TOWARD AN UNDERSTANDING OF AUTOMATIC GRASPING RESPONSES IN THE ABSENCE OF LEFT-RIGHT CORRESPONDENCE

by

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ABSTRACT

Several researchers have claimed that passively viewing manipulable objects results in automatic motor activation of affordances regardless of intention to act upon an object. Support for the *automatic activation account* stems primarily from findings using stimulus-response compatibility paradigms in which responses are fastest when there is correspondence between one's response hand and an object's handle. Counter to this view is the *spatial coding account*, which suggests that past findings are a result of abstract spatial codes stemming from salient object properties and their left-right correspondence with responses. Although there is now considerable support for this account, there has been little attention paid to determining whether evidence in favor of the automatic activation account will be evident after accounting for the spatial issues demonstrated by the spatial coding account.

The present study involved five experiments conducted to bridge this gap in two steps. First, I aimed to demonstrate the importance of considering spatial issues and left-right correspondence when studying object-based motor activation by numerous objects championed by past researchers who attempted to similarly address the aforementioned issue (Experiments 1 and 2). Second, I sought to determine whether evidence favoring the automatic activation account could be obtained when the possibility for left-right correspondence was absent in a novel set of stimuli created specifically for this purpose (Experiments 3, 4, and 5).

Experiment 1 examined a stimulus set that some researchers have suggested can more definitively tease apart evidence for automatic activation from the influence of spatial factors studies. Experiment 2 was more narrowly focused and investigated a single object presented in different horizontal orientations. These experiments effectively demonstrated the importance of giving more consideration to the nature of the stimuli used in object-based compatibility studies and how they are presented. The results of Experiment 1 suggest that a stimulus set that has been claimed to sidestep spatial confounds does not, in fact, do so. Moreover, Experiment 2 demonstrated that performance could be influenced by simple rotation of the object to which a response was required.

Having established the importance of controlling the stimuli used to investigate automatic activation of afforded responses, I turned to determining whether a novel stimulus set would yield findings favoring the automatic activation account even after accounting for left-right

correspondence (Experiments 3, 4, and 5). Three sets of novel object stimuli were developed that do not allow for left-right correspondence and could iteratively assess support for the automatic activation account based on criteria for activation that have been put forth in the literature. The three sets of stimuli contained no information about shape nor functionality (i.e., silhouette iteration) or information about shape and functionality (i.e., functional iteration), or they were an intermediate between the two other types (i.e., intermediate iteration).

Critically, the three latter experiments progressively approached the conditions that researchers have suggested are ideal for automatic activation of afforded responses to occur. Experiment 3 tasked participants with completing a color discrimination task in which they viewed only one of the three object iterations and responded with button presses. Experiment 4 used the same experimental configuration, but instead, required participants to respond with a grasping response. Finally, Experiment 5 required participants to complete a reach-and-grasp response in an object discrimination task using both the silhouette and functional iterations.

Across Experiments 3, 4, and 5, no support for the automatic activation account of afforded responses was found. Although the automatic activation account would predict that individuals should be fastest at responding to the functional stimuli than to the other two object iterations, no such evidence was observed. Given that the possibility for left-right correspondence was removed from the novel stimulus set studied here, these results provide indirect support for the spatial coding account of prior results and further indicate that past findings favoring the automatic activation account have largely been a result of left-right correspondence.

INTRODUCTION

The majority of constructed objects have at least one intended function and associated action. For instance, mugs can be used to drink liquids, scissors to cut certain objects, and a pencil to write on paper. Although there are several uses for the aforementioned items or, even combinations of the three (e.g., using the mug as a vessel for the scissors and pencil), there are object-action pairs that most individuals would readily report if prompted. It is partly this tendency to associate objects with actions that prompts some to promote the notion that the perception of an object is intimately intertwined with its commonly associated action. Over the last three decades, researchers have claimed that viewing an object, regardless of one's intention to handle the object in question, automatically results in relevant motor activation. In the simplest of terms, this would mean that viewing the aforementioned mug would result in the activation of a grasping response since this is the action that it is commonly associated with.

The idea that human actors and the objects they perceive have a special relationship stems primarily from ecological psychology. Researchers from various fields have employed use of the term "affordance effects" to explain how individuals respond to objects perceived in a laboratory setting. Specifically, affordance effects have been used to capture the tendency for individuals to respond faster when a keypress response is compatible with an object's handle. The affordance term was originally proposed and developed by James J. Gibson (1979) to be used within a broader theoretical framework to describe how individuals interact with the world. Gibson proposed the concept of affordance paired with that of direct perception to theorize on how organisms, whether human or not, perceive and move about in natural settings. Both of the aforementioned concepts make up the cornerstone of his ecological approach to perception but mention of affordances is often in the absence of direct perception.

Beyond the tenuous relation to ecological psychology, the idea that motor activation is automatic and can occur outside of the relevant context also stems from work focused on neural activity resulting from viewing manipulable objects. Chao and Martin (2000), for instance, reported that simply viewing or naming an object resulted in brain activation in the left ventral premotor cortex, an area associated with action. This activation, and that observed in non-human primates (e.g., Murata et al., 1997) has been taken as demonstration that there is a propensity to be ready to act upon an object even without the intention to do so.

The findings of Chao and Martin (2000) and others have since been extended to several behavioral studies. Researchers interested in understanding how this activation might occur have primarily relied upon stimulus-response compatibility paradigms in which participants register keypresses to another property of asymmetrical, handled items. The idea underlying these studies is that manipulable objects activate a motor response which, in turn, facilitates motor actions in a non-preferential manner (e.g., grasping *and* keypresses). Participants have been found to respond faster when there is a match between the handle of the objects under investigation and the finger(s) used to make the response. These results have come to be interpreted as support for the automatic activation hypothesis.

At the time of this writing, there are hundreds of articles on the matter. In fact, this topic has sparked the imagination of many researchers and has even led to studies conducted on how participants respond when viewing ordinary objects with broken handles (Buccino et al., 2009), never-before-seen novel objects (Chua et al., 2018), and even objects with disembodied handles (Rounis et al., 2018), among many others. Further, although the present study is focused on object-based compatibility effects as they are often studied in choice-reaction time tasks, the notion of a privileged relationship between the perception of manipulable objects and action has seeped into other areas of research, such as with the study of memory (e.g., Apel et al., 2012).

Despite widespread interest, the study of object-based compatibility effects using choice-reaction time tasks has certainly not been without its critics (e.g., Proctor & Miles, 2014). Several researchers have come to suggest that any benefits that have been observed when a handle is aligned with a response cannot be entirely attributed to automatic motor activation. Spatial aspects independent of the manipulability of an object have been found to contribute to the effects observed. Employing some of the ingenuity with stimuli that was mentioned earlier, researchers have used teakettle silhouettes (Cho & Proctor, 2011), clock faces (Anderson et al. 2002), and other types of stimuli to demonstrate that an object's manipulability might not be a particularly special determinant of performance.

As it stands, the work favoring accounts related to spatial codes have demonstrated that the salient components of an object, whether they be a handle or not, contribute to reaction time performance differences. Specifically, it is the left-right correspondence between an individual's response and the handles being viewed that result in object-based compatibility effects. However, these accounts have not entirely ruled out the possibility that action can indeed have some influence. Although the salient properties of an object *can* be a driver of the effects that have been observed to date, this evidence in itself does not definitively point to it as the *only* contributor nor does it rule out the possibility that action possibilities might be influencing responses. In order to do this, the spatially imbalanced stimuli that are so frequently used in this line of work must be reimagined to reduce any possible impact of spatial effects. In fact, it would behoove those adopting either of the two aforementioned hypotheses to direct their attention to this imbalance to set a baseline for future.

The present study aimed to address the imbalance and set a baseline in two steps. Experiment 1 adopted the same large stimulus set used by Azaad and Laham (2019) in a study purporting to control for spatial compatibility effects. This experiment used a different choice-reaction time task than they did to determine whether stimulus properties that they did not consider in their study could have influenced performance. Following this, Experiment 2 then employed one stimulus that was selected to reflect those from the larger set and examined it more closely. That experiment sought to establish the significance of presenting stimuli without a clear left/right component by showing that the same object can influence responses when it is oriented to the left or the right. This demonstration is particularly informative as steps were taken to ensure that the stimuli met what have been prescribed as the necessary conditions for activation to take place. Specifically, the object was one with an associated function, which could be manipulated and with which the individuals would have had experience, and lastly, presented in the same upright state.

Second, after demonstrating that unbiased stimuli are necessary for the study of object perception, attention was turned to employing a series of stringent tests using novel stimuli that could more comprehensively account for spatial confounds. Experiment 3 used a color discrimination task with button press responses; Experiment 4 used the same task with a more comparatively realistic grasping response. Finally, Experiment 5 required participants to engage in an explicit object categorization task using a reach-and-grasp response. Notably, no previous studies have set out to study object-based compatibility effects in the aforementioned manner. The novel stimuli employed in this study are particularly informative for two reasons. For one, these stimuli are objects that, if rotated along the *x*-axis, would have the same appearance. Additionally, the images of these stimuli were manipulated to directly compare responses to (a) silhouettes, (b) objects without an apparent functional component, and (c) objects with an obvious functional component. In the following sections, this document delineates (1) the work on object-based compatibility effects that has been conducted and the methods that have prevailed thus far, (2) the primary obstacle, if overcome, that would allow for a significant advancement of this area of research, and finally, (3) how the present dissertation attempted to address these issues.

Background

Beginning with Tucker and Ellis (1998), many researchers have promoted the notion that responses made to object handles are shorter if the 2D object corresponds with the hand making a button press response, which have been referred to as affordances. Although there is much ambiguity as to exactly what factors result in this facilitation, Rowe and colleagues (2017) have stated that “the defining feature of an affordance is that it represents priming of the motor system (regardless of the ultimate requirement to act or not)” (p. 103). It is this and similar claims that have been made related to passive viewing of 2D objects that this dissertation is aimed at addressing. Specifically, the two leading accounts on this matter (i.e., the automatic activation account and the spatial coding account) are evaluated as well as the claims related to which factors influence performance in object-based choice-reaction time tasks.

However, prior to delving into a discussion of these two approaches, it is first necessary to address two critical points. First, given the underlying issues of using the affordance term outside of an ecological psychology framework (Chong & Proctor, 2020; de Wit et al., 2017), so-called affordance effects will be referred to as object-based compatibility effects throughout. Circumvention of the affordance term is necessary as it implies adoption of tenets from Gibson’s approach to perception.

Second, this dissertation is not intended to dissect and study the decades of comprehensive work that have been conducted within kinesiology. There is a plethora of work related to how individuals act directly upon 3D objects and which factors influence their movements toward items that are physically present (e.g., Fikes et al., 1994; Glowania et al., 2017; Paulun et al., 2016). Instead, the present work is focused on evaluating the claims that have been made about the perception and subsequent motor activation resulting from passively viewing 2D stimuli.
Having stated these two caveats, what follows is a discussion of the two primary approaches in the object-based compatibility literature, followed by how the present study can illuminate the field’s understanding of the object-action relationship.

Automatic Activation Account

In Tucker and Ellis's (1998) influential study, participants were presented with photographs of common day manipulable objects like pans and kettles. Participants were tasked with making keypress responses to denote the upright or inverted orientation of the objects. Responses made to corresponding trials (e.g., left hand response to a pan with the handle to the left) were 12-ms faster than responses made to noncorresponding trials. Tucker and Ellis interpreted these results to mean that there was automatic motor activation for a grasping response which, in turn, facilitated the keypress response. They stated that "it [was] the affordance for grasping by a particular hand that [gave] rise to the binary left-right distinction" (p. 838).

The work of Tucker and Ellis (1998) has now been cited over 1,000 times (Google Scholar). Fascination with this topic is understandable, as there seems to be a myriad of potential research avenues to pursue. After all, throughout the course of any given day, humans interact with a number of objects that allow them to complete any number of goals. However, objects can vary in shape and color, the actions associated with them, and the contexts in which they are used, among various other dimensions. Given the large number of objects currently in existence, it becomes necessary to delineate what types of objects are considered to have a privileged relationship with actions and which objects do not fall under this umbrella. Operationalizing which objects are under consideration for this study is necessary prior to delving into work on how objects might potentiate actions. Although Tucker and Ellis did not explicitly state under which conditions or what kind of manipulable object(s) might potentiate action, other researchers have since built an informal registry about which objects should be expected to facilitate action. After going through the literature on the matter, it appears that there are four major requisites that have been deemed necessary for automatic activation to occur that are related to (1) object manipulability, (2) object experience, (3) object functionality, and (4) object state.

Requirement 1: Object manipulability. Objects that do not allow for manipulation should not potentiate an action. In the object-based compatibility literature, manipulable objects are items that can be manipulated with one's hands whereas non-manipulable objects are those that cannot be manipulated by an individual. Manipulable items have been considered items such as frying pans (e.g., Pappas, 2014) and kettles (e.g., Yu et al., 2014), whereas non-manipulable items have include airplanes (Pappas, 2014) and tires (Handy et al., 2006).

Requirement 2: Object experience. Beyond allowing for manipulation, for automatic activation to occur, individuals have to have experience with how to use or operate the object to begin with. In other words, objects that individuals have not previously handled should be processed distinctly from objects that they regularly interact with. Evidence supporting the notion that novel objects are processed differently from commonly handled objects comes from research studying brain activation when viewing the two types objects. Consider, for instance, the work of Handy et al. (2006) who employed fMRI scanning to measure activation when viewing doorknobs, with which the average individual has replete experience, and artificial rock climbing holds, with which the aforementioned individual would have little, if any, experience. The researchers recruited individuals without past rock climbing experience and those with at least a year of consistent experience. In the inexperienced group, blood-oxygen-level-dependent (BOLD) signals in motor- related areas (e.g., left ventral premotor and motor cortices) for the doorknobs and rock-climbing holds were distinct. However, for the experienced group, BOLD signals in motor-related areas were comparable for doorknobs and holds. Handy and colleagues determined that past motor experience modulated the activation that was observed.

Handy et al. (2006) stressed the difference between past experience and general semantic familiarity when studying object-induced motor activation. Specifically, they commented on the stimuli used in previous studies and questioned whether they were appropriate for studying the aforementioned topic. They stated that these items "although perhaps familiar at a semantic level, were nevertheless objects not strongly associated with actual real-world motor experience…many people may be semantically familiar with watering cans or pliers, but rarely if ever use them" (p. 164). In other words, activation is not only dependent upon whether an object is familiar, but also whether individuals have sufficient experience with this item.

Requirement 3: Object functionality. An object must have a clear function associated with it (e.g., drinking from) and the features that communicate this function should be intact. If the stimulus features that convey this information (e.g., depth) are obscured, then motor activation will not occur. It has been claimed that object silhouettes produce different response patterns than photographs of the same object (Pappas, 2014).

An example put forth by Creem-Regehr and Lee (2005) to highlight differences between types of objects can be used to illustrate the importance of an object's manipulability, familiarity, and functionality. For this example, consider two objects: a toothbrush and a rock. While the toothbrush has an associated action (i.e., brushing one's teeth), the rock, although graspable, is considered not to have a singular associated action. It is important to note here than an object does not necessarily have to have a handle so that it might be considered manipulable. Along these lines, one would contend that a cup without a handle or a typical handle-less soda can would be considered to be a tool used for the purpose of drinking.

Requirement 4: Object state. It has been suggested that the state of the object and its place in space will determine whether automatic activation will occur and the nature of activation. This last requirement is related to where the item is located relative to an observer and how it is oriented.

First, some argue that objects must be presented within reach, or in peripersonal space, for activation to occur (Costantini et al., 2010; Costantini et al., 2011). Costantini and colleagues have used virtual reality to provide evidence that the possibility or opportunity to act upon an object will modulate behavior. Rowe and colleagues (2017) have further suggested that an object's relation to one's dominant hand is also critical to automatic motor activation. They used electroencephalography to measure brain activation when passively viewing photographs of an empty desk or one with 3D objects that required a precision grip (e.g., tweezer; button) or power grip (e.g., hairbrush; mug) placed on the desk. Participants were right-handers who were tasked with adopting one of two postures that required them to be rotated 45° to the left or right away from a screen with their head facing the screen. Even though viewing distance was technically the same for both postures, there was a different pattern of brain activation depending on the posture. Specifically, differences in the N2 event-related potential component, which has previously been suggested to be enhanced when viewing manipulable objects (Proverbio et al., 2011; Proverbio et al., 2013), were observed. An interaction was found in the N2 component between posture and object grip type in the left hemisphere. The authors took this as evidence in favor of a benefit for the dominant hand over the nondominant hand when an object was present compared to when no object was present.

Second, the orientation of the object in question will also factor into whether response selection is automatically facilitated. Objects presented in their canonical form should facilitate action to a greater degree than an object presented in a non-typical orientation (Bub et al., 2018). For instance, a downturned glass will produce a different pattern of results than would an upright glass. Along the same lines, Azaad and Laham (2019) put forth the idea that an item with two handles (e.g., a laundry basket) should potentiate keypresses made simultaneously by both hands, whereas an item with a single handle or two handles grouped together should potentiate a keypress with only one hand. In other words, even if an object has two handles that allow for grasping with both hands, if they are presented together in a manner that would enable grasping and carrying with a single hand, only motor activation in one hand should be potentiated.

At the time of this writing, the four aforementioned requirements have not previously been formally put forth in one comprehensive list. However, these requirements arise repeatedly in the literature, and their delineation is necessary to advance the study of how objects are believed to potentiate action. Here, it is necessary to point out that these requirements are all related to how 2D images of items might potentiate action and not the objects themselves.

Spatial Coding Account

More recently, researchers have argued that the results that have been obtained thus far can more simply be explained by spatial codes (e.g., Proctor & Miles, 2014). Specifically, critics have suggested that object-based compatibility effects arise not because an object has a manipulable component, but because of its visual properties. Specifically, an object's salient properties, whether manipulable or not, may be what is primarily guiding performance. In other words, facilitation for handles arises not because they are handles but because they protrude.

Tucker and Ellis (1998) conceived of this possibility in their original study. To address it, they conducted a second experiment in which individuals responded with two fingers of the same hand (i.e., index and middle fingers of the right hand) instead of two fingers of different hands.

Because individuals were tasked with responding unimanually instead of bimanually, motor activation for the same hand should not change. More critically, they reasoned that if responses were due to abstract codes, the same result pattern should occur as in their first experiment. Mean RT showed only a nonsignificant trend toward a correspondence effect, but median RT showed a significant effect. However, Tucker and Ellis interpreted these ambiguous results as evidence that a spatial coding account could not satisfactorily explain their results obtained with fingers on different hands.

The unimanual findings of Tucker and Ellis (1998) have been contested by results showing that how participants respond does not reliably conform to predictions of the affordance account. Shortly after the Tucker and Ellis study, Phillips and Ward (2002) released a three-part study that evaluated how different hand mappings and effectors (i.e., feet) might influence the results. They employed a procedure in which participants responded to an imperative stimulus presented on images of frying pans with handles pointed in different directions by responding in several different ways. They made a button press with their hands uncrossed (i.e., left index to a left response) or crossed (i.e., left index to a right response), and a foot-pedal press with uncrossed legs (i.e., left foot to a left foot pedal). The frying pan was presented at variable stimulus-onset asynchronies (SOA) prior to the onset of the critical stimulus. Although the affordance account would predict a distinct pattern of results for the conditions in which hands were uncrossed versus when they were crossed, this was not the case. These results suggest that the orientation of the handle did not exclusively activate a specific hand. Furthermore, and also counter to the affordance account, handle-foot correspondence effects were obtained when foot pedals were used to make responses.

There have been several other studies demonstrating that the salient dimensions of an object play a critical factor in how compatibility effects take shape (e.g., Cho & Proctor, 2010; 2013). A recent demonstration of this notion is that of Xiong and colleagues (2019), who used three experiments to investigate whether the manipulable properties of an object facilitate responses when they are task-relevant. Their Experiments 2, 3A, and 3B investigated whether chopsticks, which have a side that is grabbed by one’s fingers (i.e., the graspable end) and another that is used for picking up food (i.e., the functional end), would bias responses when saliency was manipulated. Participants were told to respond to one of the two chopstick ends with either a compatible or incompatible response. Further, the chopstick images were varied so that the chopsticks were a single color and were only tapered on the functional end (Experiment 2) or had an additional, salient red handle at the graspable end (Experiment 3). To assess the influence of familiarity with chopsticks, participation was restricted to those of East Asian descent (Experiments 2 and 3B) or not (Experiment 3A). The results across the experiments suggested that familiarity with the eating utensil did not differently affect the obtained results and, more critically, that the side of the chopstick that received preference in the task could be flipped. In other words, the results showed that it was not a matter of the action that could be performed with the object, but a matter of its salient features (e.g., the red handle). Xiong et al. succinctly summarize the state of affairs stating that their results and those of others "imply that affordances play at most a small role in the obtained compatibility effects" (p. 1462).

Prior to delving into how the automatic activation account and the spatial coding account might possibly be reconciled, it is necessary to note that the two accounts have separate claims related to automaticity in information processing, although the term "automatic" is only used for the former account. The automatic activation account is termed as such only as a form of shorthand, but the spatial coding account can also be explained in terms of automaticity. For instance, the most well-known model for explaining compatibility effects is that of Kornblum, Hasbroucq, and Osman (1990). Theirs is a dual-route model which puts forth the idea that when there is overlap between a stimulus and a response (e.g., a circle presented on the right side requiring a right-handed response), the stimulus automatically activates the corresponding response. This model can be used to explain Simon-like tasks, which have generally been put forth as a reflection of automaticity related response selection processes as opposed to the preceding stimulus identification or subsequent response execution stages (Proctor & Vu, 2006). The spatial coding account does not deviate from this assumption; however, the affordance-centered automatic activation account maintains automaticity is related to the response execution stage.

Solving the Activation Equation

Although there is disagreement as to what is driving the previously mentioned object-based compatibility effects (i.e., spatial codes or automatic motor activation), those working in this area are essentially attempting to solve for the exact same regression equation. Specifically, researchers are trying to solve for an equation that predicts how viewing an object manifests into motor activation. With a typical simple regression equation, an error term must be included to account for any discrepancies that arise between a predicted value and the actual value of the variable of interest. In the case of the aforementioned object-based compatibility effect regression equation, the error term that would have to be accounted for relates to the influence of the spatial components of the task. Researchers in favor of an automatic activation account tend to give this error term little weight, if any, whereas those with a more nuanced background of these effects tend to assign this term more weight.

Given that researchers are ultimately attempting to address the same problem, but are doing so from different approaches, it may be possible to construct a novel approach to the study of object-based manipulation that meets the four requirements set forth in the literature while simultaneously addressing the saliency concerns that have also been raised. Prior to presenting a possible remedy for these issues, it is first important to untangle what exactly lies at the crux of the problem. The following sections provide a more detailed overview of the problem of how the stimuli are presented, followed by consideration of what might be more appropriate for advancing the field's understanding of automatic object-based activation.

The current error term. The majority of studies, regardless of discipline and their stance on whether actions are automatically activated or not, have depicted stimuli so that they have a distinct left/right component (e.g., Buccino et al., 2009; Iani et al., 2018; Masson et al., 2011). As mentioned previously, most studies in this line of research have followed the procedures used by Tucker and Ellis (1998). These studies typically employ images of objects that are depicted so that they have a clear left/right component. Pans and tea kettles, for instance, are depicted so that their handles are pointing to the left or right. Consider as an example the study of Yu and colleagues (2014), whose work is a particularly notable example because of their comparatively large stimulus set of over 50 items. The stimulus set included items such as a hammer, axe, wrench, comb, and many other everyday objects. Although some of their items would be symmetrical if presented from the front (and therefore not have a salient component that protrudes to the left or right when it is upright), all items were rotated so that they ultimately had a handle protruding to the side.

Related to saliency issues of how objects are oriented for presentation is the issue of how they are placed on the screen. Masson (2018) refers to two methods that are commonly used to present stimuli as pixel-based displays and whole-object centered displays. In the pixel-based displays, the body of an object is centered on screen and between trials, its handle appears to flip between the left and right with a relatively stationary body. In a whole-object centered display, the entire object is centered so that both the body and its handle vary between trials. Masson reports that in an unpublished study, the type of object centering employed was found to mitigate responses.

The issue with the stimuli used in the aforementioned studies is not an issue with the objects per se. There is no inherent issue with studying pans or tea kettles, for instance. Instead, the problem exists because of the manner in which they have been presented. Selection of these stimuli has been intentional as researchers have been interested in investigating whether handle-response matches allow for bettered performance compared to mismatches. However, given that it has now been demonstrated that performance on these choice-reaction tasks might be due to in part to the saliency of the handles, it no longer seems appropriate to continue to study the possibility of automatic motor activation in this manner.

Reducing the error term. A discussion of the issues related to what makes prior stimuli far from ideal begs the question, what is the ideal way to present stimuli to allow for determining whether images of objects do indeed facilitate motor activation? A more ideal stimulus would be one without a left/right distinction (i.e., symmetrical), but with a clear function associated with its upright form. Consider, for instance, the toothbrush depicted in Figure 1. Among several other presentations, it is possible to depict the toothbrush so that it is presented (a) on its side and front facing, (b) upright and front facing, or (c) upright and rotated so that it faces to the left or right. Although the majority of studies have opted for the first two options, a more ideal presentation would be the upright and front facing depiction. Further, given that researchers have long argued that objects automatically activate associated actions which, in turn, facilitate keypress responses, the presentation of an object in its front facing form should not inhibit or alter this activation. The toothbrush presented in Figure 1c should allow for the same activation as the toothbrush in Figure 1b.

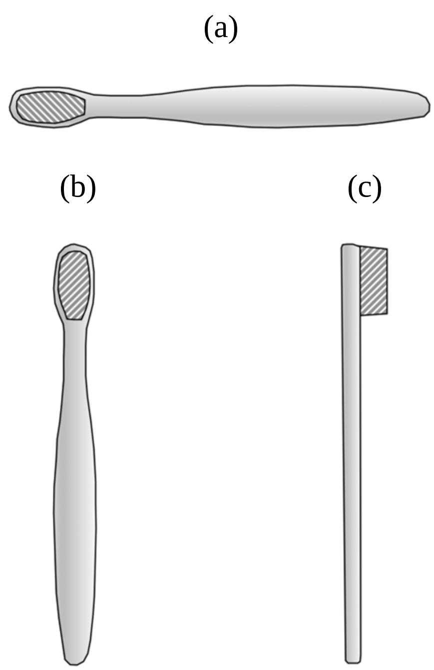


Figure 1. Different orientations for depicting the same object: (a) front-facing, rotated; (b) front-facing, upright; and (c) side-facing, upright.

There is also the issue of invariance. It is possible that those in favor of the automatic activation account might argue that a front-facing presentation partially obscures the object and its intended use, which in turn would affect processing and ultimately hinder motor activation. This argument is understandable as although the toothbrush depicted in Figure 1b can easily be discerned as a toothbrush, other objects presented in a similar manner (e.g., a hammer) may not be as easily recognized. A more ideal stimulus would be a depiction of a manipulable object that, when rotated, remains relatively invariant despite its orientation. Although objects with these characteristics are not the norm, there are indeed some objects that fit this requirement. Consider, for instance, a wine glass or a soda can. Even if rotated at its base, the presentation of these objects would remain unchanged.

Innovative Approaches

The methodological and theoretical issues that are prevalent in the study of object-based automatic motor activation have encouraged some researchers to pursue more novel methods of attempting to address this problem. Unfortunately, even these novel approaches have not entirely been able to avoid falling prey to problems related to spatial coding. Nevertheless, these attempts warrant discussion as they demonstrate consideration for what the field should move toward.

One set of researchers who have demonstrated a clear understanding of how methodological issues might limit the understanding of the object-action relationship are Daniel Bub and Michael Masson. They have amassed a large body of work in which they deviate from using keypresses to grasping actions. They have employed the “Graspasaurus”, a grasping implement that allows for the registration of a grasping action when an electrical current is broken (e.g., Bub et al., 2008; Chua et al., 2018). Bub and Masson typically employ a priming paradigm in which an object is presented prior to a gesture that needs to be performed with the manipulandum. Through their work they have come to emphasize the importance of context and that objects can indeed facilitate motor responses, but that this only occurs when the appropriate actions are taken (i.e., grasping; Bub et al., 2018).

Although the work of Bub and Masson is marked with their innovative efforts, they are also marked by critical spatial issues. Their stimuli are not only presented with a handle off to the side, but their action stimuli also have distinct left/right components. Admittedly, their priming stimuli are hands presented in profile. The work and Bub, Masson, and their colleagues is particularly notable because they have demonstrated a clear understanding of all of the spatial effects that might influence performance and have approached this issue with a comparatively enlightened approach. They have systematically ruled out alternative interpretations. Despite their meticulousness, spatial confounds have creeped into their work. This suggests that until spatial confounds are first addressed, any work attempting to understand whether or not objects do indeed result in automatic motor activation must be approached with caution.

Most recently, Azaad and Laham (2019) proposed the bimanual affordance task (BMAT) as a method of studying object-based compatibility effects that could "sidestep" the spatial confounds typical of object-based SRC tasks. Recognizing that objects with handles protruding to the left or right lead to potentially confounded results, they employed stimuli that either had a handle(s) on each side or stimuli that had a handle(s) at the top. Their stimuli included photos of real objects such as baskets, suitcases, and handbags, among others. The BMAT task requires that participants complete what is essentially a three-choice task in which they responded to the color of the stimuli with one of three button-press combinations (i.e., a left button press; a right button press; or simultaneously responding with both buttons). They posited that objects with handles on the sides would potentiate grasping with both hands and, as such, facilitate responding with two keypresses. In contrast, objects with a single handle at the top would potentiate grasping with a single hand and would facilitate responding with a single keypress.

Azaad and Laham's (2019) results revealed an interaction between response type and handle type wherein bimanual responses made toward objects that had two handles were approximately 15-ms shorter than the same responses made to objects with one handle. A less pronounced 9-ms difference was found for unimanual responses made toward objects with one handle compared to objects with two handles. The authors specifically go on to state, "Since objects in our study were symmetrical, we can conclude that object-based CEs are, at least in part, driven by object affordances rather than mere spatial compatibility" (p. 8). In other words, Azaad and Laham concluded that they had indeed sidestepped spatial confounds and found evidence for automatic motor activation.

To their credit, Azaad and Laham (2019) correctly identified asymmetrical stimuli as being problematic and sought to employ stimuli that are more symmetrical. However, although they made a noteworthy attempt to address the prevailing confound that has plagued this area of research, they were not entirely successful in their endeavor for two major reasons. First, Azaad and Laham's stimulus set consisted of items presented in different sizes on the screen. The authors were generous enough to provide the images of their stimuli, and inspection revealed that the size of the objects varied widely from one stimulus to the next. For example, a handbag intended to elicit a unimanual response was found to be approximately a third of the width of a laundry basket meant to elicit a bimanual response. Ideally, to rule out the possibility of spatial coding, stimuli should be relatively homogeneous and matched along their spatial dimensions.

Second, Azaad and Laham's (2019) items were not mirrored along the *y*-axis and, as such, had distinct left/right components (see Figure 2 for an adapted version). In their attempt to circumvent the use of objects with left or right protrusions, they overlooked object shadows and objects that were rotated. Consequently, even if an object did not innately have a protrusion, it could have nevertheless facilitated responding on one side or the other, depending on the more salient components of the object. The basket depicted in Figure 2, for instance, has a left side that is larger than the right side despite its naturally being symmetrical. Moreover, the ribbon has a bow to the right side. Although these asymmetries may seem negligible, these differences can become more apparent when stimuli are flashing quickly on a display screen.

The aforementioned issues in the more innovative approaches are concerning, but somewhat understandable. Masson (2018) even referred to spatial effects as being "insidious" to communicate how ever-present they are. Researchers have to be meticulous in how objects are placed on the screen, how keys might be arranged, whether one side of an object has a shadow, and many other potential object and task characteristics that could lateralize the stimulus and/or response. Azaad and Laham's recent work exemplifies a broader issue: Although those within this area of research are now generally aware of the spatial confounds found in object-based SRC tasks, these issues may not be understood entirely by those attempting to address them. This lack of understanding is a problem that is a consequence of the spatial world in which humans reside. Even if stimuli are selected in a systematic and thoughtful manner, characteristics that make one side more salient tend to creep in unless one is highly vigilant and sensitive to this possibility. However, this is not to say that efforts cannot be made to tackle these "insidious" factors. Instead, systematically addressing these issues will require a certain degree of ingenuity and diligence.

Figure 2. Stimulus exemplar adapted from Azaad and Laham (2019).

The next question might understandably then be, is there an ideal stimulus for this line of research? This is a more nuanced question as it is possible that by prescribing that researchers only investigate one type of object, there may be a loss of what might be gained from a broader approach. As mentioned previously, there is no inherent problem with using a frying pan to study how action might be facilitated. However, given that this area of study is replete with possibly confounded results, I have developed a stimulus set that would allow for a systematic understanding of which factors contribute to the effects observed previously. This stimulus set, which is introduced later, allows for different factors to be held constant (e.g., shape) while allowing for functionality to be varied. This stimulus set may potentially enable the field to build a more stable foundation with which to study object-induced automatic motor activation.

Study Implications

The present experiments were conducted for the purpose of developing a better understanding of whether passively viewing 2D objects results in automatic motor activation that facilitates motor responses in a non-discretionary manner. Specifically, this study aimed to deliberate more clearly on whether evidence for the automatic activation account could be obtained after removing the possibility for left-right correspondence, which has been shown to contribute to object-based compatibility effects. This aim was addressed with a two-pronged approach that involved (1) demonstrating the importance of carefully considering which objects are used to study this topic and (2) investigating a novel set of stimuli created specifically for the purpose of controlling spatial confounds of past studies reported in the literature.

The first prong involved investigating whether the two potential issues identified with the Azaad and Laham (2019) stimulus set (i.e., width and orientation of the stimuli) could have indeed influenced performance. This step is informative because stimuli in object-based compatibility studies are not typically systematically studied, and such systematic investigation has been a missed opportunity. By establishing whether certain stimulus characteristics influence performance, appropriate control can be exercised in the area of object-based compatibility to enable conclusions that are more accurate. Further, this step is particularly important because it demonstrates the value of creating and using novel stimuli in the second prong.

The second prong of this study dealt with implementing a novel stimulus set to determine whether 2D objects without obvious left-right components can produce a pattern of results indicative of automatic motor activation. Across experiments, whether these effects are more pronounced with increasingly more realistic responses was evaluated. If 2D objects carefully selected to rule out the possibility of left-right spatial coding demonstrate evidence favoring automatic response activation, this result would support the notion that both the spatial coding and automatic activation accounts have been, to some degree, intertwined and influencing previously reported effects. However, if the aforementioned 2D objects do not yield a pattern indicative of automatic motor activation, this would lend support to past conclusions suggesting that the spatial properties of stimuli have been the primary driver of results in object-based compatibility studies.

Although the results of the present experiments can contribute to the issue of whether the automatic activation account can be substantiated, more practically, the requirements for activation that were delineated for the purposes of this study also can provide some structure to an otherwise unorganized area of study. Furthermore, the novel stimuli that I created can lend themselves for use in future studies. At the very least, the considerations that were adopted for their creation may inform the generation of other related stimulus sets, whatever they may be.

Furthermore, the present experiments can weigh in on whether responses more closely matching real world responses do, in fact, facilitate motor activation. Recently, researchers have suggested that whereas keypress responses often fail to produce results that are in line with the automatic activation account, more realistic responses do result in effects supporting this stance. The present experiments systematically investigate this possibility by progressing from button presses, which are the most removed from grasping, to reach-and-grasp responses, which are a more comparatively similar match. The study's findings can provide evidence as to whether the type of response that participants are required to perform does indeed facilitate motor activation or if past evidence supporting this notion might be more directly linked to other methodological decisions made by researchers.

Along these lines, beyond allowing for determination of whether there can be simultaneous support for both non-discriminant automatic motor activation and the influence of spatial coding, this study can serve as a baseline for understanding how symmetrical 2D objects are processed without priming. The study did not employ the priming that has been used in numerous studies (e.g., Bub et al., 2018), primarily to avoid the addition of left-right correspondence into a task explicitly designed to avoid this possibility. In addition to circumventing confounds by not employing priming, this study can weigh in on the automaticity of motor activation in such paradigms. Without priming, the results of this study can be considered to be a more accurate determination of whether motor activation is automatic, because any performance differences that are obtained are not contingent upon the priming.

Beyond a few select articles that have discussed using symmetrical 2D objects to study motor activation (e.g., Azaad & Laham, 2019; Scerrati et al., 2020), there has yet to be a concerted effort to determine how the nature of the stimuli might affect performance when these stimuli do not allow for a left/right distinction and when they are held constant across different tasks. This document is the first to note in detail what the ideal presentation for stimuli might be and to implement such stimuli in a systematic manner.

EXPERIMENT 1: INFLUENCE OF OBJECT WIDTH

Experiment 1 was aimed to address one of the issues (i.e., object width) identified with the Azaad and Laham (2019) stimulus set. As a reminder, they claimed that their results are particularly informative as, by using stimuli that differed in one or two handles, they had eliminated any possible left-right spatial-relations from influencing the effects they observed. Azaad and Laham put forth the notion that individuals and the responses they ultimately produce are sensitive to the number of handles an object possesses. According to their view, objects with a single handle or grouped handles that allow for grasping with one hand facilitate unimanual button presses, whereas objects with two handles that require both hands facilitate bimanual button presses.

Although Azaad and Laham (2019) interpreted their results as evidence for this possibility, confounds in their study preclude such a seemingly straightforward interpretation. Their stimuli varied in height and width for the two types of objects. Given the evidence that irrelevant spatial features that can influence performance, Experiment 1 was designed to investigate Azaad and Laham's conclusions by assessing whether spatial confounds related to object width were truly bypassed. Critically, Experiment 1 employed the same stimulus set as Azaad and Laham without any variations to their presentation or color.

There are several key differences between Azaad and Laham's (2019) study and Experiment 1, which are rooted in the distinct goals of each study. Azaad and Laham sought to understand automatic activation of unimanual and bimanual grasping with an array of different handled objects. To this aim, they tasked participants with completing a three-choice color determination task meant to reflect unimanual and bimanual grasp activation. However, Experiment 1 was focused instead on examining how stimulus properties might affect performance, independent of response type. As such, a two-choice color discrimination task with unimanual responses was used. Finally, the data for Experiment 1 were analyzed using multi-level modeling, which is robust method of analysis (Quené & van der Berg, 2004) that can be used for continuous data like those related to an object's width.

The potential results can be grouped into supporting the automatic activation account or the spatial coding account. Support for the former account would mean that although different types of objects (i.e., unimanual or bimanual objects) might predict changes in reaction time, the spatial features of these objects (i.e., height and width) should not reliably predict performance. However, any deviation from the aforementioned results would lend support for the spatial coding account. Specifically, if performance for different objects differs as a function of its width, for instance, then this would suggest that lateral factors affect performance.

Method

Participants

Participants were 40 undergraduates (19 males; 100% right-handed) who were recruited from Purdue University's introductory psychology subject pool and granted course credit for their participation. All participants in this study were recruited from the same pool and awarded credit in the same manner.

All participants were required to have normal or corrected-to-normal vision. Participants were also screened for red-green color blindness. Additionally, all participants in Experiment 1 and across all of the other experiments in this study were required to be right-handed. This restriction was to avoid the potential of responses being influenced by different hand dominances and associated object-handling habits (e.g., Wang & Sainburg, 2007; Willems et al., 2009). Handedness was assessed using the Edinburgh Handedness Inventory (Oldfield, 1971; Appendix A) and individuals with scores below 41 were replaced. A summary of average handedness scores and ranges across experiments can be found in Table 1.

The sample size recruited for Experiment 1 is customary for studies investigating object-based compatibility effects (e.g., Azaad & Laham, 2019) and is comparable to other studies using larger stimulus sets in choice-reaction time tasks (e.g., Yamaguchi et al., 2018).

Table 1. Handedness Data Across Experiments 1-5. Handedness is Calculated on a 100-Point Scale With Values Above 40 Being Considered Right-Handed

	Experiment 1 n = 40	Experiment 2 n = 40	Experiment 3 n = 120	Experiment 4 n = 120	Experiment 5 n = 40
Average (SD)	85 (20)	87 (15)	85 (17)	86 (18)	83 (21)
Minimum	43	54	43	43	43
Maximum	100	100	100	100	100

Apparatus, Stimuli, and Procedure

The experiment was conducted in a dimly lit lab room. Participants were seated approximately 65 cm away from a computer monitor, although this varied between individuals. Participants were presented stimuli controlled by an E-Prime 2.0 program (Psychology Software Tools, Pittsburgh, PA) and were tasked with responding to the color of an object (i.e., red or blue) with the corresponding buttons on a response box. The same laboratory room and monitor were used for all of the experiments.

The complete set of 10 object images used in this experiment was provided by Azaad and Laham (2019), who manipulated everyday objects so that they were either modified to appear blue or red and were presented centrally on the screen. Visual angle was calculated using a viewing distance of 43 cm, which would be the closest viewing distance a participant might adopt. On average, objects subtended a horizontal visual angle (HVA) of 16.50° and a vertical visual angle (VVA) of 13.82°. A breakdown of the objects used in this study and their respective visual angle values can be found in Table 2.

Participants first read task instructions displayed on the computer monitor and started a block of 24 intermixed practice trials. Participants then completed 8 blocks of 40 trials for a total of 320 trials per participant. Each test block was immediately preceded by two randomly selected trials that were introduced to account for any performance delays that might occur after the inter-block breaks. These 16 trials were not included in the analysis. Each trial began with a fixation cross which was presented for 500 ms and followed by the object stimulus for up to 2000 ms or until a response was made. Each trial terminated with feedback based on the accuracy of the response (i.e., “Correct!” or “Incorrect!”) or the lack of a response (i.e., “No response detected!”).

Data and Variables

The original data set for this study was made up of 12,800 trials (i.e., 40 participants responded to each of the 10 objects 32 times during the experiment). A summary of the object visual properties and participants’ reaction time performance can be found in Table 2.

Reaction Time

Data were filtered out based on their reaction time outlier status. Specifically, trials in which reaction time fell either below or above 2.5 standard deviations for an individual’s mean reaction time for each of the 10 objects object would be excluded. Approximately 5% of trials were removed based on their outlier status or if no response was detected, yielding a total of 12,114 valid trials.

Visual Angle and Object Type

Both HVA and VVA were centered around their grand means. As such, positive and negative values indicate a visual angle value above and below average, respectively. Unimanual and bimanual objects were coded as 0 and 1, respectively.

Data Analyses

Analyses were conducted using R (Version 3.61; R Core Team, 2019) with the lme4 package (Bates et al., 2015). A series of multilevel models were estimated to assess reaction time performance (Level 1) for unimanual and bimanual objects (Level 2) varying in horizontal and visual angle (Level 2) nested within individuals (Level 3). Conditional models included a random intercept, random slope for each individual (i.e., certain individuals might have shorter or longer reaction time, as a function of angle or object, as well as on average). For the first step in analysis, an unconditional model was run (Model A). Next, a series of five conditional models were run.

Table 2. Experiment 1: Visual Angle Properties and Physical Screen Size, Mean Reaction Time, and SD for Unimanual and Bimanual Objects. Objects are Presented as Silhouettes, Though They Were not Presented This Way in the Experiment

Object Type	Visual Angle		Reaction Time	
	HVA	VVA	Mean RT	SD
Unimanual				
	13.26° (10 cm)	16.54° (12.5 cm)	425 ms	162 ms
	12.61° (9.5 cm)	12.34° (9.3 cm)	421 ms	135 ms
	9.97° (7.5 cm)	15.36° (11.6 cm)	419 ms	138 ms
	14.58° (11 cm)	11.4° (11.4 cm)	422 ms	151 ms
	18.23° (13.8 cm)	13.27° (10 cm)	435 ms	150 ms
Bimanual				
	19 cm (24.92°)	10 cm (13.26°)	423 ms	139 ms
	10.7 cm (14.18°)	14 cm (14.49°)	430 ms	148 ms
	14.9 cm (19.66°)	7.5 cm (9.97°)	423 ms	141 ms
	12.5 cm (16.54°)	12 cm (15.89°)	421 ms	147 ms
	16 cm (21.08°)	9 cm (11.95°)	427 ms	150 ms

Model B examined a main effect for Object Type; Model C included a main effect of HVA and Object Type; Model D examined main effects of VVA and Object Type; and Model E included main effects and two-way interactions. The full model (i.e., Model E) can be summarized as follows:

$$Y_{ij} = \gamma_{00} + \gamma_{10}(HVA)_{1ij} + \gamma_{20}(VVA)_{2ij} + \gamma_{01}(Obj\,Type)_{1j} + \gamma_{11}(HVA)_{1ij}(Obj\,Type)_{1j} + \gamma_{11}(VVA)_{2ij}(Obj\,Type)_{1j} + \mu_{0j} + \mu_{1j}(HVA)_{1ij} + \mu_{2j}(VVA)_{1ij} + r_{ij}$$

Results

Overall

The mean reaction time was approximately 416 ms across the models that were run. Table 3 provides a summary of the models applied toward reaction time.

Object Type

Bimanual objects tended to be negatively associated with reaction time. In Model E, object type was found to be a significant predictor of reaction time ($p < .01$). Specifically, reaction time for bimanual objects was approximately 6 ms less than that for unimanual objects.

Vertical Visual Angle

Objects with VVA values above the mean tended to be negatively associated with reaction time. However, VVA was not found to be a significant predictor of reaction time across the conditional models, nor was there a significant interaction with object type (*ps* > .05).

Horizontal Angle

Objects with HVA values above the mean were positively associated with increases in reaction time. In Model E, HVA was found to be a significant predictor of reaction time ($p < .01$). Specifically, there was an approximately 1 ms increase for every degree increase in HVA. Note that 1 ms/degree translates to 9 ms between the widest and slimmest objects, which differed by 9°, for which the actual difference was an even larger 16 ms.

Table 3. Experiment 1: Null and Conditional Multilevel Models Predicting Individual Trial Reaction Time (ms) by Object Type, Horizontal, and Vertical Visual Angles

	Model AModel B		Model C		Model D		Model E			
	Unconditional		OT		OT + HVA		OT + VVA		Full Model	
	Estimate	*SE*	Estimate	*SE*	Estimate	*SE*	Estimate	*SE*	Estimate	*SE*
Fixed Effects										
OT~			-1.6	1.7	-4.7*	2.2	-3.1	1.9	-6.3**	2.2
HVA					0.6*	0.3			1.4**	0.5
VVA							-1.0	0.5	-1.4	0.9
OT × HVA									-1.3*	0.6
OT × VV									1.6	1.0
Intercept	412***	12.53	419***	12.5	415***	12.6	416***	12.4	418***	12.6
Random Effects										
Individual Variance	6253		6288		6259		6362		6263	
HVA Variance			1.4		0.1		1.5		1.4	
VVA Variance			7.5		1.8		8.2		8.0	
Residual Variance	8328		8301		8317		8298		8291	

Note. ~ Referent = Unimanual object. $N = 40$; Number of observations = 12,114. OT = object type; HVA = horizontal visual angle; VVA = vertical visual angle.

*$p < .05$; **$p < .01$; ***$p < .001$.

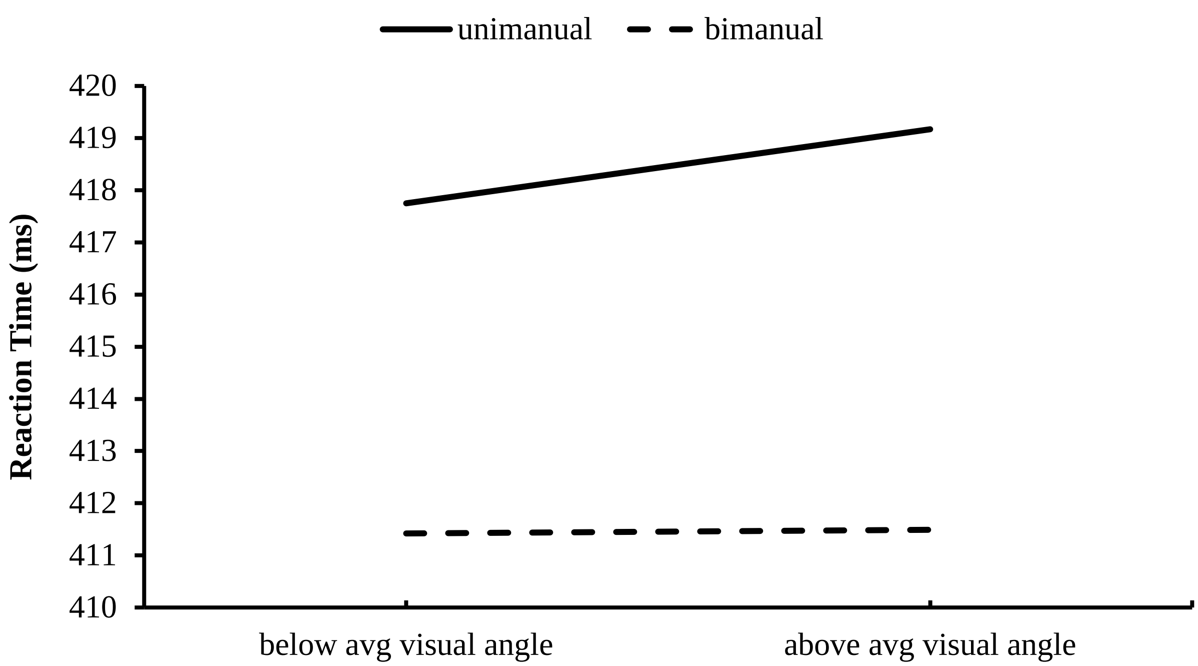


Figure 3. Reaction time as a function of unimanual or bimanual object type and horizontal visual angle.

Furthermore, Model E revealed a significant interaction between HVA and object type ($p < .01$). Although reaction time tended to be longer for unimanual objects with HVA values above average compared to unimanual objects with HVA values below average, reaction time values were similar across bimanual objects and their different HVA values. The interaction between HVA and object type is depicted in Figure 3.

Discussion

Experiment 1 investigated how one of the potential issues identified with the Azaad and Laham (2019) stimulus set (i.e., the various width of their objects) could have affected performance in a choice-reaction task. The experiment was not aimed at finding counterevidence for their claims related to unimanual or bimanual grasp activation, but instead focused specifically on their stimulus set. The results demonstrated that reaction time varied as a function of the visual properties of the objects. The most relevant finding was the interaction between HVA and object type in which the width of the object was found to modulate performance more for unimanual objects than bimanual objects. These results emphasize the importance of carefully considering stimuli and their properties when employing them for the purposes of studying object-based motor activation.

One of the underlying assumptions Azaad and Laham (2019) made about their stimulus set was that there was homogeneity within their object categories (i.e., unimanual and bimanual objects). Although they did not state this assumption explicitly, their conclusions relating to the automatic activation account necessitate such homogeneity. Further, counter to other studies that have considered multiple objects (e.g., Skiba & Snow, 2016), Azaad and Laham did not include an analysis of performance for the different objects they employed, which suggests that they did not give much consideration to how the objects might have differed. By demonstrating in the present experiment that their stimulus set did not have the aforementioned homogeneity, their conclusions require further consideration

Experiment 1 demonstrates the relative ease with which spatial confounds can influence results in an experiment designed with the intention of eradicating this possibility. Admittedly, the statistical analyses conducted by Azaad and Laham (2019) would not have been particularly sensitive to the influence of the visual properties of the objects they employed. However, this was not the case for my Experiment 1. The multi-level modeling procedure that was used in Experiment

1 is particularly powerful as it allows for non-binary groupings of the data. Data related to the object properties were centered around the average visual angles and remained continuous. As such, less information was lost than would have been the case for binning the data.

In sum, the findings of Experiment 1 suggest that the stimuli selected by Azaad and Laham (2019) might not have been ideal for teasing apart spatial coding from motor activation. The following experiment turns toward investigating another potential issue with their stimulus set, the visual asymmetries in their objects, and how such asymmetries may have affected performance.

EXPERIMENT 2: INFLUENCE OF OBJECT ORIENTATION

The results of Experiment 1 suggest that the findings of Azaad and Laham (2019) could have been affected by the various widths of the stimulus set that they employed. A second, and probably more critical, issue that has been raised herein is related to the object asymmetries in their stimulus set. Although Azaad and Laham attempted to select relatively symmetrical items, some of their items were oriented to one side or had prevalent features that could have drawn attention to either the left or the right. Experiment 2 was conducted to determine if orientation could have possibly influenced performance.

Unlike Experiment 1, which used the large stimulus set employed by Azaad and Laham (2019), Experiment 2 used a much smaller stimulus set. The primary goal was to demonstrate that a single object that meets all of the four requirements that have been established for automatic activation to occur can be shown, in two different presentations, to produce two unique patterns of results. Critically, the four previously discussed object requirements (i.e., manipulability, familiarity, functionality, and state) were held constant across an object's two presentations (i.e., front-facing or rotated to face the left or right).

The primary reason why only one type of object was examined was because the number of stimuli employed by Azaad and Laham (2019) and by design, in Experiment 1, may have exaggerated the issues brought forth from the spatial characteristics of the stimuli. In other words, the large variation in the different types of stimuli may have directly drawn attention to these spatial features. As such, a more appropriate stimulus set would be one with more consistency from object to object.

In Experiment 2, the stimuli were photographs of plastic grocery baskets that fit all of the necessary requisites for automatic motor activation. Further, the stimuli were presented in one of two orientations (i.e., front-facing or rotated), which should not affect the aforementioned requisites for activation.

Method

Participants

Participants were 40 undergraduate students (24 males; 100% right-handed). The number of participants recruited was based on a *G*Power* (Erdfelder et al., 1996) a priori sample size determination with power (1 - β) set at 0.80 plus an additional 25% of participants added for cushion. This sample size and the others used for this study were predicted using the value for a small effect size (.20), which falls within the range of effect sizes commonly found for object-based compatibility effect studies (see Azaad et al., 2019 for a meta-analytic review), in addition to relying on past experience within this domain.

Apparatus and Stimuli

The experiment was conducted using the same equipment, software, and laboratory room setup as in Experiment 1. Stimuli were photographs of plastic shopping baskets that were either forward-facing and symmetrical or rotated to either the left or the right and asymmetrical. The stimuli were modified so that the baskets were colored green or red and were presented at the center of the screen with a white background. The stimuli were based off the basket used in the Azaad and Laham (2019) object set, but were not taken directly from the set itself in order to exercise more control over the features of the stimulus itself (e.g., no shadows or bows on the basket). The front-facing stimuli subtended 8.80° × 7.04° and the left- and right-oriented objects subtended 8.80° × 7.92°.

Design

This experiment used a within-subjects design, with each participant responding to every possible stimulus iteration. Specifically, the object stimuli were (a) facing forward or rotated to either the (b) left or (c) right.

Procedure

Each participant was tested individually. Prior to commencement of the study, participants were given general instructions for the experiment. Further instructions were then provided on the screen, and clarification was provided by the experimenter as needed. Most critically, participants were instructed to respond to the color of the stimulus (i.e., red or green) as quickly and accurately as possible with one of two buttons using their left and right index fingers. Color-response mappings (e.g., left key for green and right key for red) were counterbalanced across participants.

The experiment consisted of one practice block and four test blocks. The practice block was made up of 18 intermixed trials and each test block was made up of 90 intermixed trials each. An equal number of trials were presented for each combination of the following variables: object orientation (front-facing, rotated right, rotated left) and color (red or green).

Each trial began with a fixation cross which was presented for 500 ms. Following the fixation period, the stimulus was presented for 1,500 ms or until a response was registered. Feedback immediately followed for 500 ms and was either “Correct” or “Incorrect”, depending on accuracy. If a response was not registered within the 1,500 ms stimulus presentation window, the trial was terminated and “No response detected!” was presented for 500 ms.

Results

Two analyses of variance (ANOVA) were conducted with Response Hand (Left or Right) and Object Orientation (Front-Facing, Rotated Right, or Rotated Left) as within-subjects factors on reaction time (RT) and percent error (PE) for each experiment. Prior to analysis, data was cleaned in a manner similar to that conducted by previous studies (e.g., Xiong et al., 2019). For RT, trials with premature responses or relatively delayed responses (i.e., RT above or below 2.5 standard deviations from an individual’s trial mean) were excluded. For PE, any participant with average accuracy lower than 80% was to be excluded. However, no participants had to be replaced because of poor accuracy (i.e., less than 80% accuracy) and fewer than 3% of cases were excluded based on RT cutoffs. A summary of mean reaction time and percent error can be found in Table 4.

Table 4. Experiment 2: Mean Reaction Time in Milliseconds and Percent Error in Parentheses

	Object Orientation		
Response-Hand	Left-Facing	Front-Facing	Right-Facing
Left Hand	385 (99.0%)	389 (99.8%)	385 (98.8%)
Right Hand	371 (98.4%)	377 (99.1%)	370 (98.9%)

Reaction Time

There was a main effect of Object Orientation, $F(2, 78) = 10.48$, $p < .001$, $\eta_p^2 = .21$. Responses to the objects that were oriented to the left (*M* = 378 ms, *SE* = 8 ms) or right (*M* = 377 ms, *SE* = 9 ms) were shorter than responses to the object facing forward (*M* = 383 ms, *SE* = 8 ms). There was no significant difference between the left- and right-facing orientation types ($p > .05$). There was also a main effect of Response Hand, $F(1, 39) = 22.72$, $p < .001$, $\eta_p^2 = .37$. Responses made with the right hand (*M* = 373 ms, *SE* = 8 ms) were shorter than responses made with the left hand (*M* = 386 ms, *SE* = 9 ms). Finally, there was no significant interaction between Object Orientation and Response Hand ($F < 1.0$). A summary of the ANOVA results for reaction time and percent error can be found in Table 5.

Table 5. Experiment 2: ANOVA Results for Reaction Time and Percent Error

Measure	Source	*F*	*p*-value	η_p^2
Reaction Time	Object Orientation	10.48	< .001	.21
	Response Hand	22.72	< .001	.37
	Object Orientation × Response Hand	.33	.72	.008
Percent Error	Object Orientation	.56	.57	.01
	Response Hand	.39	.54	.01
	Object Orientation × Response Hand	2.58	.08	.06

Percent Error

The ANOVA did not reveal any significant main effects for either Object Orientation or Response Hand (*Fs* < 1.0). A marginal interaction was found between Object Orientation and Response Hand, $F(2, 78) = 2.58$, $p = .08$, $\eta_p^2 = .06$. Accuracy for the left and right hands was comparable for objects facing front and those oriented to the right. But, there was a difference between the two hands for the objects that were oriented to the left. Specifically, percent error was approximately half a percent higher with the right hand than with the left hand.

Discussion

Experiment 2 was conducted with the goal of demonstrating the importance of object presentation in a choice-reaction task. Specifically, the orientation of a single object and how this might influence performance were evaluated. Accordingly, the results of Experiment 2 show that a singular object presented in different orientations can lead to categorically different results. When an object was oriented to the left or the right, responses were significantly shorter than when the object had no salient left or right component in the front facing orientation.

According to the automatic activation account, the stimuli that were used (i.e., shopping baskets) should allow for a similar pattern of results across at least two of the orientations: when objects were oriented to the right-hand side and they were presented facing forward. Both of these presentations should activate a grasping response with one's dominant hand, which was the right hand for all participants. However, these two orientations did not result in the same pattern of results. Instead, the left- and right-oriented objects, which should differentially activate the left- and right-hand, were more comparable to one another than the right-oriented and front-facing stimuli. The findings of Experiment 2 provide support for the spatial coding account and demonstrate that one of the factors that has undoubtedly driven past findings in object-based compatibility studies is the saliency of an object's left-right features. If the handles of the basket stimuli resulted in automatic activation of a grasping response, this activation was overshadowed by the left-right protrusions that were created by presenting oriented objects.

Accuracy differed as function of object orientation and response hand for percent error, indicating that accuracy was poorer when the shopping basket was oriented to the left and a response had to made with the right hand than when the response was made with the left hand. In other words, specifically with the left orientation, when there was a mismatch between response hand and object orientation, accuracy suffered. It is unclear as to why this effect was more pronounced for left-oriented objects compared to right-oriented objects, and speculation about this pattern without first engaging in systematic investigation would be premature. Nevertheless, though these results did not reach statistical significance, they appear to suggest that the spatial components played a role in the results.

Alongside the results of Experiment 1, the results of Experiment 2 demonstrate that Azaad and Laham (2019) did not entirely sidestep the spatial issues they attempted to circumvent. As was demonstrated here, the same object, if presented in different orientations, might influence performance in distinct ways. This suggests that, for the purposes of comparing across stimuli, they should be presented in a neutral presentation (e.g., not oriented to the left or right). At the very least, efforts should be made to equate the number of stimuli with different orientations across conditions if comparisons are to be made across groups.

The findings of Experiments 1 and 2 present an opportunity to revisit the drawing board and employ a stimulus set without the issues found with the Azaad and Laham (2019) set. Recycling their stimulus set or a variation of it might inadvertently reintroduce the confounds that need to be addressed. The following experiments in this study focused instead on employing a novel set of stimuli that would allow for a clearer determination of which object properties, if any, influence performance in a binary choice-reaction task. Most critically, the novel stimulus set removes the possibility of any left-right correspondence effects which have been demonstrated consistently in the literature and once more in Experiment 2.

EXPERIMENT 3: NOVEL STIMULI WITH BUTTON PRESS RESPONSES

Experiment 3 employed novel stimuli without salient left-right features in a two-choice reaction time task typical to the field. The nature of the novel stimuli does not allow for a direct comparison between past findings related to whether object handle and response hand congruency results in better performance. However, predictions can nevertheless be made about how performance should be influenced if responses are made with one's dominant hand and if an object fits the requirements set forth for activation. Specifically, better performance should be associated with responses made with one's dominant hand (as opposed to one's nondominant hand) as this hand should be the most experienced with reaching for and controlling objects. Further, trials featuring an object iteration that meets more of the automatic activation requirements should also facilitate performance.

As mentioned previously, an ideal stimulus for studying object-based motor activation would be one that does not have a distinct left/right component, but has a clear function associated with its upright presentation and is relatively invariant when rotated along its base. To add to this, an even more ideal stimulus would permit for iterative manipulation that would allow for ruling out exactly which object features drive performance. Stimuli that fit these three criteria have yet to be introduced in the literature and the current proposal is the first to attempt to do so.

The stimuli that were created for this study can be globally divided into cylinders or cubes. The two objects were systematically manipulated so that each had three iterations that meet different sets of automatic activation requirements (Figure 4). The three iterations of each stimulus type are (1) Silhouette, (2) Intermediate, and (3) Functional, which will be discussed in turn.

Silhouette Iteration

The first iteration of the cylinder and cube objects are silhouette versions of each. The silhouettes allow for a general detection of shape and as a result the object's orientation can be detected. However, it does not provide information related to its manipulability, familiarity, or functionality. Given that it is missing three of the four requirements for automatic activation, there should be little to no facilitation when responding to these objects.

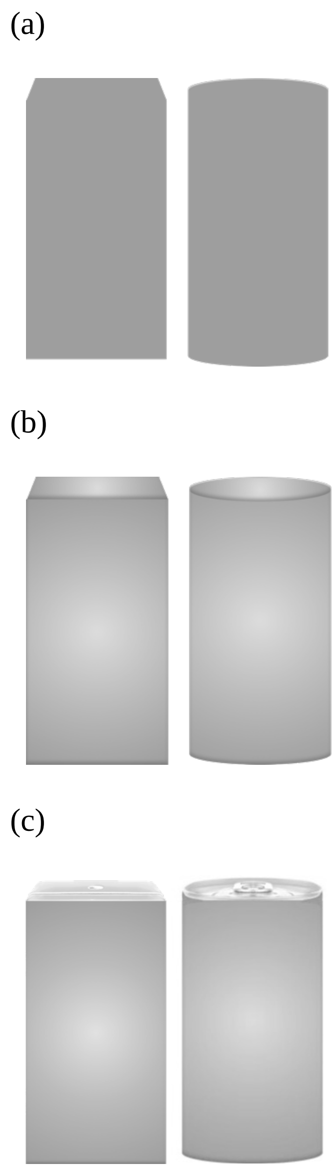


Figure 4. Exemplars for the novel stimuli in grayscale for the (a) Silhouette, (b) Intermediate, and (c) Functional iterations.

Intermediate Iteration

The second iteration provides relatively more manipulation information than the Silhouette iteration and includes information about its sides and contains depth information. However, this iteration lacks an obvious functional component. Here, it is important to place emphasis on the absence of *conspicuous* functional component as technically, any object can provide some function. For the sake of brevity, this object iteration will be referred to as the Intermediate iteration as it falls between the Silhouette and Functional iterations, but it can also be thought of as the object with inconspicuous function.

Functional Iteration

The Functional iteration of the objects introduces a functional component which allows the cube to become a juice box and the cylinder to become a soda can. This last iteration is an important deviation from past attempts to move toward spatially unbiased stimuli for two critical reasons. First, the functional components are symmetrical and mirrored so that they are not biased to either the left- or the right-hand side. Second, the functional components have been modified from real-world objects.

Given that the final functional iterations meet all four of the requirements for activation, these objects should receive comparatively more facilitation than the two previous iterations. For a summary of the requirements met by each of the object iterations, see Table 6.

Table 6. Summary of Automatic Activation Requirements Met by Each Object Iteration

	Object Iteration		
Activation Requirement	Silhouette	Intermediate	Functional
State	X	X	X
Manipulability		X	X
Familiarity		X	X
Functionality			X

Method

Participants

Participants were 120 undergraduates (56 males; 100% right-handed). The number of participants recruited was based on a *G*Power* a priori sample size determination with power (1 - β) set at 0.80 plus an approximate 25% of participants added for cushion. This sample size is more conservative than similar studies (e.g., Cho & Proctor, 2010).

Apparatus

The experiment was conducted using a personal computer controlled by E-Prime 3.0 software (Psychological Software Tools, Inc., Sharpsburg, PA) and responses were registered using a Chronos response box (Figure 5a).

Stimuli

Stimuli were three different iterations of cylinder and cube objects each, allowing for six possible stimuli. Further, each of these stimuli were presented in either an upright or inverted orientation. All stimuli were modified so that they were presented in either red or green and were presented at the center of the screen on a white background. The stimuli subtended 3.08° × 6.60°.

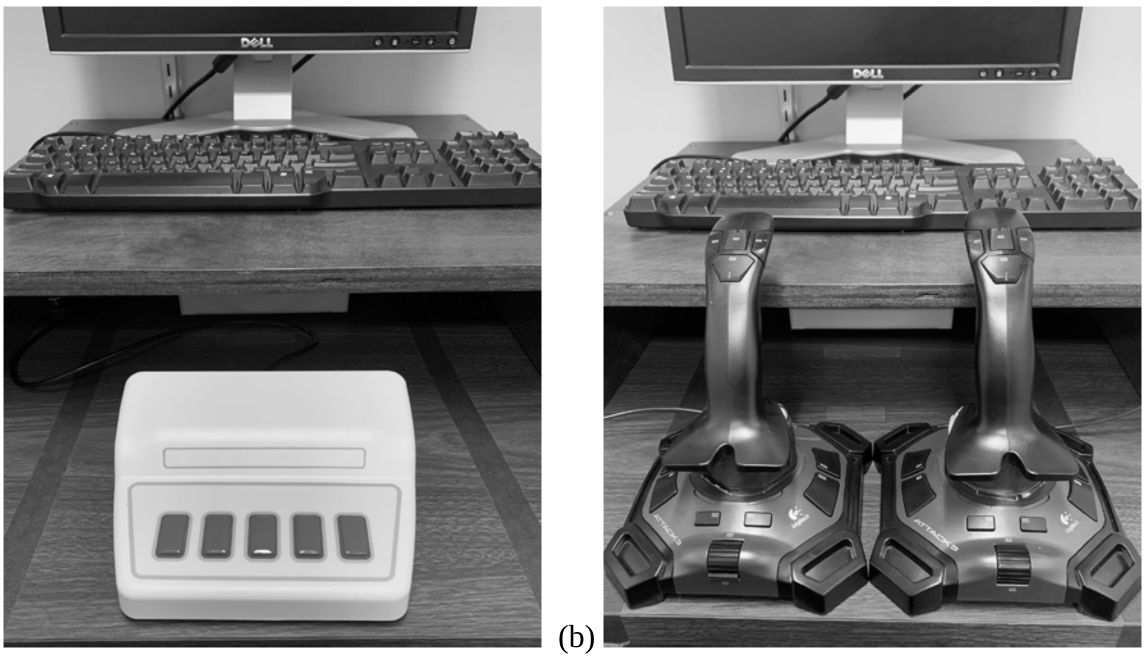
(a) (b)


Figure 5. Laboratory setup for (a) the response box used in Experiment 3 and (b) the joysticks used in Experiment 4.

Design

This experiment used a mixed factorial design. The between-subject manipulation was the object iteration that participants were assigned to (i.e., Silhouette, Intermediate, or Functional). This factor was manipulated between subjects in order to avoid any possible carryover effects between iteration presentations. The within-subject manipulation was how the stimuli were oriented (i.e., upright or inverted).

Procedure

At the beginning of the experiment, participants were explicitly told what stimuli they would be responding to. For the silhouette, intermediate, and functional items, participants were told that they would be responding to shapes, cylinders and cubes, and juice boxes and soda cans, respectively. However, there was no mention of grasping nor was attention drawn to any particular aspect of the stimuli (e.g., the pull tab on the soda can). Participants were instructed to respond to the color of the stimulus (i.e., red or green) and to do so as quickly and accurately as possible to the stimuli with one of two buttons using their left and right index fingers. Color-response mappings (e.g., left key for green and right key for red) were counterbalanced across participants.

The experiment consisted of one practice block and four test blocks. The practice block was made up of 16 intermixed trials and each test block was made up of 96 intermixed trials each. An equal number of trials were presented for each combination of the following variables: stimulus type (cylinder or cube), color (red or green), and orientation (upright or inverted). The trials followed the same sequence as that used in Experiment 2.

Results

Two separate mixed measures ANOVAs were conducted with Response Hand (Left or Right) and Object Orientation (Upright or Inverted) as within-subjects factors and Stimulus Type (Silhouette, Intermediate, or Functional) as a between-subjects factor on RT and PE. Data were screened for outliers in the same manner as that of Experiment 2. No participants had to be replaced because of poor accuracy and fewer than 3% of cases were excluded based on RT cutoffs. A summary of mean reaction time and percent error can be found in Table 7.

Table 7. Experiment 3: Mean Reaction Time in Milliseconds and Percent Error in Parentheses

	Object Iteration		
Response Hand and Orientation	Silhouette	Intermediate	Functional
Left Hand			
Upright	373 (96.7%)	365 (96.3%)	377 (96.8%)
Inverted	372 (97.4%)	364 (96.8%)	373 (97.3%)
Right Hand			
Upright	371 (96.4%)	358 (96.1%)	367 (97.0%)
Inverted	365 (97.0%)	356 (96.0%)	366 (95.8%)

Reaction Time

There was a main effect of Object Orientation, $F(1, 117) = 9.27$, $p = .003$, $\eta_p^2 = .07$. Responses made to the objects that were inverted (M = 366 ms, SE = 4 ms) were shorter than responses made to the objects that were upright (M = 368 ms, SE = 4 ms). There was also a main effect of Response Hand, $F(1, 117) = 15.15$, $p < .001$, $\eta_p^2 = .12$. Responses made with the right hand (M = 364 ms, SE = 4 ms) were shorter than responses made with the left hand (M = 370 ms, SE = 4 ms). There were no other significant main effects or interactions ($Fs < 1.7$). A summary of the ANOVA results for reaction time and percent error can be found in Table 8.

Table 8. Experiment 3: ANOVA Results for Reaction Time and Percent Error

Measure	Source	F	p-value	η_p^2
	Object Orientation	9.27	.003	.07
	Response Hand	15.15	<.001	.12
	Stimulus Type	.77	.47	.01
Reaction Time	Object Orientation × Response Hand	.12	.73	.001
	Object Orientation × Stimulus Type	.47	.63	.008
	Response Hand × Stimulus Type	.59	.56	.01
	Object Orientation × Response Hand × Stimulus Type	1.62	.20	.03
	Object Orientation	.97	.33	.008
	Response Hand	5.61	.02	.05
	Stimulus Type	.57	.57	.01
Percent Error	Object Orientation × Response Hand	5.42	.02	.04
	Object Orientation × Stimulus Type	2.28	.07	.05
	Response Hand × Stimulus Type	.22	.80	.004
	Object Orientation × Response Hand × Stimulus Type	1.76	.18	.03

Percent Error

There was a main effect of Response Hand, $F(1, 117) = 5.61$, $p = .02$, $\eta_p^2 = .05$. Responses made with the left hand ($M = .031$, $SE = .002$) were more accurate than responses made with the right hand ($M = .036$, $SE = .003$). Further, a significant two-way interaction was found between Response hand and Orientation, $F(1, 117) = 5.43$, $p = .02$, $\eta_p^2 = .04$ (see Figure 6). This interaction involved a greater difference in accuracy for the upright and inverted objects when responding with the right hand than when responding with the left hand. Specifically, responses made with the right hand to upright objects were approximately 1% more accurate than responses made to the inverted objects. There were no other main effects or interactions that reached significance, although the mean data showed a tendency for the higher accuracy for the right hand to be evident mainly for the functional stimuli.

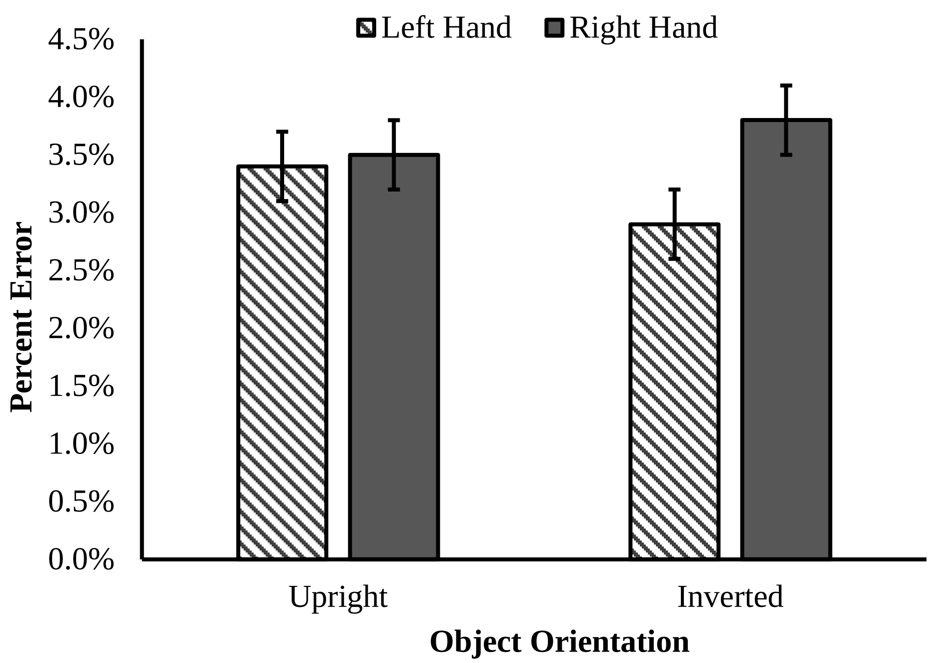


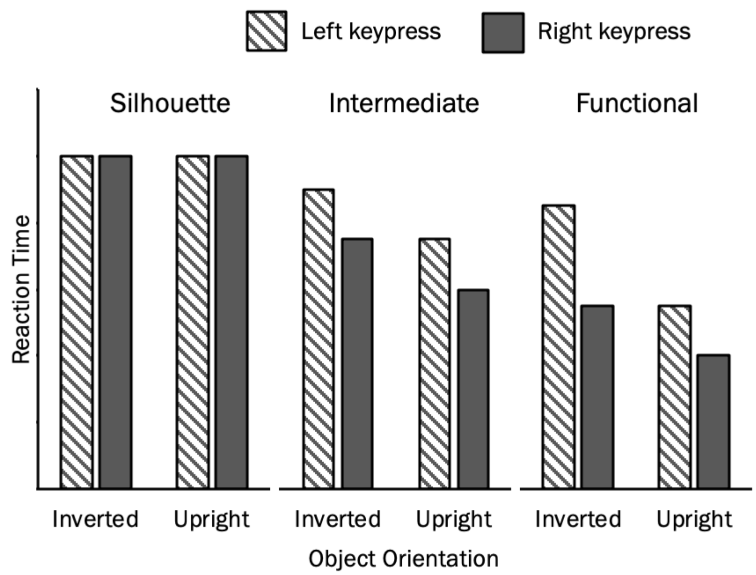
Figure 6. Percent error as a function of Object Orientation and Response Hand for Experiment 3. Error bars represent ±1 standard error of the mean for this and all other graphs, computed using the method for within-subjects designs (Cousineau, 2005).

Discussion

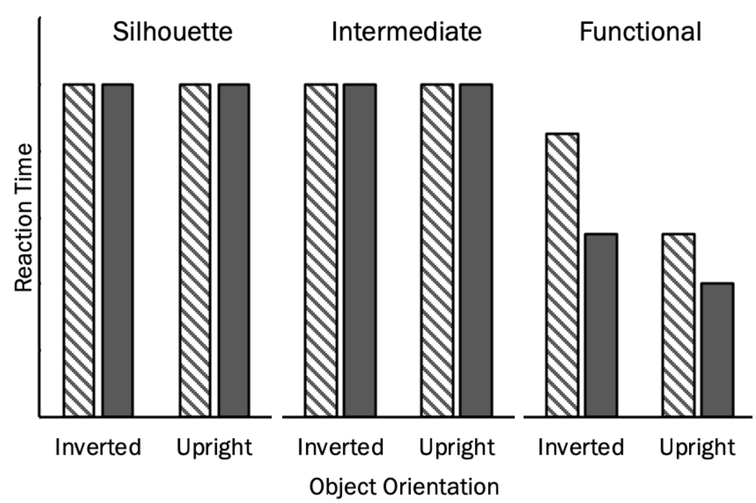
Experiment 3 was conducted to determine whether performance differs for responses made toward stimuli of the same general shape but with varying features that communicate different types of information regarding manipulation. According to the automatic activation account of object-based compatibility effects, there are two possible patterns for how participants could respond to the three types of stimuli. The first possibility is one in which a stepwise pattern could occur where with each iteration going from Silhouette to Intermediate to Functional, performance gets a benefit boost (Figure 7a). A second possibility is an all-or-none pattern in which both the Silhouette and Intermediate iterations fail to show a performance boost evident in the Functional iteration (Figure 7b). In either case, the Functional iteration should allow for the best performance when compared to the other two iterations.

The results of Experiment 3 did not reveal any systematic differences between performance as a function of condition and, more importantly, did not follow either of the two aforementioned patterns predicted by the automatic activation account. For all intents and purposes, the three object iterations yielded virtually identical results. Beyond a lack of difference between the three object iterations, orientation differences also failed to provide support for the automatic activation account. Responses made toward the inverted objects were shorter than responses made toward the upright objects. However, the automatic activation account would predict the opposite pattern. That is to say, individuals should be more prepared to respond to objects presented in their canonical form than when they are inverted.

In sum, the findings from Experiment 3 do not provide evidence in support for the automatic activation account. In the absence of left-right correspondence, there was no evidence demonstrating that individuals are automatically prepared to respond to manipulable objects. Of note is that this experiment followed the requirements that have been informally put forth as necessary for activation. Despite these efforts, there was no evidence favoring the automatic activation account. However, these results do not do away with the possibility of supporting the automatic activation account in their totality. In fact, it has recently been suggested that an additional requirement for activation might be how engaged one is in in the action elicited by the objects being viewed (e.g., Bub et al., 2018). It is to this possibility to which the following experiment pivots.



(a)



(b)

Figure 7. Possible pattern of results favoring the automatic activation account for (a) stepwise and (b) all-or-none pattern.

EXPERIMENT 4: NOVEL STIMULI WITH GRASP-LIKE RESPONSES

Historically, studies relating to object-based compatibility effects have opted to have participants press buttons and keys in response to objects and other types of responses have been systematically overlooked (Azaad et al., 2019). It has been suggested that button presses cannot inherently detect the motor activation that has been claimed to occur. For instance, Suzuki and colleagues (2012) have argued that, “The action most strongly afforded by graspable objects is a grasping action, not a key press” (p. 882). Researchers have supported the claim that responses that more closely resemble real-world actions are more likely to result in a pattern of results that would favor the automatic activation account. For instance, Bub et al. (2018) have stated that they have found support for the notion that, “pictured objects, under the right task conditions, trigger motor constituents of real-world actions” (p. 57).

Given the aforementioned possibility, Experiment 4 was designed to determine whether responses more removed from typical button presses and closer to an actual grasping response would result in support for the notion that viewing objects without the explicit intention to act toward them would facilitate motor responses. Experiment 4 tasked participants with responding to the novel stimuli with grasping actions. In sum, Experiment 4 was conducted to determine whether employing a grasp-like response would allow for the automatic activation that has been proposed in the literature.

Method

Participants

Participants were 120 undergraduates (57 males; 100% right-handed) who were recruited, screened, and awarded credit in a manner similar to those recruited in the previous experiments.

Apparatus and Stimuli

Two Logitech Attack 3 ambidextrous joysticks with triggers were used to collect responses from both hands. The joysticks were approximately 24 cm tall and had a base measuring approximately 18 cm. The joysticks were placed side by side in the same location as the response box in Experiment 3 (Figure 5b). Ambidextrous joysticks were required for Experiment 4 because non-ambidextrous joysticks typically have a shelf for right-handed users to rest their right palms on and as such, were inappropriate for collecting responses from both hands. The distance between the index finger, which pressed down on the trigger to respond, and the thumb, which was used to support the hand on the joystick, was approximately 4.5 cm and comparable to the width of the objects on the screen (3.5 cm). The stimuli, laboratory setup, and experimental software were the same as those used in Experiment 3.

Design

Experiment 4 used a mixed factorial design identical to Experiment 3. The between-subjects manipulation was the object iteration that participants were assigned to (i.e., Silhouette, Intermediate, or Functional). The within-subjects manipulations were how the stimuli was oriented (i.e., upright or inverted) and response hand used (i.e., left or right hand).

Procedure

The procedure was identical to that of Experiment 3 with a few exceptions related to the joysticks used to make responses. First, all participants were instructed to hold the joysticks so that their respective index and middle fingers were on the trigger, their thumb was grasping the joystick and approximately level to the index finger, and their remaining two fingers did not touch the joystick (Figure 8). Instructions for the hand postures were explicitly framed as simulating a grasping response by both the experimenter before the experiment begun and by the on-screen instructions. Second, participants received an additional reminder about how they should position their hands on the joysticks after the practice session and before each test block.

(a) 

(b) 

Figure 8. Experiment 4 hand placement (a) with a single joystick and (b) both joysticks. Hand placement is depicted in (a) to show exact finger placement, but all participants responded with both joysticks as depicted in (b).

Results

Two separate mixed measures ANOVAs were conducted with Response Hand (Left or Right), Object Orientation (Upright or Inverted) as within-subjects factors and Stimulus Type (Silhouette, Intermediate, or Functional) as a between-subjects factor on RT and PE. Data were screened for outliers in the same manner as that of the prior experiments. No participants had to be replaced because of poor accuracy and fewer than 3% of cases were excluded based on RT cutoffs. A summary of mean reaction time and percent error can be found in Table 9.

Table 9. Experiment 4: Mean Reaction Time in Milliseconds and Percent Error in Parentheses

	Object Iteration		
Response Hand and Orientation	Silhouette	Intermediate	Functional
Left Hand			
Upright	372 (96.7%)	374 (97.9%)	385 (97.0%)
Inverted	373 (97.0%)	374 (97.7%)	384 (97.0%)
Right Hand			
Upright	371 (96.9%)	365 (97.0%)	378 (97.6%)
Inverted	372 (96.8%)	366 (96.9%)	378 (96.3%)

Reaction Time

There was a main effect of Response Hand, $F(1, 117) = 8.39$, $p = .004$, $\eta_p^2 = .07$. Responses made with the right hand (M = 373 ms, SE = 4 ms) were shorter than responses made with the left hand (M = 377 ms, SE = 4 ms). There were no other main effects or interactions that reached significance ($Fs < 1.9$). A summary of the ANOVA results for reaction time and percent error can be found in Table 10.

Table 10. Experiment 4: ANOVA Results for Reaction Time and Proportion Correct

Measure	Source	*F*	*p*-value	η_p^2
Reaction Time	Object Orientation	1.55	.22	.01
	Response Hand	8.40	.004	.07
	Stimulus Type	1.07	.35	.02
	Object Orientation × Response Hand	1.54	.22	.01
	Object Orientation × Stimulus Type	.59	.56	.01
	Response Hand × Stimulus Type	2.47	.09	.04
	Object Orientation × Response Hand × Stimulus Type	1.89	.16	.03
Percent Error	Object Orientation	1.92	.17	.02
	Response Hand	2.30	.13	.02
	Stimulus Type	.49	.61	.008
	Object Orientation × Response Hand	2.41	.12	.02
	Object Orientation × Stimulus Type	2.58	.08	.04
	Response Hand × Stimulus Type	1.91	.15	.03
	Object Orientation × Response Hand × Stimulus Type	1.50	.23	.03

Percent Error

Although the interaction between Response Hand and Object Orientation did not reach statistical significance, $F(1, 117) = 2.41$, $p = .12$, $\eta_p^2 = .02$, the trend was similar to that obtained in Experiment 3, in which there was a distinction between responses made to upright and inverted objects with the right hand, but not with the left hand (Figure 9). This pattern is discussed more in depth in the following section. The ANOVA did not reveal any significant main effects or interactions between the other factors (*Fs* < 2.4).

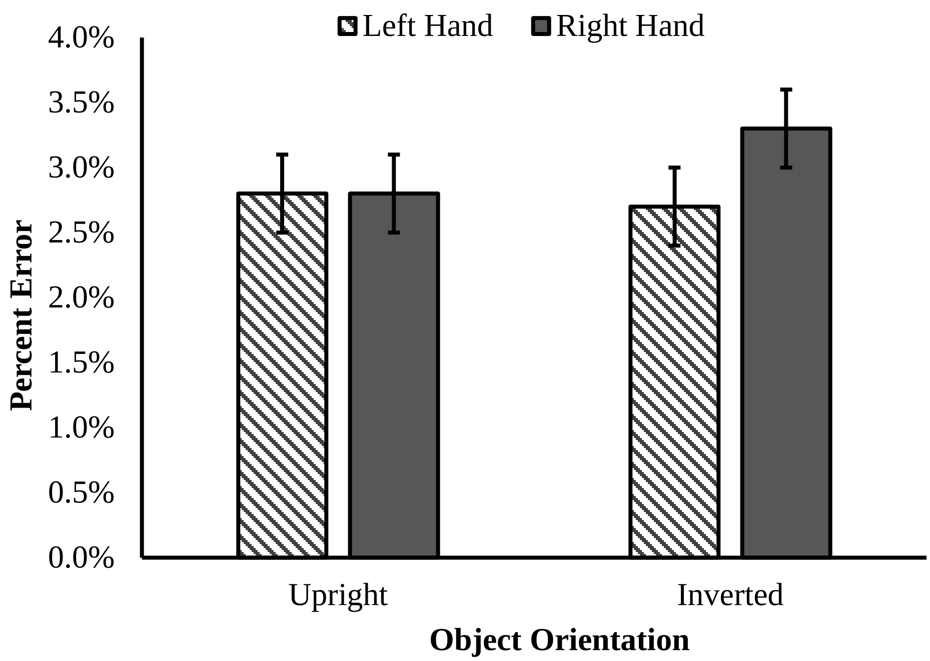


Figure 9. Percent error as a function of Object Orientation and Response Hand for Experiment 4.

Supplementary Analyses

As a reminder, Experiments 3 and 4 were identical in all regards except for the type of response that had to be completed. In Experiment 3, participants responded by pressing buttons with their index fingers, whereas in Experiment 4, they made grasping trigger-press responses using their index and middle fingers. Across both experiments, there was a noticeable pattern of interaction in the accuracy data between two factors: object orientation and response hand. This interaction only reached statistical significance in Experiment 3, but a similar pattern was evident in Experiment 4. Further, when stimulus type is considered in addition to object orientation and response hand, it appears that this trend is most marked for the functional iteration compared to the silhouette and intermediate iterations.

To explore these trends across the two experiments, two mixed measures ANOVAs were conducted on accuracy and reaction time pooled across both experiments with the within-subject factors and Response Hand (Left or Right) and Object Orientation (Upright or Inverted), and the between-subject factors of Stimulus Type (Silhouette, Intermediate, or Functional) and Experiment (Experiment 3 or Experiment 4).

Percent error. First, a critical step in the combined analysis was to determine if the results differed across experiments. There was no main effect of the experiment factor nor did experiment interact with any of the other factors (ps > .05). These results indicate that there were no systematic differences in results between the two experiments and that pooling across experiments would be suitable.

The ANOVA revealed similar findings to the previously conducted analyses. There was a main effect of Response Hand, $F(1, 234) = 7.63$, $p = .006$, $\eta_p^2 = .03$. Responses made with the left hand ($M = .030$, $SE = .002$) were more accurate than responses made with the right hand ($M = .034$, $SE = .002$). There was also a two-way interaction between Object Orientation and Stimulus Type, $F(2, 234) = 5.29$, $p = .006$, $\eta_p^2 = .04$. There were no differences in accuracy between the upright and inverted intermediate stimuli ($|PE_\Delta| = .000$), but there was a mirrored difference for the silhouette and functional stimuli ($|PE_\Delta| = .005$ for both). Responses for the inverted objects were more accurate than the upright objects for the silhouette stimuli, but this pattern was opposite for the functional stimuli.

Object Orientation also interacted with Response Hand, $F(1, 234) = 7.60$, $p = .006$, $\eta_p^2 = .03$. When responses were made with the left hand, accuracy was higher for the inverted objects than the upright objects ($|PE_\Delta| = .003$). This pattern was reversed for the right hand as accuracy was higher for the upright objects compared to the inverted objects ($|PE_\Delta| = .003$). Finally, there was a three-way interaction between Object Orientation, Response Hand, and Stimulus Type that did not attain the standard .05 significance level, $F(2, 234) = 2.78$, $p = .06$, $\eta_p^2 = .02$. This interaction reflects that the advantage for upright objects shown by the right hand was evident primarily for the functional stimuli. There were no other main effects or interactions. A summary of the ANOVA results for percent error can be found in Table 11.

Table 11. Experiments 3 and 4: ANOVA Results for Supplemental Analysis for Percent Error

Measure	Source	F	p-value	η_p^2
	Object Orientation	.007	.93	<.001
	Response Hand	7.63	.006	.03
	Stimulus Type	.002	.99	<.001
	Experiment	2.15	.14	.009
	Object Orientation × Response Hand	7.60	.006	.03
	Object Orientation × Stimulus Type	5.29	.006	.04
Percent Error	Object Orientation × Experiment	2.66	.10	.01
	Response Hand × Stimulus Type	1.08	.34	.009
	Response Hand × Experiment	.46	.50	.002
	Object Orientation × Response Hand × Stimulus Type	2.78	.06	.02
	Object Orientation × Response Hand × Experiment	.38	.54	.002
	Object Orientation × Stimulus Type × Experiment	.13	.88	.001
	Response Hand × Stimulus Type × Experiment	.97	.38	.008
	Object Orientation × Response Hand × Stimulus Type × Experiment	.51	.60	.004

Reaction time. First, the only interaction regarding the Experiment factor was that of Object Orientation and Experiment, $F(1, 234) = 8.60$, $p = .004$, $\eta_p^2 = .04$. There was a pattern showing that for Experiment 3, responses for the inverted objects were 2-ms shorter than for upright objects. For Experiment 4, this pattern was reversed, and responses for the inverted objects were 1-ms longer than for the upright objects. However, the difference in orientation was found to reach statistical significance for only Experiment 3 and not for Experiment 4. Importantly, there were no interactions between the experiment factor and stimulus type or response hand.

Furthermore, there was a main effect of Response Hand, $F(1, 234) = 23.46$, $p < .001$, $\eta_p^2 = .09$. Right responses ($M = 368$ ms, $SE = 3$ ms) were shorter than left responses ($M = 368$ ms, $SE = 3$ ms).

There was also a three-way interaction between Object Orientation, Response Hand, and Stimulus Type, $F(2, 234) = 3.41$, $p = .04$, $\eta_p^2 = .03$. Follow-up analyses based on stimulus type showed the following: For the silhouette stimuli, there were no systematic differences as a function of object orientation or response hand (*F*s < 1.8; *p*s > .05). For the intermediate condition, there was an effect of response hand in which responses made with the right hand were approximately 8-ms shorter than those made with the left hand ($p < .001$). However, there was no influence of object orientation or an interaction between the two factors for the intermediate stimuli (*F*s < 1.0; *p*s > .05). For the functional condition, there was a similar effect of response hand wherein responses made with the right hand were approximately 7-ms shorter than those made with the left hand ($p < .001$). Though there was no effect of orientation, there was an interaction between this factor and response hand ($p = .03$). This interaction revealed an approximately 9-ms shorter response for the upright stimuli when responding with the right hand than with the left hand.

There were no other main effects or interactions. A summary of the ANOVA results for percent error can be found in Table 12.

Table 12. Experiments 3 and 4: ANOVA Results for Supplemental Analysis for Reaction Time

Measure	Source	*F*	*p*-value	η_p^2
Reaction Time	Object Orientation	1.10	.30	.005
	Response Hand	23.46	<.001	.09
	Stimulus Type	1.53	.22	.01
	Experiment	2.05	.15	.003
	Object Orientation × Response Hand	.41	.52	.002
	Object Orientation × Stimulus Type	.28	.76	.002
	Object Orientation × Experiment	8.60	.004	.04
	Response Hand × Stimulus Type	2.00	.14	.02
	Response Hand × Experiment	1.22	.27	.005
	Object Orientation × Response Hand × Stimulus Type	3.41	.04	.03
	Object Orientation × Response Hand × Experiment	1.26	.26	.005
	Object Orientation × Stimulus Type × Experiment	.80	.45	.007
	Response Hand × Stimulus Type × Experiment	.76	.47	.006
	Object Orientation × Response Hand × Stimulus Type × Experiment	.11	.90	.001

Discussion

Experiment 4 was conducted to determine whether an action more closely related to how one might grasp either a cylindrical or cubed object would facilitate responses toward the novel stimuli introduced in Experiment 3. As a reminder, the automatic activation account would predict that performance would follow either a stepwise or all-or-none pattern favoring the functional iteration in either case. However, across both Experiments 3 and 4, no support was found for the automatic activation account.

The overlap between Experiments 3 and 4 allowed for the data from the two experiments to be pooled. This was primarily prompted by an interaction pattern between response hand and object orientation in the two experiments. The analyses conducted for both accuracy and reaction time demonstrated that the interaction between the two aforementioned factors was most evident for the functional stimuli. Specifically, responses made with the right hand to upright functional objects tended to shorter and more accurate than to the other variations of the functional stimuli. Although at first glance this result might be interpreted as evidence for the hypothesis of automatic activation of one's right hand to items presented in their canonical orientation, a more likely possibility is that it reflects what is called *polarity correspondence*. This term refers to a mapping benefit for canonical (positive) and non-canonical (negative) items to the right hand and negative items to the left hand (Lakens, 2012; Proctor & Cho, 2006; Proctor & Xiong, 2015). This polarity-correspondence interpretation implies that even though left-right correspondence was removed from this experiment's stimulus set, a more subtle form of compatibility effect for response selection was present.

In all, the results of Experiment 4 run counter to the automatic activation account. Beyond the possibility for polarity correspondence, which highlights the importance spatial coding, the supplementary analyses both generally supported that there were no systematic differences between the two experiments. These findings suggest that, for all intents and purposes, button presses were identical to the grasping responses. Critically, Experiment 4 attempted to approximate realistic responses made toward objects and, in turn, be more likely to create patterns supporting the automatic activation account, but it appears that this may not have come to fruition. There are two possible reasons for why evidence favoring an automatic activation account may not have been observed.

First, the grasping responses made with the joysticks may be too removed from actual everyday grasping responses. From the onset to end of each session in Experiment 4, participants were continuously reminded of the grasping responses they were attempting to imitate, but this may not have been sufficient to automatically activate the respective motor programs that have been credited with producing performance benefits. Bub et al. (2018) have stated that "certain effects–in particular, those obtained when subjects actually engage in speeded reach-and-grasp actions–do support the idea that pictures of objects can trigger motor affordances" (p. 54).

Second, lack of support for the automatic activation account may have been produced by the color determination task employed in all three of the previous experiments. Bub et al. (2018) have stated that "task conditions that demand attention to color are probably not ideal for revealing an early impact of shape on speeded grasp responses" (p. 56). The importance of the task that participants are to perform has been echoed by other researchers (e.g., Yu et al., 2014).

EXPERIMENT 5: NOVEL STIMULI WITH REACH AND GRASP RESPONSE

Experiment 5 was designed to study responses made to the novel stimulus set with both a response and task that, based on past claims in the literature (e.g., Bub et al., 2018), would be relatively more likely to match the contexts that have been proposed to be ideal for automatic activation to occur. Here, it can be useful to discuss the notion of an individual's task set which is defined as "the mental representation of the task that is to be performed" (Xiong & Proctor, 2018b). Stated differently, a task set is related to the representation of activities that a particular individual is prepared to accomplish. Consider a scenario in which an individual goes to the grocery store with a list of items to make a sandwich (e.g., a loaf of bread; tomatoes). If the individual in question had intentions to be more economically minded during the grocery trip, he or she might be more aware of discounts or special offers being held by the grocery store whereas an individual without such monetary restrictions may not notice this information to the same degree. This commonplace example highlights the importance of context and one's particular preparedness for a task in executing said task.

It is possible that similar logic might apply to acting upon an object. In Experiment 4, participants had to engage only in a grasping response. However, in everyday life, grasping actions require a preceding reaching component. Although this is certainly an oversimplification that overlooks the many other facets that make grasping possible, it is meant to highlight that grasping is far more complex than what has been presented thus far. As such, Experiment 5 attempted to determine whether tasking participants to engage in an action require both a reach and a grasp would better simulate a grasping response.

Method

Participants

Participants were 40 undergraduates (21 males; 100% right-handed) who were recruited, screened, and awarded credit in a manner similar to those recruited in the previous experiments. Unlike the previous experiments, however, participants were not screened for red-green color blindness as all stimuli were presented in greyscale.

Apparatus and Stimuli

Experiment 5 employed the Chronos response box used in Experiment 3 and only one of the joysticks used in Experiment 4. The joystick was affixed to the table behind the response box.

Participants were seated approximately 20 cm further away from the monitor than in the previous experiments. This change was implemented to fit both the response box and joystick directly in front of the monitor. In regard to stimuli, only two iterations of the cylindrical stimuli were used (i.e., the silhouette and functional). These stimuli were presented in gray scale.

Design

Experiment 5 used a mixed factorial design. The repeated measures manipulations were the stimulus type to which participants were assigned (i.e., Silhouette or Functional) and its orientation (i.e., upright or inverted). The independent measures manipulation was the type of category-response mapping (i.e., left hand for drink item and right hand for non-drink item or left hand for non-drink item and right-hand for drink item). Category-response mappings were counterbalanced across participants.

Procedure

Different from the prior experiments, participants were not tasked with making color judgments about the stimuli. Instead, participants were instructed to determine whether the stimulus presented was an item that could be used for drinking or not. Participants were told to respond as quickly and accurately as possible to the stimuli with a reach-and-grasp response. The experiment consisted of one practice block and three test blocks. The practice block was made up of 32 intermixed trials, and each test block was made up of 80 intermixed trials each. An equal number of trials were presented for each combination of the following variables: stimulus type (silhouette or functional) and object orientation (upright or inverted).

Each trial was self-initiated and began when the response box registered that the outermost response buttons were depressed when the fixation cross was presented (Figure 10). This was followed by a blank screen presented for 500 ms preceding stimulus presentation. Once the stimulus appeared, participants were to release only the index finger of the hand with which they were to make a response while keeping the other index finger depressed. Participants were

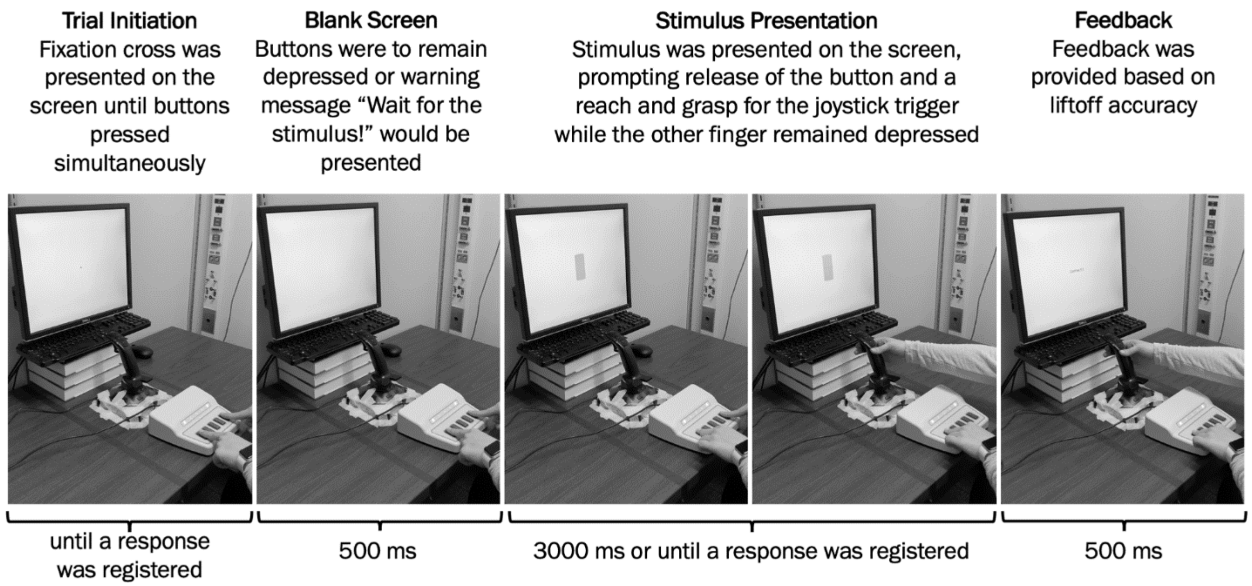


Figure 10. Trial sequence for Experiment 5.

instructed to wait to release the appropriate index finger after the stimulus appeared and only after they had made their decision about how to respond. Participants then reached for the joystick and pressed down on the joystick trigger, which ended the trial. Feedback was either “Correct!” or “Incorrect!” and based on the finger that was released to make the response. Following the feedback screen, the fixation cross for the next trial would appear, but the next trial would not initiate until both index fingers were depressed on the outermost response box buttons.

There were two possible deviations from the aforementioned trial sequence. First, if a premature button release was detected before the stimulus appeared (i.e., during the blank screen immediately preceding the stimulus), participants received the reminder, “Wait for the stimulus!” Additional trials were not added to make up for these missed trials. Second, trials would automatically terminate if no response was detected within 3,000 ms of stimulus onset.

Results

Four separate mixed measures ANOVAs were conducted with Object Orientation (Upright or Inverted) and Stimulus Type (Silhouette or Functional) as the within-subjects factors and Category Mapping (Left Hand Functional/Right Hand Silhouette or Left Hand Silhouette/Right Hand Functional) as the between-subjects factor were carried out on total response time, initiation time, movement time, and lift-off accuracy. Total response time was defined as the time between stimulus onset and registration of a trigger response. Initiation time was defined as the time between stimulus presentation and release of an index finger from its home button. Movement time was defined as the time between the release of an index finger from its home button and the time when a response was registered by the joystick trigger. Finally, lift-off accuracy was defined as the accuracy of the hand that was used to first initiate a response as registered by the release of either the left or right index finger.

Data for the different dependent variables were separately screened for outliers in the same manner as that of the prior experiments, and no participants had to be replaced because of poor accuracy. Fewer than 5% of cases were excluded for each measure based on cutoffs. A summary of total response time, initiation time, movement time, and percent error is given in Table 13.

The results are broken down by the main effects and interactions that overlapped between the different measures. A summary of the ANOVA results for initiation time, movement time, total response time, and percent error can be found in Table 14.

Table 13. Experiment 5: Mean Total Response Time (TRT), Initiation Time (IT), and Movement Time (MT) in Milliseconds and Percent Error

	Stimulus Type							
	Silhouette				Functional			
Category-Response Mapping and Orientation	TRT	IT	MT	PE	TRT	IT	MT	PE
Drink Left, Non-Drink Right								
Upright	1060	517	514	96.1%	1073	522	539	95.9%
Inverted	1035	514	510	96.7%	1040	530	520	96.1%
Non-Drink Left, Drink Right								
Upright	1071	513	551	97.5%	1069	512	548	96.5%
Inverted	1080	517	551	96.8%	1074	530	534	96.1%

Table 14. Experiment 5: ANOVA Results for Initiation Time, Movement Time, Total Response Time, and Liftoff Accuracy

Measure	Source	*F*	*p*-value	η_p^2
Initiation Time	Object Orientation	18.51	<.001	.33
	Stimulus Type	4.25	.05	.10
	Category Mapping	.03	.87	.001
	Object Orientation × Stimulus Type	8.50	.006	.18
	Object Orientation × Category Mapping	6.96	.01	.16
	Stimulus Type × Category Mapping	.32	.58	.008
	Object Orientation × Stimulus Type × Category Mapping	.15	.70	.004
Movement Time	Object Orientation	23.64	<.001	.38
	Stimulus Type	.89	.35	.02
	Category Mapping	.57	.45	.02
	Object Orientation × Stimulus Type	11.15	.002	.23
	Object Orientation × Category Mapping	2.01	.17	.05
	Stimulus Type × Category Mapping	12.69	.001	.25
	Object Orientation × Stimulus Type × Category Mapping	.04	.84	.001

Table 14 continued

Measure	Source	F	p-value	η_p^2
Total Response Time	Object Orientation	4.92	.03	.12
	Stimulus Type	.76	.39	.02
	Category Mapping	.21	.65	.005
	Object Orientation × Stimulus Type	.93	.34	.02
	Object Orientation × Category Mapping	12.17	.001	.24
	Stimulus Type × Category Mapping	4.78	.04	.11
	Object Orientation × Stimulus Type × Category Mapping	.15	.70	.004
Liftoff Accuracy	Object Orientation	.02	.90	<.001
	Stimulus Type	1.61	.21	.04
	Category Mapping	.57	.46	.02
	Object Orientation × Stimulus Type	<.001	.98	<.001
	Object Orientation × Category Mapping	.96	.33	.03
	Stimulus Type × Category Mapping	.21	.65	.005
	Object Orientation × Stimulus Type × Category Mapping	.16	.70	.004

Main Effects

There was a main effect of Object Orientation for the three time measures, though the pattern was not the same for all three. For total response time, $F(1, 38) = 4.92$, $p = .03$, $\eta_p^2 = .12$, total response time for the inverted stimuli (M = 1057 ms, SE = 24 ms) was 11-ms shorter than for upright stimuli (M = 1068 ms, SE = 24 ms). Likewise, for movement time, $F(1, 38) = 23.64$, $p < .001$, $\eta_p^2 = .38$, responses for the inverted stimuli (M = 528 ms, SE = 17 ms) were shorter than for upright stimuli (M = 538 ms, SE = 17 ms). In contrast, for initiation time, $F(1, 38) = 18.51$, $p < .001$, $\eta_p^2 = .33$, responses for the upright stimuli (M = 516 ms, SE = 9 ms) were 7-ms shorter than for inverted objects (M = 523 ms, SE = 9 ms).

Furthermore, there was a main effect of Stimulus Type, $F(1, 38) = 4.25$, $p = .05$, $\eta_p^2 = .10$, for initiation time only. Initiation time for the silhouette iteration (M = 515 ms, SE = 9 ms) was shorter than for the functional iteration (M = 523 ms, SE = 9 ms). There were no other main effects found.

Interactions

Object orientation × category mapping. First, there was an interaction between Object Orientation and Category Mapping for both total response time and initiation time. For total response time, $F(1, 38) = 12.17$, p = .001, $\eta_p^2 = .24$ (Figure 11), responses for the Left Hand Functional/Right Hand Silhouette mapping were shorter for the inverted stimuli (M = 1037 ms) than the upright stimuli (M = 1066 ms), whereas the Left Hand Silhouette/Right Hand Functional mapping showed a much smaller opposite numerical advantage for the upright (M = 1070 ms) objects over the inverted objects (M = 1077 ms).

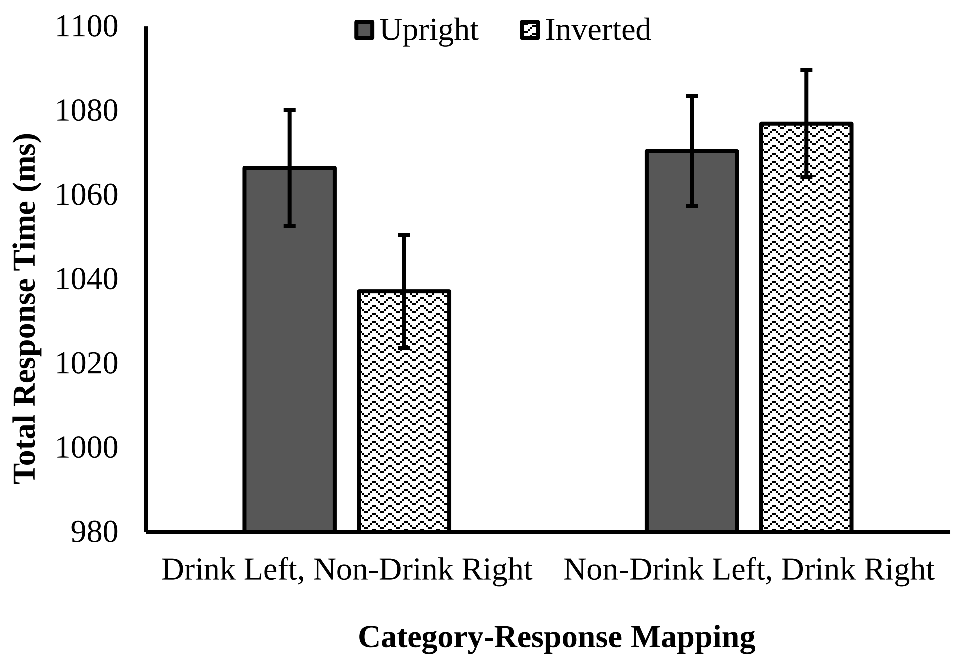


Figure 11. Total response time as a function of upright or inverted Object Orientation and Category-Response Mapping for Experiment 5. For brevity, the Left Hand Functional/Right Hand Silhouette and Left Hand Silhouette/Right Hand Functional Mappings have been labeled Drink Left, Non Drink Right and Non-Drink Left, Drink Right, respectively.

For initiation time, *F*(1, 38) = 6.96, *p* = .01, η_p^2 = .16 (Figure 12), responses for the Left Hand Functional/Right Hand Silhouette mapping were comparable for upright (*M* = 520 ms) and inverted orientations (*M* = 522 ms), unlike for total response time. There was a more pronounced difference in the Left Hand Silhouette/Right Hand Functional mapping with faster initiation time for the upright objects (*M* = 512 ms) than the inverted objects (*M* = 523 ms). This 11-ms difference is slightly larger numerically than the 7-ms difference in total response time. Follow-up analyses aimed at determining whether the lattermost pattern differed between the two stimulus types suggested that the pattern tended to be driven by the functional stimuli, although this did not reach statistical significance ($p > .05$)

Stimulus type × category mapping. Second, there was an interaction between Stimulus Type and Category Mapping for total response time and movement time. For total response time, *F*(1, 38) = 4.78, p = .04, η_p^2 = .11 (Figure 13), responses made with the Left Hand Functional/Right Hand Silhouette mapping were 9-ms shorter for the silhouette stimuli (*M* = 1047 ms) than for the functional stimuli (*M* = 1056 ms). This pattern was reversed slightly for the left hand silhouette/right hand functional mapping with faster total response time for the functional stimuli (*M* = 1072 ms) than for the silhouette stimuli (*M* = 1075 ms).

For movement time, *F*(1,38) = 12.69, *p* = .001, η_p^2 = .25 (Figure 14), responses for the Left Hand Functional/Right Hand Silhouette mapping was 18-ms shorter for the silhouette stimuli (*M* = 512 ms) than the functional stimuli (*M* = 530 ms). This pattern was reversed for the Left Hand Silhouette/Right Hand Functional mapping, with 10-ms shorter movement time for the functional stimuli (*M* = 541 ms) than the silhouette stimuli (*M* = 551 ms). This pattern is stronger than the corresponding values of 9 ms and 3 ms in the total time analysis, indicating that it largely reflects movement time.

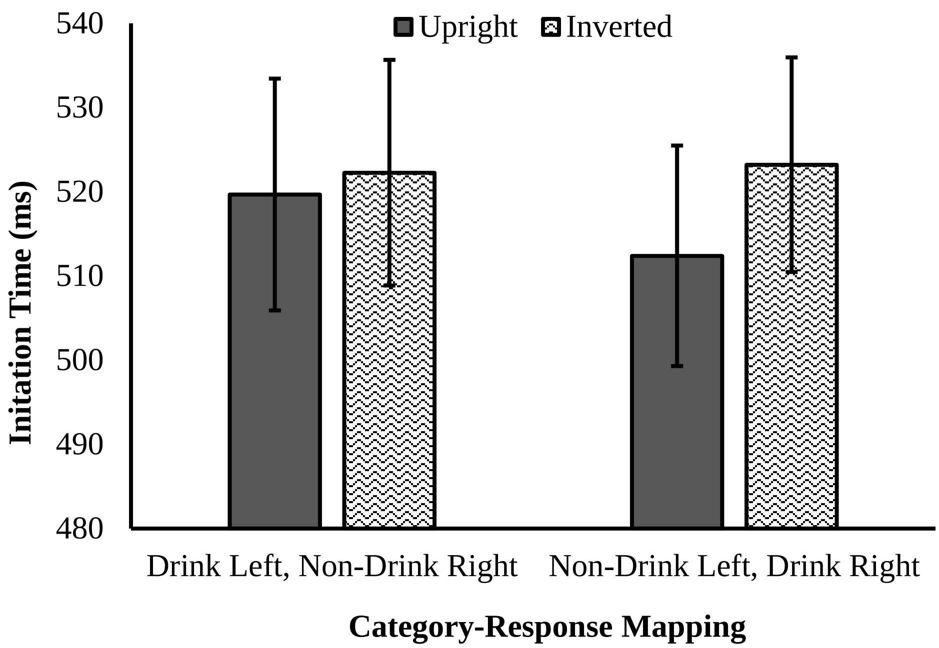


Figure 12. Initiation time as a function of upright or inverted Object Orientation and Category-Response Mapping for Experiment 5.

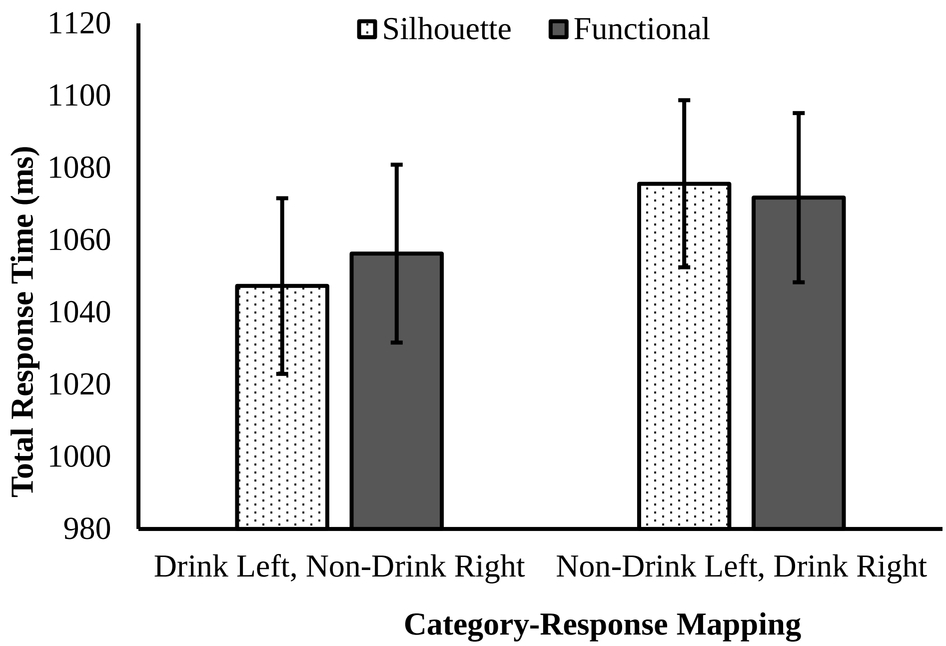


Figure 13. Total response time as a function of silhouette or functional Stimulus Type and Category-Response Mapping for Experiment 5.

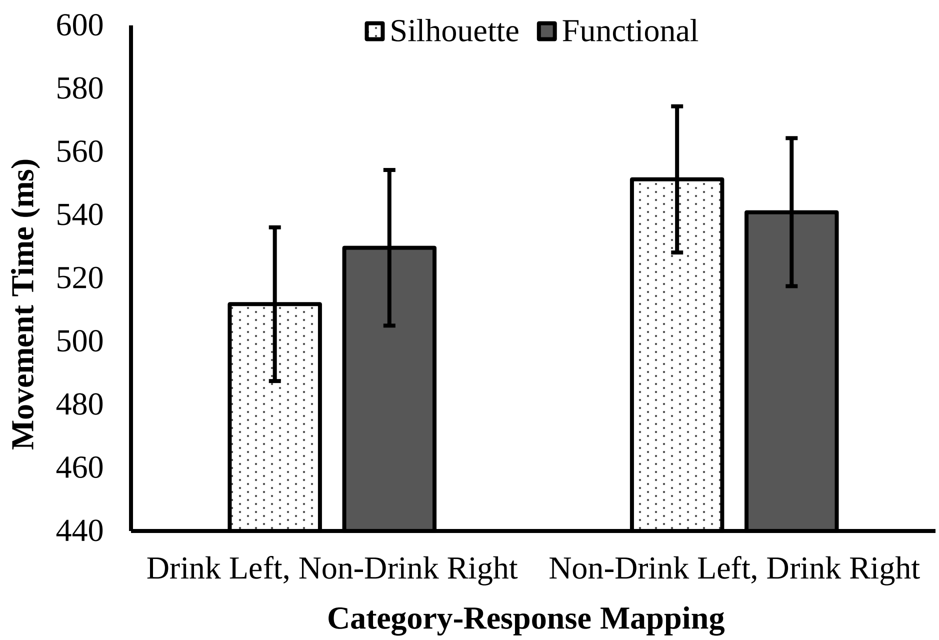


Figure 14. Movement time as a function of silhouette or functional Stimulus Type and Category-Response Mapping for Experiment 5.

Object orientation × stimulus type. Finally, there was an interaction between Object Orientation and Stimulus Type for initiation time and movement time. For initiation time, $F(1, 38) = 8.50$, p = .006, $\eta_p^2 = .18$ (Figure 15), there was no difference between the upright (*M* = 515 ms) and inverted silhouettes (*M* = 515 ms). Initiation time for the upright functional items was similar (*M* = 516 ms) to those of the silhouette condition, but initiation time for the inverted functional items was comparatively longer (*M* = 530 ms).

For movement time, $F(1, 38) = 11.52$, $p = .002$, $\eta_p^2 = .23$ (Figure 16), there was no difference in movement time between the upright (*M* = 532 ms) and inverted silhouette presentations (*M* = 531 ms). For the functional stimuli, there was a marked difference between the upright (*M* = 543 ms) and inverted presentations (*M* = 527 ms). This pattern is opposite that for initiation time, for which the upright functional items (*M* = 516 ms) had a 14-ms advantage over the inverted functional items (*M* = 530 ms). The opposite patterns account for why stimulus type did not interact significantly with object orientation in the total response time analysis. It also implies that the apparent advantage for upright functional items in initiation time is not an advantage in processing but a tradeoff between duration of initiation time and movement time.

Discussion

The absence of support for the automatic activation account in Experiments 2 and 3 prompted Experiment 5, which was devised based on claims related to the particular conditions under which automatic activation is most likely to occur. Compared to all of the other experiments, it can be argued that Experiment 5 can be considered to be the most likely to produce evidence in support for automatic motor activation as it more closely resembles the methods that have been employed by Bub and Masson, though there are some differences that are discussed later. Finally, the reach-and-grasp response in Experiment 5 allows for the analysis of both initiation time and movement time, which might reveal different types of information related to the processing of the stimuli and the programming of actions. Each measure will be discussed in turn.

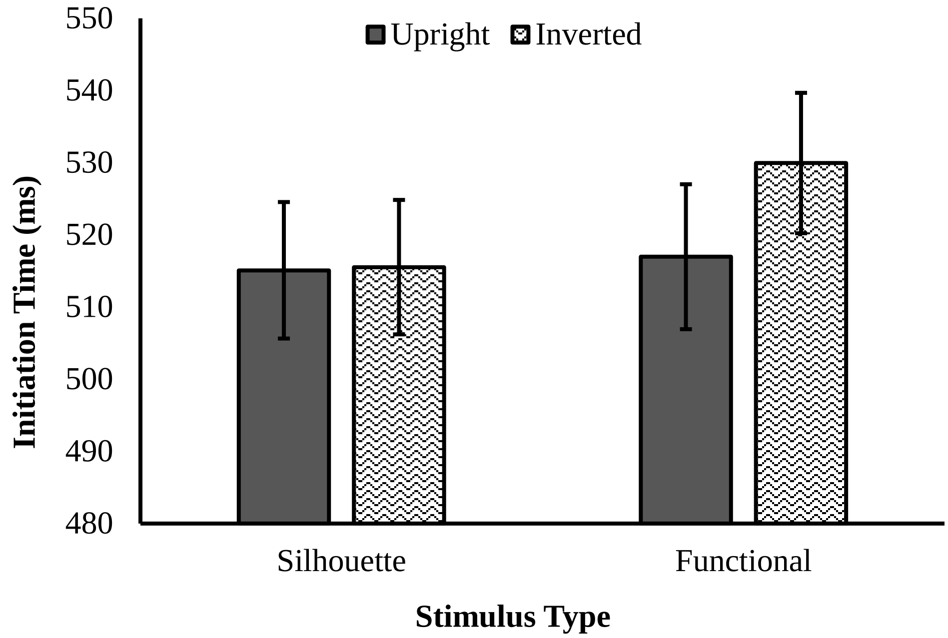


Figure 15. Initiation time as a function of upright or inverted Object Orientation and Stimulus Type for Experiment 5.

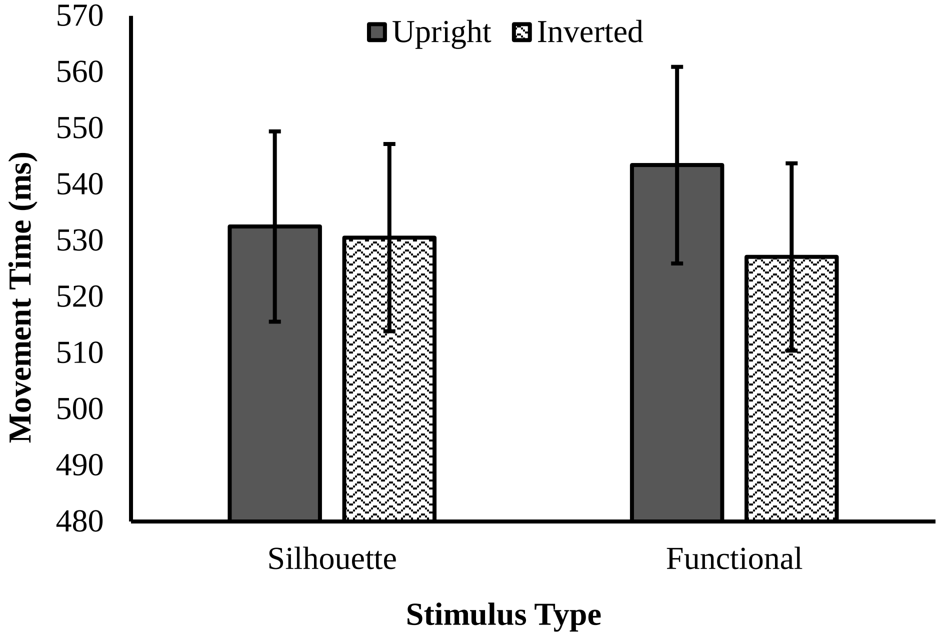


Figure 16. Movement time as a function of upright or inverted Object Orientation and Stimulus Type for Experiment 5.

First, initiation time for the upright objects was faster when participants responded using the Left Hand Silhouette/Right Hand Functional mapping, but this pattern was not observed with the Left Hand Functional/Right Hand Silhouette mapping. These findings can be considered to be some evidence, albeit extremely tenuous, consistent with the automatic activation account. Specifically, the follow-up exploratory analyses revealed that the functional upright objects were primarily driving this finding, though this did not reach significance. However, this account would not necessarily predict that the silhouettes would otherwise be similar to the inverted items, which was found to be the case.

Second, for movement time, there was an interaction between Stimulus Type and Category Mapping, which demonstrated two distinct response patterns between the two mappings in which responses to silhouettes were faster than the functional stimuli with one mapping but this trend was reversed with the other mapping. Although these results are particularly compelling upon first glance, given closer inspection, in the case of both mappings, the left hand was slower than the right hand, regardless of stimulus type. This finding is not particularly surprising given that all of the participants who were recruited were right-handed.

Finally, there were two mirrored patterns in the initiation and movement time data as they pertained to the interactions between Stimulus Type and Object Orientation. Similar to past studies which have attempted to disaggregate response selection from motor programming with task instructions (e.g., Miles et al., 2010), participants were given explicit instructions to decide upon their response before initiating a movement. However, the mirrored results suggest that the stages may not have been as discrete as intended and that there may have been bleeding across the stages.

In all, the results of Experiment 5 do not appear to suggest that employing a reach-and-grasp allowed for the detection of automatic motor activation. How might discrepancies between the results obtained in Experiment 5 be reconciled with the findings of other studies? For this, the methods employed by others might be examined closely. Consider, for instance, Bub, Masson, and their colleagues regularly employ primes to test whether there is automatic motor activation when responding to different objects (e.g., Bub et al., 2018). This study did not similarly employ object primes because they would reintroduce the possibility for left-right correspondence when attempts were made to sidestep this possibility. However, based on the null results that were obtained this may suggest that including primes might be a critical component of inducing the activation that has been observed by others.

GENERAL DISCUSSION

This study attempted to provide more clarity to a topic of study that is highly contentious. There were three overarching goals for the study. First, I sought to establish the importance for considering left-right correspondence in object-based compatibility studies (Experiments 1 and 2). Second, I aimed to determine how performance might be modified when objects that do not allow for left-right correspondence are used (Experiments 3 through 5). Finally, I investigated how performance with the aforementioned objects might change with more realistic responses (Experiments 4 and 5).

Left-Right Correspondence Matters

Experiments 1 and 2 were conducted to establish the importance of considering left-right correspondence in choice-reaction time tasks. Both experiments directly tested claims made by Azaad and Laham (2019) about their stimulus set having successfully sidestepped spatial confounds.

Experiment 1 demonstrated that even if items are relatively symmetrical, control needs to be exercised over the types of objects that are used as stimuli because factors unrelated to their functionality can influence responses. Mutli-level modeling methods were used as they are more sensitive to continuous data and as such, more comprehensive to the spatial dimensions of their original stimulus set. The horizontal visual angle of the stimuli influenced performance, but according to the automatic activation account, this should not have been the case. These results show that the claims made by Azaad and Laham (2019) related to having sidestepped spatial confounds may have been premature.

Having established that employing several stimuli that vary along several dimensions can confound results in a choice-reaction time task, Experiment 2 employed a single object that was presented in one of three upright orientations. According to the automatic activation account, these different iterations should not affect performance. However, counter to what would be predicted by this account, performance did differ based on the left-right correspondence present in the task. Responses were most affected by how the stimuli were oriented and whether they appeared to be pointing in the direction of the response.

Although Experiments 1 and 2 do not singlehandedly cancel out the possibility for automatic activation, they point to the need to consider spatial relationships in such tasks. More fundamental still, however, they demonstrate the necessity of taking an iterative approach to experimental design by implementing baseline conditions. This is particularly true for studying oft-debated effects.

A Novel Stimulus Set to Address Left-Right Correspondence

As mentioned previously, the main contributions of this study rest in attempting to define more clearly the equation related to object-based compatibility effects and provide some clarity by employing a novel stimulus set that removes the possibility for left-right correspondence. Although those favoring the spatial coding account would argue that the spatial components of a task are what have contributed to past findings, those in favor of the automatic activation account would argue that the primary contributor is related to the functional components of an object. The novel stimuli can help parse out which account holds after accounting for left-right correspondence.

Across the three lattermost experiments, which employed the novel stimulus set (i.e., Experiments 3, 4, and 5), there was no support found for the automatic activation account. Instead, the results suggest that left-right correspondence is likely the primary, if not sole, driver behind previously observed effects. Stated differently, past studies claiming to study the automatic facilitation of complex motor movements have been studying location-based coding with relatively simple keypress responses and misattributing their results to factors outside of the realm of study (e.g., an intention to grasp a 2D object).

The work of Azaad and Laham (2019) was previously discussed as an exemplar of researchers attempting to address spatial confounds, but these issues arise time and time again. Consider work conducted by Fischer and Dahl (2007) as an additional example. Fischer and Dahl proposed a novel paradigm in which a handled mug that rotated along its base was presented as an irrelevant stimulus. Participants were tasked with paying attention to a fixation point that appeared in the foreground and responding whenever it changed color. Fischer and Dahl suggested that given the dynamic nature of their task compared to the static images that are usually presented would allow them to demonstrate the temporal aspects of the motor system. Of note is that they suggested that they could sidestep spatial asymmetries by shifting the horizontal position of the mug. However, given the rotating nature of their mug, the handle would nevertheless be rotating from the left to the right on the screen.

Although potential left-right spatial confounds have been previously referred to as being insidious (Masson, 2018), the more appropriate terms may be consistent and reliable. After all, there have been decades of research dedicated to understanding how response selection is affected by different codes (Lu & Proctor, 1995). If the matter at hand is not one related to automatic object processing, but is instead one related to more basic codes, then this allows researchers to base their work in decades of systematically conducted research.

Along the same lines, the findings of this study can inform on whether or not existing models of compatibility effects and their assumptions about automaticity require revision to accommodate for the influence of manipulable properties. As introduced previously, both the automatic activation account and the spatial coding account have assumptions related to automaticity, though the naming conventions used herein might suggest otherwise. Had there been evidence favoring the former account, this would mean that models such as those of Kornblum and colleagues (1990) have overlooked a critical component related to object manipulability. However, the results do not point to this possibility.

Finally, it is important to note that the results of this study are not meant to suggest that object attributes do not inform action. In, fact, this stance is easily invalidated by any particular individual's everyday experiences with mundane objects. The manner in which an individual interacts with an empty mug will differ from how they would approach the same mug if it had steam rising from it. Instead, what this study means to call into question is that motor activation occurs automatically and independent of context and how pragmatic issues within this line of study have been handled.

More Realistic Responses

The last three experiments of this study attempted to iteratively match task conditions that would demonstrate support for the automatic activation account while removing the possibility for left-right correspondence. Moving from button presses to grasp responses, and finally to reach-and-grasp responses should have, in theory, progressively resembled what humans do in everyday life. However, this was not found to be the case.

Supplementary analyses were conducted on Experiments 3 and 4, which used the same procedure but different types of responses (i.e., button and trigger and presses, respectively). The type of response that was made was not found to affect the results in a manner that would indicate support for the automatic activation account. Stated differently, the more realistic responses, which in this case would be the trigger presses meant to resemble a grasping response, did not lead to variations in performance that would indicate that individuals were preparing to grasp the novel objects.

These results bear resemblance to a pair of studies conducted to determine if objects perceived to move toward the left or right hand afford a catching action. Michaels (1988) had participants respond with a forward movement of a left or right joystick intended to mimic a "catching" response. The stimuli were left and right located squares that expanded or both expanded and shifted location to give the appearance of movement toward the corresponding or opposite side, respectively. When instructed to respond to the movement destination, participants were faster when the destination-response mapping was compatible than when it was incompatible. Michaels interpreted this result as support for a catching action being afforded by the apparent motion of the squares on the screen.

However, Proctor et al. (1993) demonstrated that Michaels' (1988) results were not limited to the joystick "catching" responses. Specifically, they obtained a similar result when the responses were keypresses made with the left and right hands. Thus, the results of Michaels and Proctor et al. relating to catching actions, like those of the present study for grasping actions, provide little evidence for affordances influencing responses in two-choice reaction tasks. They instead implicate spatial coding in response selection as the critical factor.

Of additional note is Experiment 5, which pivoted from the task used in Experiments 3 and 4 in an attempt to further approximate the conditions under which automatic motor activation would become evident. Specifically, participants had to complete a reach-and-grasp response. In addition to implementing Experiment 5 to address the issue of more realistic responses, Experiment 5 required participants to complete a category discrimination task instead of a color discrimination task because past studies have questioned the viability of the latter. However, which tasks are best suited for displaying automatic motor activation remains a debated topic (e.g., Bub et al., 2018).

In the simplest of terms, studying grasping responses is complicated. There are various factors that might affect how individuals go about grasping an object. For instance, kinematic movements made toward an object might differ based on whether an individual intends to use the object in question or whether they only intend to move it (Valyear et al., 2011). Further, movements have also been shown to be dependent on whether individuals have more than one goal to accomplish and the accuracy they would need to achieve these goals (Ansuini et al., 2006). These time differences seem to be relatively constant and have been found in both humans and non-human primates (Kien et al., 1991). Given the complexity of human movement, what recourse do individuals interested in investigating this aspect of the perception-action relationship have to turn toward?

Moving Forward

The results of this study further echo past findings: the study of automatic grasping activation is not suited for choice-reaction tasks. The different task conditions that were employed in this study demonstrate a possible problem that might result in this particular line of work. Specifically, the conditions that constitute whether an object will produce motor activation might become too narrow and overly specific. Admittedly, specificity is a desirable trait of any area of study. However, if a multitude of caveats need to be put in place in order to explain how automatic motor activation might occur, this calls into question whether it is truly automatic in any reasonable sense of the concept.

Beyond considering how automatic activation comes about, there is also the matter of how it should be studied moving forward. Some researchers have employed a pointing response to simulate the reaching aspect of a reach-and-grasp response (e.g., Couth et al., 2014). And more recently, researchers adopting the same rationale have begun to employ touch screens to register responses made with aimed movements (e.g., Garofalo et al., 2020). However, as Riddoch and colleagues (1998) have noted, “pointing is not a response associated with a particular stimulus; in contrast, actions such as grasping and picking up are, since there are some stimuli to which this response is specifically associated (e.g. a cup)” (p. 660).

To this effect, researchers aiming to demonstrate evidence in favor of the automatic activation account should move toward more realistic responses. If one remains adamant that past results are not due to the spatial aspects of a task, but can be explained in terms of motor activation, employing real objects and aimed movements should be the next logical step. Some researchers have engaged in this type of research (e.g., Jax & Buxbaum, 2010), but this is far from the norm. Although it is outside the scope of the present study, it should also be noted that choice-reaction time tasks have not been the only methods that have been employed to study how handled objects might influence human behavior. For instance, it has been suggested that handled objects can even aid instruction span (Apel et al., 2012). Topics such as this one may benefit from additional study.

Obstacles Left to Address

In addition to the discussion of the findings that were obtained in this study and methodological issues to be considered for future work, there are several other fundamental topics that merit discussion to ultimately advance this particular area of study. These issues are specifically related to elaborating upon the automatic motor activation account and operationalizing which objects result in motor activation, and more practically, issues in acknowledging the breadth of work that has centered on object perception.

Elaboration and Operationalization

As alluded to previously, the mechanisms through which automatic activation occur are fairly fuzzy. For instance, the boundary conditions of what results in automatic motor activation are far from clear and similarly ambiguous is how this activation might occur to begin with.

Anelli et al. (2012) describe the value of using motor priming to study automatic motor activation produced by objects. They suggest the possibility for two different systems: the mirror neuron system, which is activated by the motor prime, and the canonical neuron system, which is activated by viewing the object stimuli. They note that either one system predicates the other or that both systems work in tangent. However, on close inspection, this begins to suggest that motor activation might not be as automatic as has been painted in the literature. Further, results related to priming have been inconsistent (see Valyear et al., 2011 for a review). Regardless, if motor priming is necessary for any sort of facilitation to occur, can it really be argued that these effects are based in automaticity? At the very least, researchers need to add much needed caveats to their statements about activation and the possible necessity of priming for effects to be produced.

Researchers who have made claims related to the existence of motor activation have also not attempted to formally operationalize which objects should result in automatic activation and under which conditions this will happen. Buccino and colleagues (2009) stated that it is the "pragmatic features" (p. 3074) of an object that result in activation. Based on their study and the stimuli they employed, one can intuit that pragmatic features are object handles. However, what exactly these features are is never explicitly discussed.

Elaborating on the conditions that are required for activation is necessary for researchers to systematically rule out competing explanations. By providing more transparency as to which objects are theorized to facilitate motor activation, more clear predictions might be made. If this area of study remains nebulous, so will the results that are obtained.

Acknowledgement of Past Work

More practically, there is the issue of crediting and acknowledging the vast work that has been conducted to present day. By now, some authors readily credit the existence of both the automatic activation account and spatial coding account as being the two major antithetical approaches to the study of object-based compatibility effects (e.g., Azaad et al; 2019; Garofalo et al., 2020). However, even recently, considering both accounts has not always been the case.

In 2018, Rob Ellis released a book titled, *Bodies and Other Objects*, in which among other topics related to ecological psychology and embodied cognition, he covers the topic of affordances. This is certainly not surprising as his work alongside that of Mike Tucker has been, as noted previously, widely popular and heavily cited. Unfortunately, missing from his discussions of their work and the topic of affordances is even a cursory mention of the many research articles that have provided support for the spatial coding account and go counter with the automatic activation account (e.g., Anderson et al., 2002; Cho & Proctor, 2010) or the review articles that have discussed these issues at length (e.g., Proctor & Miles, 2014).

Without explicit acknowledgment of alternative views or approaches, the risk of stagnancy in any area of research increases. This is particularly true of instances in which individuals who might otherwise be considered to have been the catalysts for certain lines of work do not acknowledge competing approaches. Considering the notable efforts of dozens of researchers and the relative ease with which one can find their work in today's interconnected world, failure to reference competing accounts would either indicate deliberate oversight or an inadequate review of the literature. Whatever the case might be, for forward movement to take place, both due diligence and assignment of credit are both necessary and required.

Takeaways for Psychologists

The aforementioned steps are ones that can be taken by individuals regardless of their discipline. Exercising caution when defining concepts and conducting literature reviews can be considered to be the bare minimum moving forward. However, how do this study's efforts translate for specific disciplines within psychology? Specifically, what takeaways can be derived for ecological psychology, which prompted the use of the affordance concept, for cognitive psychology, which has since adopted this concept, and finally, for neuroscience which is regularly referred to for evidence for automatic motor activation? To assess potential takeaways, each of the three subdisciplines are framed based on their general tenets and related to the present study.

Ecological Psychology

As mentioned in the introductory section of this document, Gibson (1979) developed the affordance and direct perception concepts as part of his ecological approach to perception, which is directed at explaining how organisms perceive and act in the natural world. Although a thorough discussion of ecological psychology is outside of the scope of the present work and has been covered extensively elsewhere (e.g., Chemero, 2003; Chemero & Turvey, 2007; Chong & Proctor, 2020; Proctor & Chong, 2020), there are certain aspects that require underlining. Of particular relevance is Gibson's criticism of studying perception in artificial environments and his rejection of mental representations. Stated differently, Gibson embraced studying perception in naturalistic environments and his theorizing about perception involved direct perception of real objects.

Given the two aforementioned tenets, it is readily apparent that the present study, which was conducted in a laboratory setting with 2D objects, runs counter to both. This study, and the many others like it (e.g., Tucker & Ellis, 1998), do not adhere to an ecological approach as proposed by Gibson. These studies exemplify the tradeoff between the ability to exercise control over an experimental context and how closely this context matches to the dynamic nature of everyday life. Although the control that was exercised in this study was done with the goal of allowing for concise conclusions, this is at a cost to the ability to generalize to other contexts.

When moving toward controlled laboratory settings, the rich information from the natural world is sacrificed. If the field is to make conclusions about how activation might occur in naturalistic settings, researchers will have to adopt a different methodological toolkit in order to do so. Given these tradeoffs and perhaps not surprising to ecological psychologists, I maintain that studying object-based motor activation with choice-reaction tasks does not advance the study of affordances as Gibson (1979) originally intended.

Cognitive Psychology

If continuing to study the perception-action relationship using paradigms like that promoted by Tucker and Ellis (1998) will not advance ecological psychology, can advancements be expected for cognitive psychology? It seems unlikely that an approach that has misapplied concepts from ecological psychology, which goes counter to the information-processing approach adopted by cognitive psychologists, would buy the latter group much. In fact, a related question has been posed by Proctor and Miles (2014) who asked, "Does the concept of affordance add anything to explanations of stimulus-response compatibility effects?" Based on decades of research on stimulus-response compatibility paradigms and alternative interpretations to findings, they concluded that there was no additional benefit in having extract this concept from ecological psychology.

To echo the conclusions made by Proctor and Miles (2014), I further contend that studies on object-based compatibility effects, as they are most typically conducted, do not add more to the collective understanding of response selection. After employing choice-reaction time tasks with a novel stimulus set that did away with the possibility for left-right correspondence, indirect support for the spatial coding account was found. In order for new information to be gained, a shift toward other methods like those previously described (e.g., more realistic responses) is required.

Neuroscience

Finally, although this study did not use neuroimaging methods, some information can be gleaned on the bridge that researchers have attempted to construct between ecological psychology and object-based compatibility studies. As such, if attempting to fit the affordance peg into a hole it was never designed for does not advance ecological psychology nor cognitive psychology, can it reasonably contribute to advancing neuroscience? After all, it is common for researchers to cite neuroscience studies as the basis for studying object-based compatibility effects (e.g., Skiba & Snow, 2016).

Use of the affordance concept in neuroscience has been primarily entrenched in a representational account, which goes counter to Gibson's ecological approach. However, some have argued that Gibsonian concepts can indeed be married with neuroscience (de Wit et al., 2017). A Gibsonian neuroscience is, by necessity, highly contextual and dynamic. More importantly, it requires abandoning the view that specific structures have specific functions (Bruineberg, & Rietveld, 2019; de Wit et al., 2017). Adopting this view would mean that activation in traditionally motor-related brain areas could not form the basis for automatic activation accounts.

In sum, it appears that embracing Gibson's concepts without careful consideration of his original intentions might stifle progress in subfields within psychology. As a final remark, there is no intention to state that one approach is more particularly valuable than another. As Shaw and Bransford (1977) stated in the introduction of their text on ecological psychology, "Let us not, however, delude ourselves: Our field is much too young, our theories too sketchy, the mettle of our techniques too untried, to condemn with certitude any approach without fair trial" (p. 5). However, we must strive to maintain the integrity of our respective subdisciplines without feeling the need to dilute approaches by combining them.

CONCLUSION

In five experiments, I examined claims related to automatic motor activation from passively viewing 2D objects. In Experiments 1 and 2, I demonstrated that stimulus dimensions such as width and orientation should not be overlooked and in Experiments 3, 4, and 5, I employed a novel set of stimuli with button press, grasping, and reach-and-grasp responses. The combination of experiments that were conducted demonstrate that upon having ruled out the possibility of left-right correspondence effects in the lattermost experiments, there was no evidence for the automatic activation account. Critically, even after prompting individuals to engage in more realistic responses, there was inadequate support for the aforementioned account. On this basis, I posit that past findings from studies using Simon-like tasks have been reflective of spatial coding and not automatic motor activation.

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APPENDIX A

Edinburgh Handedness Inventory

Please note which hand you utilize for the following activities with an "**x**".

If you are indifferent, mark both columns (x | x).

Some of the activities require both hands. In these cases, the part of the task or object for which hand preference is wanted is indicated in parentheses.

Task / Object	**Left Hand**	**Right Hand**
Writing		
Drawing		
Throwing		
Scissors		
Toothbrush		
Knife (without fork)		
Spoon		
Broom (upper hand)		
Striking a match (match)		
Open a box (lid)		
Experiment Entry Only		
Total Checks	LH =	RH =
Cumulative Total	CT = LH + RH =	
Difference	D = RH – LH	
Result	R = (D / CT) x 100	
Interpretation: (Left-Handed: R < -40) (Ambidextrous: -40 <=R <=+40) (Right-Handed: R > +40		

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