced images, three different instances of each of the new pictured objects were generated, all of which were mirrored horizontally. Additionally, all pictured images were mirrored vertically creating an inverted version, resulting in a total of 384 critical images. The second difference was the use of LabJS instead of SuperLab 5. This change was done to facilitate experiment programming.

Table 3. Replaced Images of Handled Objects in Experiment III

Horizontally orientated handles

Cleaver, Garden hoe, Flashlight, Frypan, Hairbrush, Hand vacuum, Iron, Kettle, Knife, Hatchet, Saucepan, Rake, Scrub brush, Scooper, Strainer, Trowel

Vertically orientated handles

Beer mug, Blow dryer, Coffee pot, Coffee mug, Drill, Garden spray, Ladle, Hammer, Handsaw, Joystick, Measuring cup,

Figure 2.3.1 Examples of inverted images used in Experiment III.

Design. The design of this experiment was similar to the first experiment, except that participant made keypress responses to indicate if the object was upright or inverted instead of naming responses. Responses were made on an Apple keyboard (model A1243) where keys “N” and “V” were paired as a single response with the index fingers and keys “D” and “K” were paired as the other response with the middle fingers. With participants’ hands placed on the keyboard in parallel, this ensured no priming of responses to one side of space. Further, with only actions being coded for finger movement (i.e., pressing the buttons), there were no representations of action plans involving laterality and orientation. In this way, there would be no confounding any compatibility effects with keypress responses. Conditions were counterbalanced such that for half of the participants, pressing D/K together indicated the object was upright and for the other half it indicated the object was inverted. Counterbalancing with the V/N response occurred in opposition to the D/K response such that one indicated upright and the other indicated inverted for each participant.

It should be noted that half the 384 critical handled object stimuli were used in each run through of the experiment due to the 192-trial nature of Experiment I. Across the 192 critical trials, each of the 96 object instances appeared twice, once in upright form and once in inverted state.

Procedure. This experiment proceeded much like the first, with minor alterations to accommodate the changes in the design. During the training phase, four versions of each of the 32 unique images was individually presented such that the subject received practice with each of the three versions of the item, the two positions of the handle (left or right), and the different orientations of the object (upright or inverted). The orientation of the object was written below the image to which the subject responded with the appropriate key presses (V/N or D/K) to proceed to the next training image. If the incorrect keys were pressed, the participant was presented with an "ERROR" message.

The critical trial proceeded exactly like the first experiment with the only differences being that the keypresses which indicated if the image was upright or inverted initiated the next trial or hand posture probing. Further, an "ERROR" message was shown for incorrect responses.

2.3.2 **Results and Discussion**

We excluded two participants due to excessive error rates. The final sample used for analysis contained 36 participants. Within this remaining sample, there were no significant effects of error rate (4.49%) or probe accuracy (67.41%).

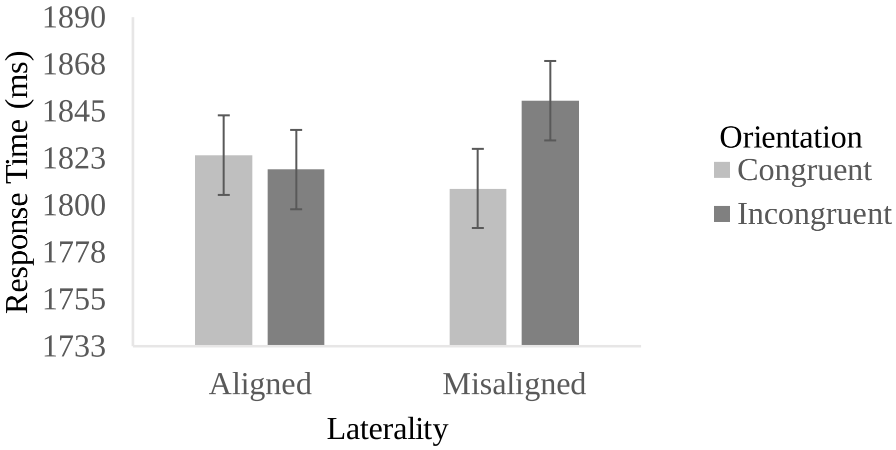

Figure 2.3.2. Mean response time (in milliseconds) in Experiment III as a function of laterality alignment and orientation congruency. Error bars represent 95% confidence intervals.

We computed a 2x2 within subject analysis of variance (ANOVA). Inspection of Figure 2.3.3 reveals that the incongruent/misaligned condition was slower (by 26.6 ms) than the next slowest condition. All the other three conditions differed by at most 16 ms and were not statistically different. These conditions were merged and contrasted with the incongruent/misaligned condition (Figure 2.3.3). There was a reliable difference between the merged conditions and the incongruent/misaligned condition ($F(1, 35) = 5.04$, $MSE = 8329$, $p < .03$). All other effects and interactions of response time, probe accuracy, and error rates were not significant. Clearly, the pattern of results in Figure 2.3.2 is very different from the pattern observed when the task is to name the depicted object rather than to determine its upright/inverted orientation.

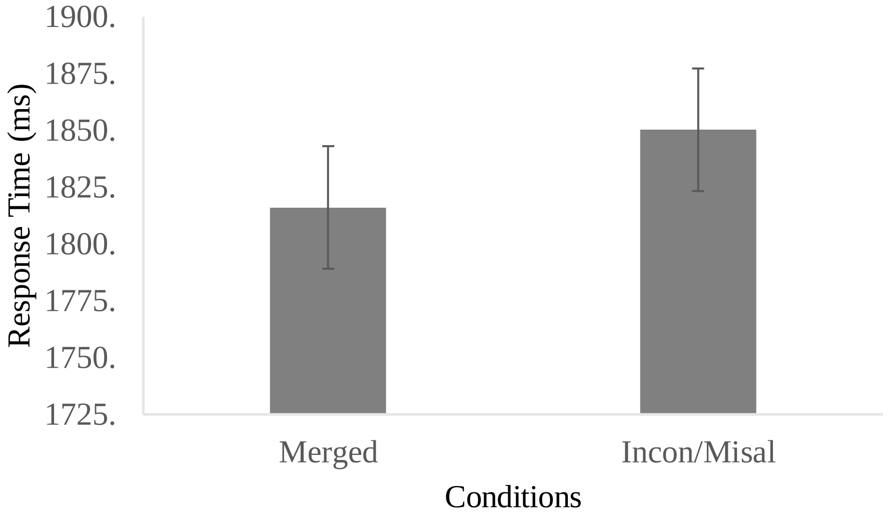

Figure 2.3.3. Mean response time (in milliseconds) for naming handled objects in Experiment III as a function of the merged and incongruent/misaligned conditions. Error bars represent 95% confidence intervals.

General Discussion

The current work demonstrate that features of a planned action held in working memory can exert a potent effect on the naming of manipulable objects. The pattern of interference effects conforms to what Hommel (2004) has referred to as a partial repetition cost as opposed to a benefit due to object-specific repetition (Hommel & Colzato, 2004). The basic assumption is that feature codes maintained in a stored action plan are temporarily bound into a coherent event representation. If these features completely match or mismatch the visuomotor features triggered by the manipulable object, performance is unaffected. Partial matches, however, prime competing feature codes. For example, a bound action plan in working memory may include the features {right hand} and {vertical wrist orientation}. These integrated features will be automatically retrieved as a conjunction even if just one of them (say, wrist orientation) overlaps with components of the grasp action afforded by the manipulable object. There is now a mismatching feature - in this case hand laterality - which differs between the grasp posture afforded by the depicted object and the integrated action plan retrieved from working memory by spreading activation. The mismatch induces conflict, leading to slower and less accurate naming of the manipulable object.

This outcome depends on crosstalk between neural systems involved in what Jeannerod & Jacob (2005) refer to as pragmatic versus semantic processes. The former deals with vision-for-action while the latter concerns vision-for-perception. It is clear that pragmatic control processes, including attention to the laterality of the hand and the orientation of the wrist, are recruited to maintain the features of an integrated action plan in working memory. A key assumption is that these control processes remain active for some time and are automatically evoked by the functional properties of the manipulable object. Attention to the handle will trigger components of the action best suited to grasp the object, and on partial mismatch trials, there is conflict between these features and at least one feature of the stored action plan.

The cost of a partial mismatch is greatly reduced when the manipulable object is named after first naming a non-manipulable object. Given that the action plan in working memory has to be maintained throughout both naming events, interference must depend on the persistence of control processes implicated in a pragmatic task set rather than the mere sharing of visuomotor features with the manipulable object. Attention to the features of the grasp action afforded by the depicted object dissipates after naming an object that affords no grasp action, leading to much less interference between the features of an action plan in working memory and the semantic representations involved in retrieving the name of the depicted object.

Additional evidence provides no support for the previous claim that upright/inverted judgements automatically trigger the components of a grasp action afforded by manipulable objects (Tucker & Ellis, 1998). According to this idea, the perceptual representation of an object includes the features of actions afforded by its structural properties. If true, it follows that responding to the orientation of a manipulable object should be clearly affected by partial feature overlap with a planned action maintained in working memory. No such result was observed. Instead, slower responses occurred when the action plan and the grasp action afforded by the depicted object differed in terms of both hand laterality and wrist posture. The effect was modest relative to the very substantial impact of feature overlap with the planned action repeatedly found on naming. Clearly, the features of a grasp action afforded by the handle of a manipulable object play no role in upright/inverted judgements. The alternative possibility is that spatial features are consulted, including features corresponding to the side and position of the handle in an extrinsic frame of reference. Assume that abstract spatial codes, in addition to limb-specific representations, are generated by the hand postures in working memory. For example, the image of a left hand with the palm facing down would be coded not only in terms of the laterality of the hand and the orientation of the wrist but also in terms of the spatial features {left} and {horizontal}. Only the limb-specific features in a body-based frame of reference are bound in working memory while the spatial features remain active but are not part of an integrated action plan. Attention to the structural properties of the manipulable object yields measurable, albeit weak interference on upright/inverted judgements when there is a complete mismatch between the spatial features of the handle and the spatial codes elicited by the hand postures.

The evidence indicates that crosstalk between pragmatic and semantic representations does occur under particular task conditions, when manipulable objects are presented for naming. It is not the case, however, that such crosstalk is simply due to the fact that features of a grasp action are inevitably triggered by structural or higher-level functional properties of the depicted object. Questions therefore arise as to the reason for the disconnect between functional imaging studies showing that motor-based representations appear to be automatically generated by pictures of graspable objects (Chouinard & Goodale, 2010) and the implications of the present set of results. The methodology developed here could be fruitfully applied to this issue. The features of an action plan in working memory have markedly different effects on speeded upright/inverted decisions versus naming tasks. A comparison of the activation patterns in motor cortical regions should elucidate the nature of the representations elicited in different task contexts.

It should be noted that there are two major assumptions within this paper that must be addressed. The first involves Experiment II; specifically, how secure is the assumption that the event files representing the action sequence in working memory persisted for the naming of both the first and second object? Event files have been shown to passively disintegrate after about five seconds (Hommel & Frings, 2020), albeit in task contexts that did not include the requirement to maintain the files in working memory. Confirming the assumption of event file persistence would require a replication of Experiment I while varying the stimulus onset asynchrony (SOA) between the hand postures and the object presented for naming. If the reduction of interference occurred as a direct result of the duration of the SOA (where less interference occurred with longer SOAs), the decaying of the event file, and therefore unbinding of the motor features, would be the cause of the three-way interaction obtained in Experiment II. If SOA duration did not affect the level of interference for conditions with partial overlap of features, our assumption that the event file functionally persisted throughout the trial would be substantiated, meaning that the working memory load was sufficient to bind the features of the event file throughout the experiment.

The second assumption is that the results obtained in the naming task would be replicated in other semantically laden tasks. Validating this assumption would require the use of a keypress response to some conceptual property of the depicted objects (for example, whether each object was found in the kitchen or garage). If the same pattern of interference occurred where partial feature overlap caused slower responses, further evidence would confirm that semantic tasks consult motor representations in working memory associated with the manipulable object.

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