The Influence of Response Discriminability and Stimulus Centring on Object-based Alignment Effects

by

Connor MacRae
B.Sc., University of Victoria, 2016

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Abstract

The present study determined how object-based alignment effects are influenced by the arrangement of the stimuli and response options. It is well established that the magnitude of these effects differ depending on the mode of responding. This finding has often been used to support claims that viewing photograph images of graspable objects can automatically trigger motor representations, regardless of the intentions of the observer. Our findings instead suggest that the distinction between response modes is primarily a difference in response discriminability. More importantly, it was found that this influence of response discriminability works in a completely opposite manner, dependent on the technique used to center the frying pan stimuli. Pixel-centered stimuli produced a handle-based alignment effect that was enhanced under conditions of high response discriminability. Object-centered stimuli produced a body-based alignment effect that was *diminished* under conditions of high-response discriminability. These findings provide overwhelming evidence that qualitatively different principles govern the alignment effect found with pixel-centered and object-centered stimuli. Crucially, these finding also provide strong evidence against the notion that motor representations are triggered by images of graspable objects in the absence of an intention to act.

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Acknowledgements

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Introduction

There is a controversial, yet persistent claim in the literature on sensorimotor processing that information about the correct way to manipulate objects can be automatically brought to mind by simply looking at the object, even without the intention to act upon the object in any way. Tucker and Ellis (1998) offer behavioural evidence for this idea. They presented subjects a number of handled object images and asked them to indicate whether each object was upright or inverted (an orientation judgement) by making a left or right-handed key-press. They found that when the handle of an object was on the same side as the hand used to correctly respond, responses were faster and more accurate, an effect that I will refer to as a handle alignment effect. This effect occurs despite the fact that the position of the handle is an irrelevant feature of the task. Crucially, they showed that this effect was not present when responses were made between two fingers on the same hand (Tucker & Ellis, 1998). Their explanation of these results centred around the idea that when looking at the handled object, we automatically recruit information on how to grasp it (Tucker & Ellis, 1998). This information in turn affects key-press responses to the object with the left or right hand. An object evoking a left-handed grasp, for example, will generate motor features that facilitate a speeded response with the same hand, and interfere with a key-press response assigned to the opposite hand. In contrast, when responses were made with two fingers on the same hand, no handle alignment effect was exhibited, since the cue provided by the handled object specifically primes either a left or right-handed grasp (Tucker & Ellis, 1998). From this result, Tucker & Ellis (1998) proposed that the handle alignment effect is based on limb-specific motor representations automatically evoked upon viewing the handled object, which they refer to as micro-affordances. This concept was derived from Gibson's (1979) notion of affordances generated by real-world objects in naturalistic settings. The extension of the term to depicted objects by Tucker & Ellis (1998) is motivated by their claim that constituents of action are intrinsic to an object's perceptual representation. However, for reasons I will discuss later in detail, the behavioral evidence in support of this claim is hardly convincing.

Attempts to replicate the pattern of results shown by Tucker & Ellis (1998) have rarely been successful. Alignment effects have been reproducible, but the crucial finding of a modulation of the alignment effect by response mode (between- versus within-hand responses) has generally been absent (Phillips & Ward, 2002; Cho & Proctor, 2010). Additionally, a number of studies have found *negative* or *reverse* alignment effects, in which responses were slower when the handle aligned with the response hand (Yu, Abrams, & Zacks, 2014; Proctor et al., 2017). As a result, the handle alignment effect has often been attributed to stimulus-response correspondence (SRC) effects that are based on the abstract spatial coding of the stimuli (Phillips & Ward, 2002; Cho & Proctor, 2010; Proctor et al., 2017).

Recently, Pappas (2014) was able to replicate the pattern of handle alignment effects originally shown by Tucker & Ellis (1998). He argued that if subjects carried out speeded upright-inverted judgements to high-quality photographs of objects instead of silhouette images, the modulation of the alignment effects by response mode could be reproduced (Pappas, 2014). The proposed reason for this distinction was that motor representations inducing a limb-specific alignment effect would only be evoked if sufficient depth cues were included in the stimuli (Pappas, 2014). Osiurak and Badets (2016) have endorsed this claim in a recent review.

These findings give some plausibility to the claim that alignment effects on speeded key-press responses can be driven by the perceived graspability of the handle of a depicted object. Nevertheless, methodological issues arise. In the tasks used by Tucker & Ellis (1998) and Pappas (2014), between-hand responses were made by pressing keys that are located far apart, while within-hand responses were made by pressing keys that were adjacent. Accordingly, the difference in alignment effects for two- versus one-handed responses may have nothing to do with the claim that objects trigger limb-specific affordances. Rather, the discrepancy in effect size (greater alignment effects for between- than within-hand responses) may have been due to a key-distance confound, an issue that will be considered here in some detail. Furthermore, the frying pan images that Pappas (2014) used for stimuli were centered in a particular way. Instead of centring the frying pan on a background with respect to the whole object, Pappas (2014) used a different technique that will be referred to as pixel-centring. This technique centres the frying pan image on a background so that there are an equal number of pixels present on the left and right sides of the image. As a result of this method, the handle of the frying pan is presented laterally and shifts noticeably when alternating between the left and right side of space. It is therefore plausible that the irrelevant feature of handle location is more salient under pixel-centring. A key distance confound, in conjunction with the use of the pixel centring technique, raise questions about the correct interpretation of Pappas's (2014) results.

A recent study done by Proctor, Lien & Thompson (2017) looked to provide a more comprehensive understanding of alignment effects by examining the effect of the key distance confound and the centring technique used. They controlled for key distance by having both within and between-hand responses made on keys that were either adjacent (near) or separated by some distance (far). Additionally, the stimuli used varied between silhouette and photographic images, depending on condition (Proctor et al., 2017). This version of the task was done using object-centered frying pans for one experiment and body-centred images in a second experiment (Proctor et al., 2017). Body centring is a technique that centres the frying pan with respect only to the body of the pan, excluding the handle. This technique produces stimuli that are nearly equivalent to pixel-centred images.

Proctor et al. (2017) showed that Pappas's (2014) findings of a modulation for photograph images by response mode could only be replicated if the stimuli were centred so that the handle was presented laterally (body-centred, where *body* refers to the pan of a frying pan, not the whole object). Additionally, they found that the direction of the alignment effect varied depending on how the stimuli were centred (Proctor et al., 2017). In their first experiment in which the images were object-centred, a *negative* alignment effect was produced (Proctor et al., 2017). In contrast, when the stimuli were body-centred, a positive alignment effect was found (Proctor et al., 2017, Experiment 2). It is important to note that a negative alignment effect has sometimes been interpreted as evidence of an inhibition to the motor representations evoked by the handle (Vainio, Hammarén, Hausen, Rekolainen, & Riskilä, 2011; Liu, Cao, Wang, Zheng & Wang, 2016). However, a much more plausible interpretation of a negative alignment effect is that the effect is based on a correspondence between the spatial location of the response and the projection of the body rather than the handle into the left or right side of space. This body-based (reversed or negative) alignment effect is a common finding for experiments that use *whole object-centred* images (Yu, Abrams, & Zacks, 2014; Proctor et al., 2017).

I propose that the source of the difference between body- versus handle-based alignment effects can be understood by determining which component of the stimulus object provides a more salient spatial cue. Under pixel-centring, the body (i.e. the container) of the frying pan remains roughly centred on the screen, while the handle shifts from left to right quite obviously from trial to trial. As a result, the position of the handle provides a strong spatial cue. In contrast, under object-centring both the body and the handle of the frying pan shift from left to right when the left-right orientation changes. Since the body makes up the greater part of the frying pan, greater attention is paid to this part of the object. Therefore, the body of the pan provides a stronger spatial cue than the handle.

The critical finding from the study by Proctor et al. (2017) concerns their analysis of how the alignment effects varied in size across the distribution of response times as a function of (a) key distance and (b) response mode (between- versus within-hand key-presses). When comparing the effects produced for the between-hands far and within-hand far condition, there was a striking difference in the size of the effect (between-hands show a greater alignment effect than within-hand responding), despite the fact that key distance was held constant between the two conditions (Proctor et al., 2017). This outcome suggests that the location of the handle on the left or right influenced the speed of selecting a left- versus right-handed response, especially when responses were made with two hands far apart (Proctor et al., 2017). Thus, Proctor et al. (2017) conceded that under these conditions, the alignment effect might be partially due to limb-specific representations induced by the frying pan handle.

A closer look at the results of Proctor et al. (2017) reveals additional features of interest worthy of deeper consideration. In their first experiment, in which the frying pan stimuli were whole-object centred, the absolute size of the alignment effect was larger for *within-hand* responses than between-hand responses (Proctor et al., 2017). For their second experiment in which the stimuli were base-centred, the opposite pattern was found; the alignment effects were larger for the *between-hand* responses than the within-hand responses (Proctor et al., 2017). The only difference between these two experiments was the technique used to centre the frying pan. Despite this, the modulation of the alignment effect by response mode reverses! Further, the effect of key distance also seemed to have opposing influences on the alignment effect depending on the centring technique. With object-centred stimuli, the largest body alignment effect was found in the within-hands near condition (Proctor et al., 2017). With base-centered stimuli, the largest handle alignment effect was produced in the between-hands far condition (Proctor et al., 2017). Given that the response mode and key separation effects work in completely opposite ways depending on the centring technique used, it is unlikely that these effects can be accounted for by a single mechanism.

An immediate question is whether these opposing results are reproducible. A consistent pattern would imply that the processes yielding alignment effects when the frying pan stimuli are object-centred are distinct from the processes responsible for effects when the frying pan stimuli are base-centred. Why this is the case is a question I will seek to elucidate. Clearly, though, if this is a reproducible double dissociation, it can be inferred that alignment effects are not based on a correspondence between the manipulation information provided by the handle of the frying pan, but instead are based solely on spatial effects of the object modulated by the discriminability of response selection.

The notion of *response discriminability* refers to how clear the mapping is between an intended response and its outcome, or in other terms, an action goal. When responses are made with two hands, the action goal of a left response (press a left key with a left hand) is highly discriminable from the action goal of a right response (press a right key with a right hand). Alternatively, I propose that when responses are made with two fingers on the same hand, the action goal for a left response (press a left key with the index finger of your right hand) is less distinct from a right response (press a right key with the middle finger of your right hand). A study done by Chen & Proctor (2014) examined the influence of response key distance in a two-choice Stroop task. It was determined that the Stroop effect was modulated not by a physical distance between responses, but a *conceptual* distance (Chen & Proctor, 2014). Conceptual distance rests on the degree of distinctiveness in the mental representations of the response options (Chen & Proctor, 2014). Chen & Proctor (2014) manipulated conceptual distance by labelling the response keys as either 1 and 9 (high conceptual distance) or 5 and 6 (low conceptual distance). Since the alignment effect is also likely governed by SRC principles, it is plausible that the pertinent difference for between and within-hand response modes is also a difference in conceptual distance (i.e. response discriminability).

In a first set of experiments, I wished to confirm the pattern of results obtained by Proctor et al. (2017) for between (far) and within-hand (near) responses. In a follow-up series of experiments, I manipulated response discriminability, holding key distance constant, by comparing straight versus crossed-hand responses. Straight-hand responses provide a condition where discriminability between responses is high, while crossed-hand responses provide a condition where discriminability between responses is very low. This is due to the fact that the action goals of the crossed-hand responses are less distinct; a left hand is used to press a right key and a right hand is used to press a left key. As a result, these response modes will clearly differ in discriminability. For the present study, three experiments were conducted using a paradigm similar to the one used by Pappas (2014) and Proctor et al. (2017). The patterns of alignment effects were examined under both pixel-centring and object-centring to further investigate the influence of the centring technique. Using this framework, I looked to better understand the principles that underlie alignment effects.

Experiment 1

The first experiment I conducted aimed to replicate the findings of Pappas (2014) and Proctor et al. (2017). More specifically, subjects performed the same two-choice orientation judgement task using pixel-centred photographs of a frying pan. To examine the influence of response mode, each subject performed both within-hand responses and between-hands responses. Similar to the original experiment by Tucker & Ellis (1998) and the replication by Pappas (2014), between-hand responses were made on two keys that were well separated, while within-hand responses were made on two adjacent keys. Since the stimuli are pixel-centred, responses should be faster when the handle of the frying pan corresponds with the side of the response (i.e. a handle alignment effect). To replicate Pappas (2014) and Proctor et al. (2017), the handle alignment effect should be larger for the between-hand responses than the within-hand responses.

1.1 Method

Subjects

Thirty-three students from the University of Victoria participated in exchange for bonus course credits in an undergraduate course. Subjects were removed from the dataset if their error rate was greater than 15% in two or more conditions of the experiment. Given this exclusion criterion, data from two subjects were removed, resulting in a total of thirty-one subjects for analysis (Median Age = 20, Age Range = 18-34, Male subjects = 4, Left-handed = 2)

Materials

Four grayscale photographs of a frying pan, each in different orientations, were created to use as stimuli (Figure 1.1A). The four images differed in terms of whether they were upright or inverted and whether the frying pan handle pointed to the left or right. The frying pan images were superimposed on a grey rectangle that was centred on the vertical midline of the monitor. Within the grey rectangle, the frying pans were positioned so that there were an equal number of pixels on the left and right sides of the rectangle's vertical midline. This is referred to as pixel-centring, which is a feature of the stimulus images of Pappas (2014) on which this experiment was modelled. The grey rectangle occupied a visual angle of 20.6˚ x 11.8˚ when viewed from a distance of 50 cm. The frying pans occupied a visual angle of 16.5˚ x 10.9˚ when upright and 16.3˚ x 10.9˚ when inverted.

Responses were made using a response box that contained seven horizontally arranged keys. Depending on the condition, responses were made either with the index fingers of both hands (between-hands condition) or with the index and middle finger of the subject's dominant hand (within-hand condition). For the between-hands responses, the leftmost and rightmost keys in the array were used. Within-hand responses were made using the two left most keys for left-handed subjects and the two rightmost keys for right-handed subjects.

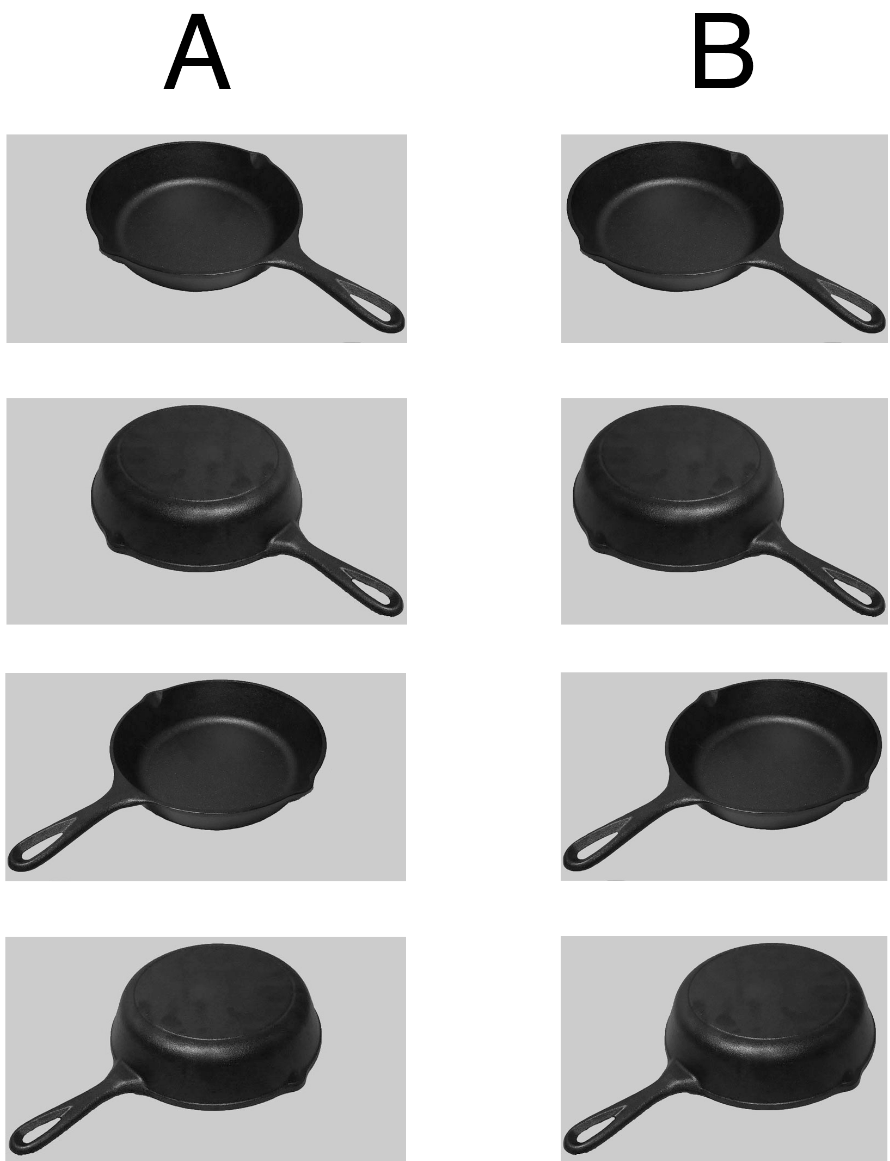

Figure 1.1 (A) Pixel-centred frying pan images used in Experiments 1 and 2 (B) Object-centred frying pan images used in Experiment 3. The frying pans appeared against a grey rectangular background, just as depicted here. On presentation to subjects, the gray background was centered horizontally and vertically on the computer monitor.

Procedure

Each subject completed the experiment individually with the guidance of an experimenter. Subjects sat at a desk with a computer monitor roughly 50 cm in front of them. Between the subjects and the monitor was a response box placed on the desk aligned with the centre of the screen. General instructions were given explaining that subjects would be presented with an image of a frying pan on each trial and their task was to simply indicate whether the frying pan was upright or inverted. To begin a trial, a fixation cross was presented in the center of the screen for 1,000 ms before being replaced by one of the stimulus images. The image remained on the screen until a response was made. Subjects completed four blocks of 176 trials. The blocks varied with respect to the response mode (within-hand or between-hands) and response-orientation mapping (left key = upright and right key = inverted, or vice versa). These blocks were presented in an independently determined random order. Before each new block of trials, they were informed of the current response-orientation mappings. Every participant completed all four of the response-orientation mappings. Each block began with 16 practice trials followed by 160 critical trials, resulting in a total of 704 trials for the complete experiment. All of the stimulus images occurred 40 times within each block and were presented in a random order. Breaks were given between practice and critical trials and halfway through critical blocks.

1.2 Results

Response time was measured from the onset of the stimulus image until a key press was made. Response times less than 100 ms (deemed to be anticipatory responses) or over 1,400 ms were removed prior to analysis. The upper cutoff was defined so as to exclude a maximum of 0.5% of correct responses from analysis (Ulrich & Miller, 1994). Due to these exclusion criteria, the upper bound for the cutoffs varies for each experiment. In classifying the critical trials, the factor of alignment refers to a spatial correspondence between the side of the response and the side on which the frying pan's handle was located. Aligned trials are defined as trials where the handle is on the same side of space as the correct response hand and misaligned trials refer to when they are on opposing sides of space. Mean response times as a function of alignment and response mode, shown separately for the upright and inverted conditions, are shown in Figure 1.2. These data were examined using a repeated-measures analysis of variance (ANOVA) with alignment, response mode, and orientation as factors. A significant main effect of alignment was obtained, $F(1, 30) = 25.07$, $MSE = 909$, $p < .001$, $\eta_p^2 = .46$, indicating that response times were shorter on aligned trials. Although the response mode main effect was not significant, there was a significant interaction between alignment and response mode, $F(1, 30) = 5.36$, $MSE = 406$, $p < .05$, $\eta_p^2 = .15$. In comparison to within-hand responses, the alignment effect was significantly larger for between-hands responses. No other significant effects were found.

Mean percent error for each condition is also shown in Figure 1.2. An ANOVA with alignment, response mode, and orientation as factors revealed a main effect of alignment, $F(1, 30) = 18.88$, $MSE = 9.5$, $p < .001$, $\eta_p^2 = .39$, with fewer errors in the aligned condition. A significant interaction between alignment and response mode was also found, $F(1, 30) = 5.01$, $MSE = 4.3$, $p < .05$, $\eta_p^2 = .14$, revealing a larger alignment effect for between-hands responses. No other significant effects were found.

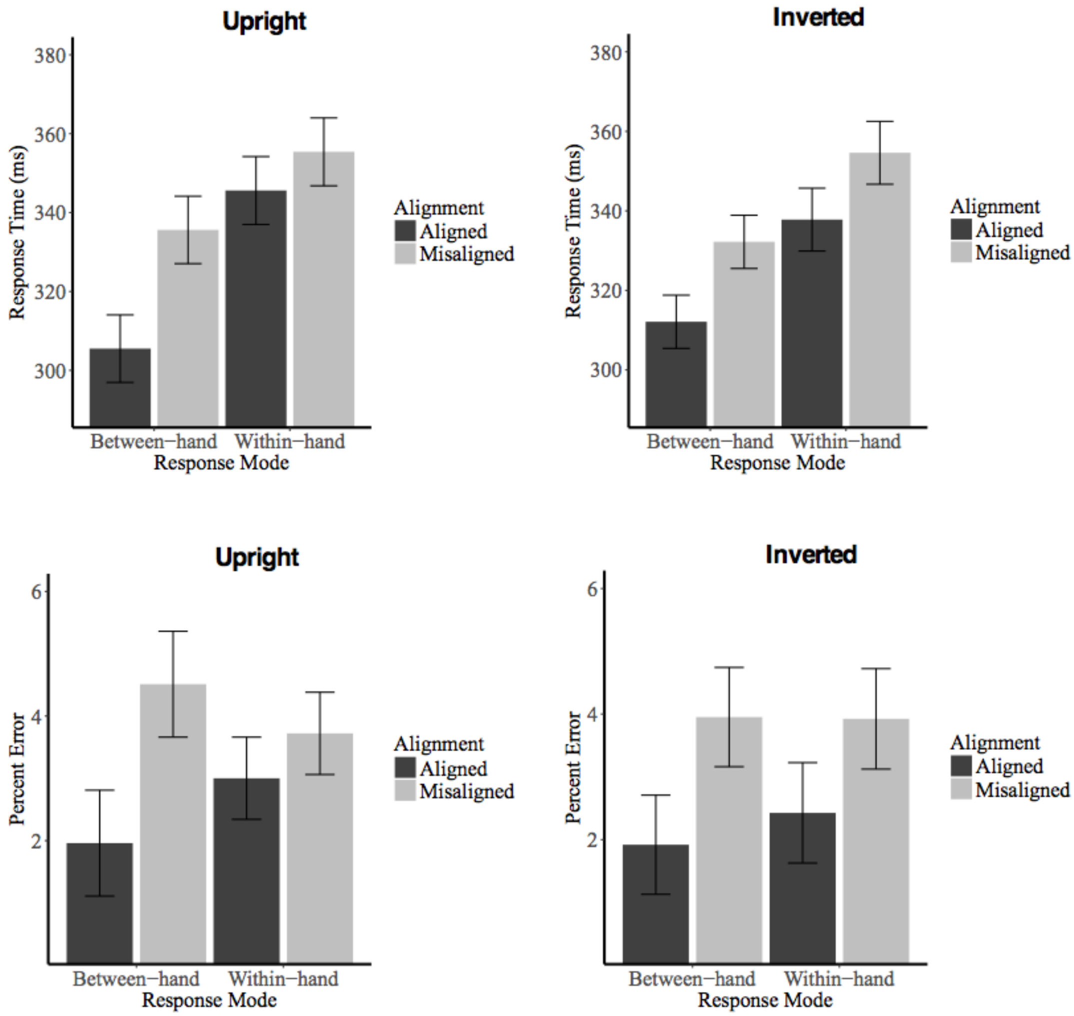

Figure 1.2 Mean response time and percent error in Experiment 1 as a function of orientation, response mode and alignment between the object's handle and the response location. Error bars indicate 95% within-subject confidence intervals, suitable for evaluating the alignment effect within each response mode (Loftus & Masson, 1994; Masson & Loftus, 2003).

To better understand the time course of the alignment effect, the effects were examined across the full distribution of response times. To do so, response times were assigned to five successive, equal-size bins, with the shortest 20% of response times in the first bin, the second-shortest 20% in the second, and so on. This arrangement of response-time observations was done separately for aligned and misaligned trials for each response mode (within-hand and between-hands). To better understand the influence of orientation, the analyses were completed separately for the upright and inverted conditions. Means for the aligned and misaligned conditions were computed for each quantile. The difference between aligned and misaligned means was then used to determine the size of the alignment effect across the quantiles. The mean alignment effect across quantiles is shown in Figure 1.3. For the upright stimuli, a test of the linear trend revealed a significant increase in the alignment effect across quantiles for between-hand responses, $t(120) = 6.24$, $p < .001$, but not for within-hand responses, $t(120) = 1.37$, $p = .17$. For inverted stimuli, there was a significant increase in the alignment effect across quantiles for between-hand responses, $t(120) = 4.73$, $p < .001$, but this increase was once again insignificant for within-hand responses, $t(120) = 1.62$, $p = .11$.

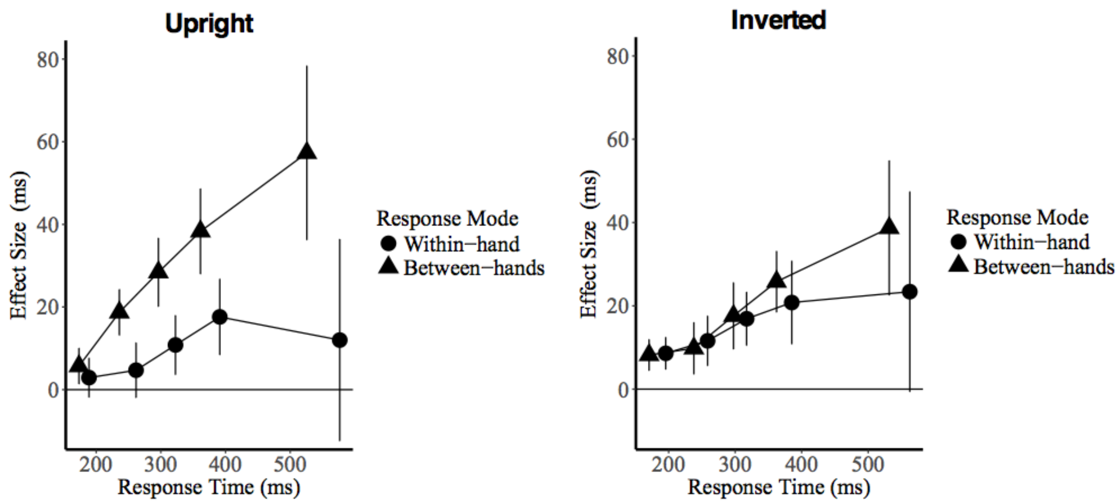

Figure 1.3 Alignment effect size across response-time quantiles in Experiment 1, shown separately for upright and inverted conditions. Mean response time for each quantile is shown on the horizontal axis. Effect size plots are shown separately for the two response modes. Error bars are 95% confidence intervals for the mean effect size at each quantile.

1.3 Discussion

The design of Experiment 1 was modelled after experiments done by Pappas (2014, Experiment 2) and Proctor et al. (2014, Experiment 2). These studies found a handle alignment effect that was larger for between-hands responses, a pattern that was replicated in the present study. The handle alignment effect was nearly twice as large for between-hands responses (25.1 ms) than within-hand responses (13.3 ms). As previously discussed, Proctor et al. (2017) found that this modulation of the alignment effect by response mode worked in the opposite direction if stimuli are instead object-centred. A previous attempt to replicate Tucker & Ellis (1998) done by Marshall (2016) had subjects perform the exact same task as Experiment 1, but with object-centred stimuli. Consistent with Proctor et al. (2017, Experiment 1), a body alignment effect was found that was larger for within-hand responses than between-hand responses. In conjunction with the results of the present experiment, this implies that the opposite modulation of the alignment effect dependent on the centring technique is a reliable finding. Under pixel centring, when the responses are highly discriminable (between-hand responses), the effect is enhanced. Under object-centring, when the responses are highly discriminable, the effect is weakened. These findings suggest that the handle alignment effect produced by pixel-centred stimuli is fundamentally distinct from the body alignment effect produced by object-centred stimuli. This possibility will be further explored in the subsequent experiments. I will also make inferences about the nature of the underlying processes governing the two different effects in the general discussion.

In accordance with Proctor et al. (2017), a quantile analysis was completed to examine how the effect changed across the response time distribution. Their analysis revealed that the alignment effect increased across the RT distribution, but in a more drastic manner for between-hand responses. The results of the quantile analysis for the present experiment are consistent with the findings of Proctor et al. (2017). For both the upright and inverted conditions, the alignment effect increased with increasing RTs for the between-hand responses. For the within-hand responses, the effect appeared to increase across most of the RT distribution, but this increase was not significant for either the upright or inverted conditions.

Previously, the modulation of alignment effects by response mode has been attributed to differential influences of the motor cue provided by the object (Tucker & Ellis, 1998; Pappas, 2014). However, this interpretation is hard to accept, given that there are unequal distances between the response keys across conditions. While Proctor et al. (2017) proposed that this response mode modulation could be due to a difference in the physical distance between the response keys, I argue that the response mode modulation is instead due to a difference in the conceptual distance between the responses. Conceptual distance, as already noted, refers to the distinctiveness of the mental representations of the two responses, which is determined by the clarity of each action goal. Between-hand responding would provide a bigger conceptual distance between the left and the right response, since each is made with a separate hand spaced far apart. In contrast, within-hand responses provide a smaller conceptual distance between the left and the right response, since each is made with the same hand. Evidence to support this distinction between physical and conceptual distance comes from a study by Chen & Proctor (2014), in which they concluded that conceptual distance played a more crucial role in determining the size of the effects in a two-choice Stroop task. For this reason, I chose to use a different response mode manipulation in subsequent experiments, straight vs. crossed hand responses. This decision will be discussed further in Experiment 2.

Experiment 2

The second experiment was conducted to examine the hypothesis that the distinction between response modes can be understood as a difference in response discriminability. Comparing between-hands responses to within-hand responses introduces a key-distance confound into the experimental setup. Proctor et al. (2017) controlled for key distance by using the same two keys for within and between-hand responses. However, the distance between responses is constrained due to limitations on how far within-hand responses can be separated. To best examine the influence of response discriminability, I wished to use a stronger comparison of response discriminability than can be provided by comparing between and within-hand responses. To do so, we compared straight-hand responses to crossed-hand responses. For both response modes, the separation between the response keys was equally large, which controls for any key distance confound. Further, using straight and crossed-hand responses allows a comparison between responses with high discriminability and responses with a lower response discriminability. If my assumption is correct that this manipulation is a stronger manipulation than between vs. within-hand responses, a larger modulation of the alignment effect by response mode should be present in Experiment 2 in comparison to Experiment 1.

Looking at the alignment effect produced by crossed-hand responses affords an additional insight into the nature of alignment effects. In all other response modes, the hand used to respond is on the same side as the key used to respond. As a result, any inference about whether the alignment effect is tied to the hand used to respond or to the location of the key used to respond cannot be made. With crossed-hand responses, these two are dissociated. If these alignment effects are due to a correspondence between the response hand and the motor cue provided by the frying pan, as suggested by Tucker & Ellis (1998) and Pappas (2014), crossing the hands should not effect the direction of the alignment effect. However, a study done by Phillips & Ward (2002) that also used crossed-hand responses provided evidence that the effect is instead based on a correspondence between the location of the response key and the frying pan handle. Given this result, I chose to define alignment as a correspondence between the location of the response key and the frying pan handle. As a result of this coding, positive alignment effects for both straight-hand and crossed-hand responding would indicate that the alignment effect is indeed tied to the location of the response key.

2.1 Method

A new sample of 32 subjects was obtained from the same source as earlier experiments to participate in Experiment 2 (Median Age = 20, Age Range = 17-29, Male subjects = 9, Left-handed = 0). The stimuli, apparatus, and procedure were identical to Experiment 1. The only difference between the experiments was the type of responses made. For all responses, the leftmost and rightmost keys on the response box were used. However, responses were either made by using their left hand to press the left key and their right hand to press the right key (straight-hands condition) or by using their left hand to press the right key and their right hand to press the left key (crossed-hands condition).

2.2 Results

Response time was measured as in the previous experiment. Response times less than 100 ms or greater than 1,700 ms (0.46% of trials) were removed prior to analysis. Mean response time and percent error for each condition are shown in Figure 2.1. Aligned trials are defined as trials where the key used to respond (left or right) corresponds with the location of the handle. Misaligned trials refer to when the key used to respond does not correspond with the location of the handle. A 2 (alignment) x 2 (response mode) x 2 (orientation) repeated-measures ANOVA was applied to the response-time data. Significant main effects of alignment were found, $F(1, 31) = 52.62$, $MSE = 300$, $p < .001$, $\eta_p^2 = .63$, with response times being shorter on aligned trials. A main effect of response mode was also found, $F(1, 31) = 13.59$, $MSE = 4773$, $p < .001$, $\eta_p^2 = .30$, with response times being shorter for straight-hand responses. There was a significant interaction between alignment and response mode, $F(1, 31) = 14.49$, $MSE = 256$, $p < .001$, $\eta_p^2 = .32$, revealing that the effect of alignment was larger for the straight-hand responses. Additionally, there was a significant interaction between orientation and response mode, $F(1, 31) = 6.95$, $MSE = 253$, $p < .05$, $\eta_p^2 = .18$, showing that for straight-hand responses only, response times were shorter for upright images. Finally, there was a significant interaction between alignment and orientation, $F(1, 31) = 5.067$, $MSE = 368$, $p < .05$, $\eta_p^2 = .14$, which revealed that the alignment effect was larger for inverted images. No other significant effects were found. A corresponding ANOVA analyzing percent error revealed only a main effect of alignment, $F(1, 31) = 17.16$, $MSE = 7$, $p < .001$, $\eta_p^2 = .36$, with the aligned trials producing fewer errors. All other effects and interactions were not significant.

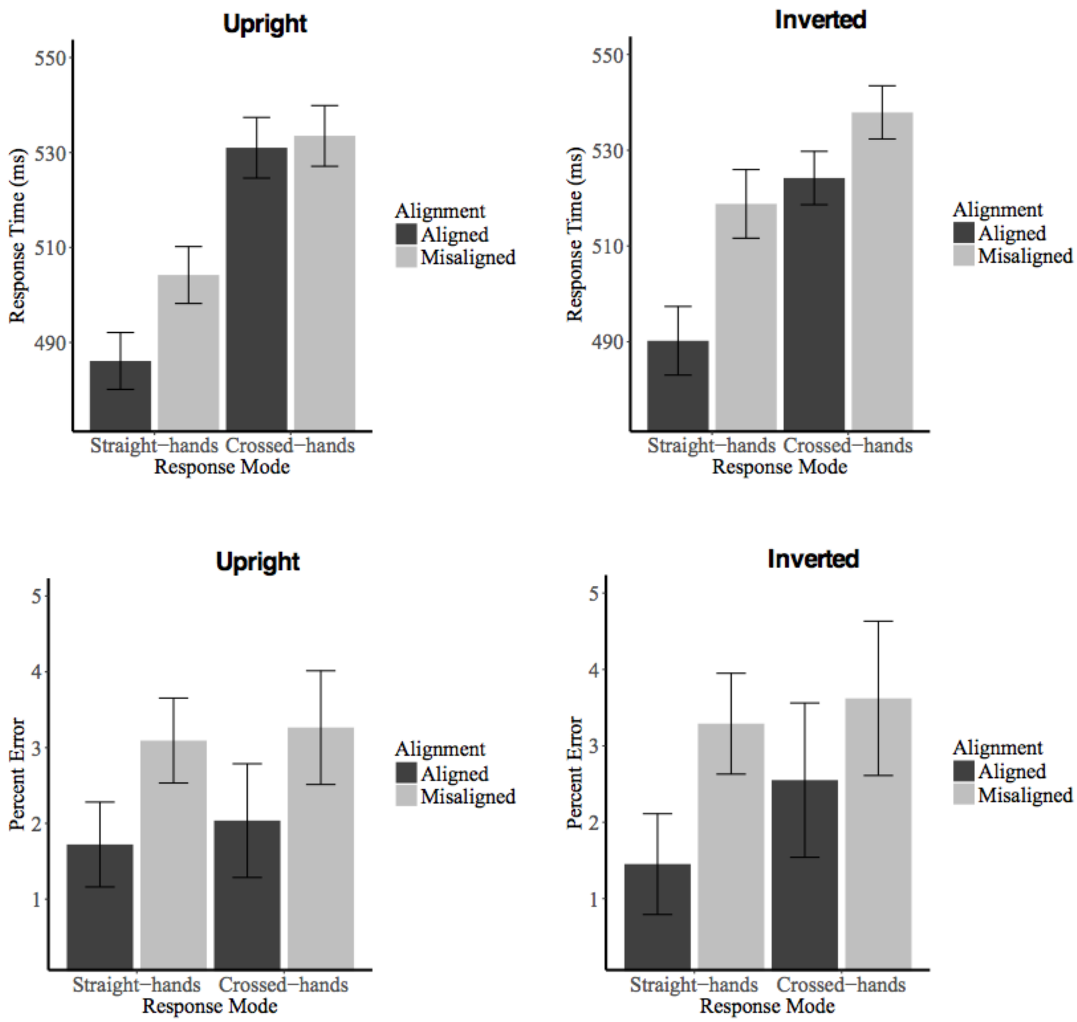

Figure 2.1 Mean response time and percent error in Experiment 2 as a function of orientation, response mode and alignment between the object's handle and the response location. Error bars indicate 95% within-subject confidence intervals, suitable for evaluating the alignment effect within each response mode (Loftus & Masson, 1994; Masson & Loftus, 2003).

As was done in the previous experiment, the alignment effects were examined across the full distribution of response times. Analyses of the linear trend for the alignment effects are shown in figure 2.2. For upright images, there was a significant increase in the alignment effect across quantiles for straight-hand responses only, $t(124) = 4.56$, $p < .001$. For inverted images, there was a significant increase in the alignment effect across quantiles for both straight-hand responses, $t(124) = 7.03$, $p < .001$, and crossed-hand responses, $t(124) = 6.45$, $p < .001$.

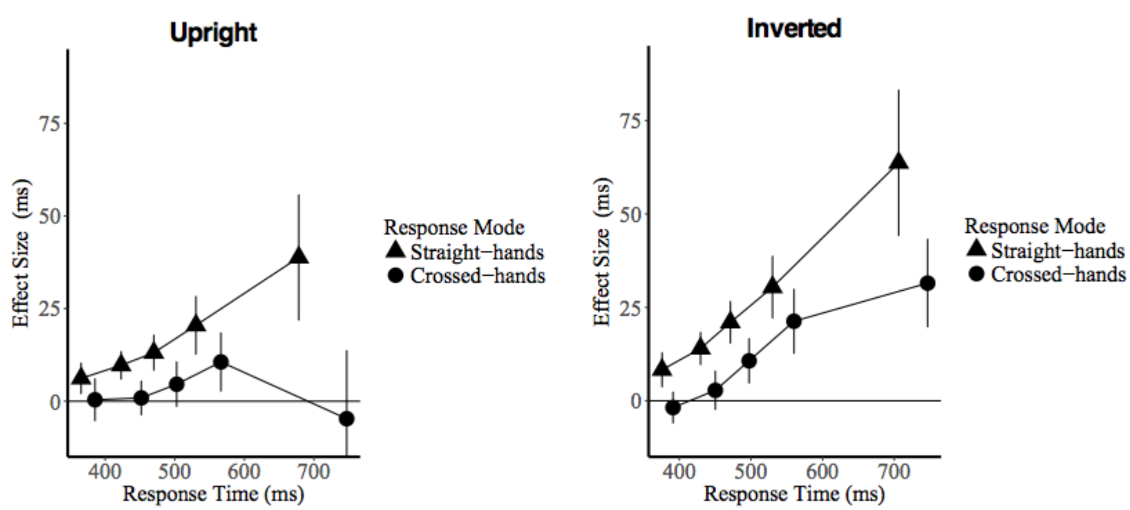

Figure 2.2 Alignment effect size across response-time quantiles in Experiment 2, shown separately for upright and inverted conditions. Mean response time for each quantile is shown on the horizontal axis. Effect size plots are shown separately for the two response modes. Error bars are 95% confidence intervals for the mean effect size at each quantile.

2.3 Discussion

As predicted, Experiment 2 produced a handle alignment effect with respect to the location of the response key, regardless of whether responses were made with hands straight or crossed. This result is consistent with the findings of Phillips and Ward (2002). This provides strong evidence against the claim made by Tucker & Ellis (1998) and Pappas (2014) that the alignment effect occurs due to a correspondence between the hand used to respond and the location of the frying pan handle. Moreover, the handle alignment effect exhibited here once again was significantly larger for straight-hand responses, consistent with the findings of Proctor et al. (2017) and Experiment 1. This modulation appeared to be larger for Experiment 2, which is in line with my assumptions that the manipulation of crossed vs. straight hands is a stronger manipulation of response discriminability than between vs. within-hand responses. More importantly, it suggests that the pertinent difference between response modes is the difference in response discriminability.

Interestingly, the orientation of the frying pan appears to have had an influence on the alignment effects observed in Experiment 2. The alignment effect was larger for inverted images, suggesting that the position of the handle had a larger influence on responding when an inverted image was shown. The factor of orientation has most often been overlooked in previous work on alignment effects. By looking at the differences in the features of the upright and inverted images, a reasonable inference can be made as to what may be driving this modulation of the alignment effect by orientation. If it is assumed that the upright/inverted judgement is made by assessing the depth cues of the frying pan, a potential source of this effect becomes more apparent. For upright stimuli, the most notable depth cue is a curved highlight on the inner base of the pan, which is located on the far side of the frying pan away from the handle. Since the location of the handle opposes the task-relevant depth cue, the influence of the handle is weakened, leading to a reduced alignment effect. For inverted stimuli, this curved highlight is located much closer to the handle. Here, the location of the handle corresponds with the task relevant depth cue, so the influence of the handle is not weakened, leading to a larger alignment effect. This is partially supported by the finding that RTs were shorter for upright images, however this effect was only significant for straight-hand responses. Although intriguing, further work is needed to confirm this influence of orientation.

The quantile analysis showed a similar pattern to Experiment 1. For straight-hand responses, the alignment effects increased across the RT distribution for both the upright and inverted stimuli. For crossed-hand responses, the alignment effect increased across the RT distribution for the inverted stimuli only. In comparison to Experiment 1, the modulation of the alignment effect by response mode is apparent throughout the RT distribution. This is further evidence for my proposal that comparing crossed vs. straight hands is a stronger manipulation of response discriminability than between vs. within-hand responses.

Experiment 3

The final experiment was conducted to examine the influence of the centring technique on alignment effects. To do so, only one change was made between Experiment 2 and the present experiment. While pixel-centred images were used in the two previous experiments, object-centred images were used in Experiment 3. As previously discussed, object-centred stimuli have been shown to produce alignment effects with respect to the body of the frying pan (Yu, Abrams, & Zacks, 2014; Proctor et al., 2017). I propose that object-centred images produce a body alignment effect due to the fact that the most salient change from trial to trial is the location of the body. The opposite is true for pixel-centred and body-centred images, which produce handle alignment effects. Here, the body of the pan remains horizontally centred from trial to trial and the salient change is the location of the handle. If these principles are correct, alignment effects based on a correspondence between the response key and the *body* of the frying pan should be found in Experiment 3. Hence, the factor of alignment was re-defined in Experiment 3 to reflect this.

Crucially, the results of Proctor et al. (2017) showed that with object-centred stimuli, the modulation of alignment effects by response mode worked in the opposite direction to when base-centred stimuli were used. Clearly, for base-centred objects the alignment effect is larger for between-hand responses than within-hand response. In contrast, the alignment effect appears to be larger for *within-hand* responses than between-hand responses for the object-centred experiment (Proctor et al., 2017, Experiment 1). The present experiment looked to replicate the opposite pattern of modulation by the response mode on alignment effects.

3.1 Method

An additional sample of 31 new subjects from the same source as the earlier experiments participated in Experiment 3 (Median Age = 20, Age Range = 18-26, Male subjects = 10, Left-handed = 0). The stimuli, apparatus, and procedure were identical to experiment 2 with one exception: the frying pan stimuli were object-centered.

3.2 Results

Response time was measured as in the previous experiments. Response times less than 100 ms or greater than 2000 ms (0.46% of trials) were removed prior to analysis. Object-centered stimuli commonly show alignment effects with respect to the location of the body of the pan. Therefore, in this experiment alignment now refers to a spatial correspondence between the response key and the body of the frying pan. Aligned trials are defined as trials where the body of the frying pan is shown on the same side of space as the correct response key and misaligned trials refer to when they are on opposing sides of space. Mean response time and percent error for each condition are shown in Figure 3.1. A 2 (alignment) x 2 (response mode) x 2 (orientation) repeated-measures ANOVA was applied to the response-time data. All three factors produced significant main effects. Response times were shorter for aligned trials, $F(1, 30) = 40.83$, $MSE = 988$, $p < .001$, $\eta_p^2 = .58$, straight-hand response trials, $F(1, 30) = 22.21$, $MSE = 4985$, $p < .001$, $\eta_p^2 = .43$, and upright trials, $F(1, 30) = 4.84$, $MSE = 648$, $p < .05$, $\eta_p^2 = .14$. Additionally, there was an interaction between alignment and response mode, $F(1, 30) = 11.43$, $MSE = 522$, p <

.01, η_p^2 = .28, which revealed that the alignment effect was larger for crossed-hands responses. No other significant effects were found. A corresponding ANOVA analyzing percent error revealed a significant effect of alignment, $F(1, 30) = 25.17$, MSE = 19.7, $p < .001$, η_p^2 = .46, with aligned trials producing fewer errors. An effect of response mode was also found, $F(1, 30) = 6.08$, MSE = 5.4, $p < .05$, η_p^2 = .17 , showing that the crossed-hand condition produced more errors. Finally, the interaction between alignment and response mode was significant, $F(1, 30) = 8.95$, MSE = 9.11, $p < .01$, η_p^2 = .23, revealing that there was a larger alignment effect for crossed-hand responses. No other significant effects were found. Once again, the alignment effects were examined across the full distribution of response times. Analyses of the linear trend for the alignment effects are shown in figure 3.2. None of the conditions produced a significant increase in the alignment effect across quantiles.

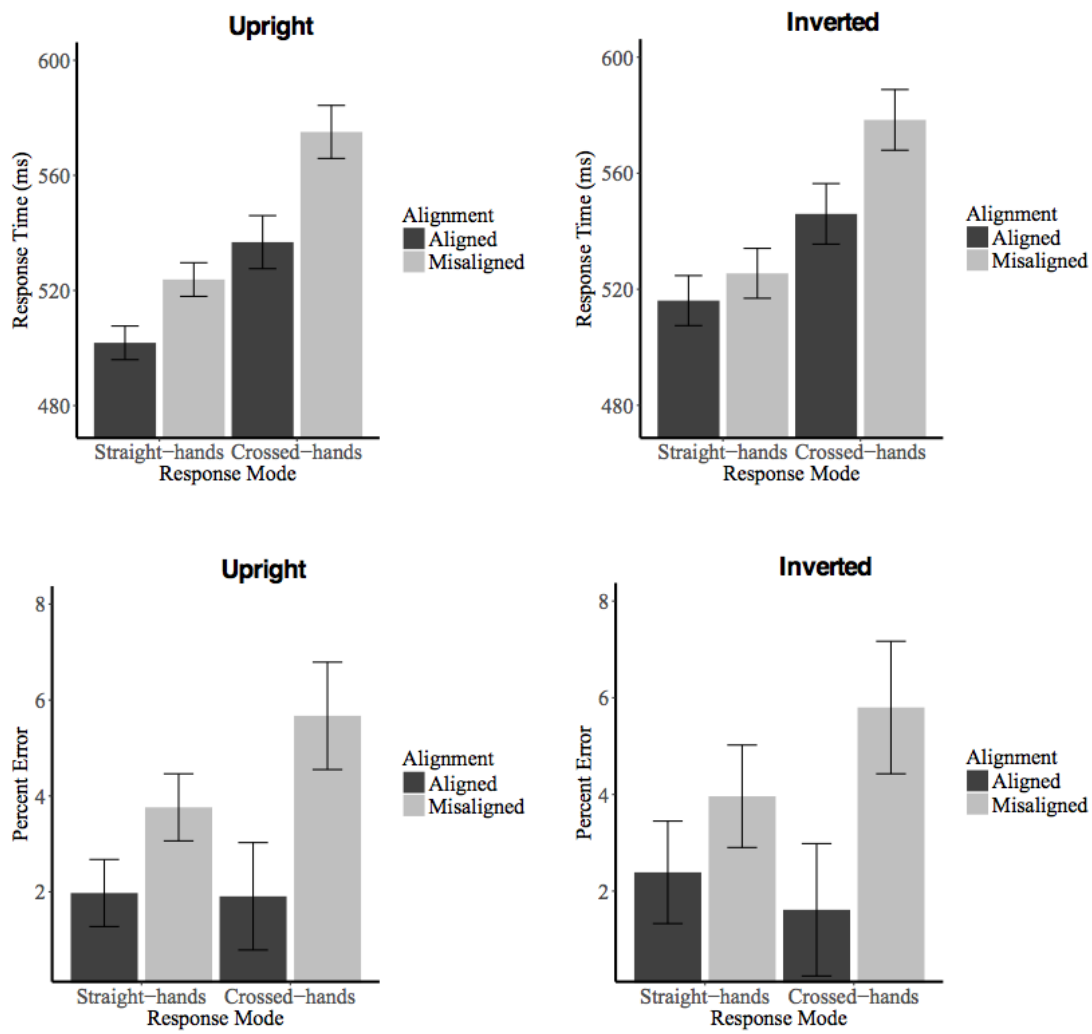

Figure 3.1 Mean response time and percent error in Experiment 3 as a function of orientation, response mode and alignment between the object's body and the response location. Error bars indicate 95% within-subject confidence intervals, suitable for evaluating the alignment effect within each response mode (Loftus & Masson, 1994; Masson & Loftus, 2003).

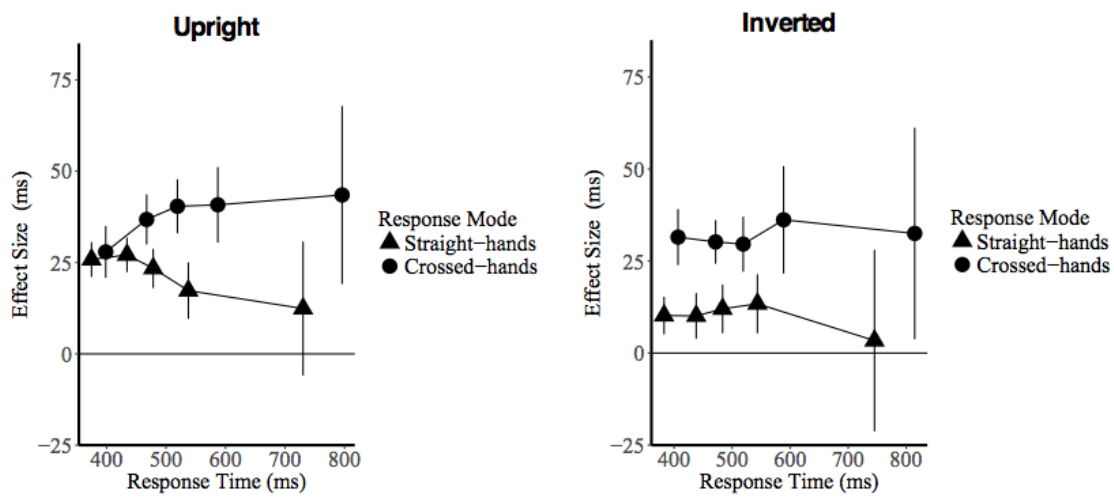

Figure 3.2 Alignment effect size across response-time quantiles in Experiment 3, shown separately for upright and inverted conditions. Mean response time for each quantile is shown on the horizontal axis. Effect size plots are shown separately for the two response modes. Error bars are 95% confidence intervals for the mean effect size at each quantile.

3.3 Discussion

In the final experiment, I looked to examine how the pattern of alignment effects change when using object-centred stimuli. Previous experiments have shown that a body alignment effect is produced by object-centred stimuli (Yu, Abrams, & Zacks, 2014; Proctor et al., 2017). The results of the present experiment are consistent with these findings. Both straight and crossed-hand responses produced an alignment effect that was due to a correspondence between the location of the response key and the body of the frying pan. As previously discussed, I propose that object-centred stimuli produce an effect with respect to the body due to the fact that the body of the pan provides a stronger spatial cue than the handle in this setting.

When the stimuli alternate left/right orientation, the most salient change is the position of the frying pan body.

The crucial finding of Experiment 3 concerns the modulation of alignment effects by response mode. In the study by Proctor et al. (2017), the direction of this modulation varied depending on the centring technique. With base-centred stimuli, the alignment effect was larger for between-hand responses than within-hand responses. When using object-centred stimuli, the alignment effect was larger for within-hand responses than between-hand responses. In other words, base-centred stimuli produced a larger alignment effect when response discriminability was high and object-centred stimuli produced a larger alignment effect when response discriminability was low. The results of the present experiment were consistent with these findings. The alignment effect was larger for crossed-hand responses (low discriminability) than for straight-hand responses (high discriminability). This result confirms that a double dissociation exists for the alignment effects found under the pixel/base-centred frying pans and object-centred frying pans. This suggests that the underlying principles guiding these effects are qualitatively distinct. Further support for this is exhibited by the quantile analysis. While pixel-centered images tend to produce alignment effects that increase with increasing RTs, as shown in Experiment 1 and 2, the effects produced by object-centred stimuli remain relatively constant throughout the RT distribution. Taken together, this strongly suggests that the processes involved in completing the task are fundamentally different depending on the centring of the stimuli.

General Discussion

This study was focused on assessing the reliability of Proctor et al.'s (2017) finding that indicated a possible double dissociation between the modulation of the alignment effects by response mode produced in the body-centred and object-centred version of the task. Although not emphasized by Proctor et al. (2017), I observed that under base-centring, larger alignment effects were produced by the between-hand responses than within-hand responses. Under object-centring, larger alignment effects were produced by within-hand responses in comparison to between-hand responses. I took this asymmetry as indication that there could be two fundamentally distinct processes underlying the alignment effects produced for the two centring techniques. In order to replicate this pattern, three experiments modelled after Pappas's (2014) and Proctor et al.'s (2017) experiments were conducted. In tandem with an earlier attempt by Marshall (2016) to replicate Pappas (2014), I was able to compare within-hand responses to between-hand responses using pixel and object-centered stimuli. Consistent with the findings of Proctor et al. (2017), response mode modulated the alignment effect in an opposite manner depending on the centring technique.

Experiment 2 and 3 also compared the different pattern of alignment effects found for pixel-centered and object-centred stimuli, but instead compared straight-hand responses to crossed-hand responses. By doing this, I was able to assess the plausibility of the claim that the crucial distinction between response modes is a difference in response discriminability. While this factor differs for within-hand responses and between-hand responses, comparing crossed-hand responses to straight-hand responses allowed me to compare responses with low discriminability to responses with high discriminability, without any complication of key distance confounds. Consistent with the earlier experiments, the alignment effect was larger for the more discriminable responses (straight-hand) than the less discriminable responses (crossed-hand) for pixel-centred stimuli. For object-centred stimuli, less discriminable responses produced a larger alignment effect than highly discriminable responses. This finding further supports the notion that the alignment effects produced by pixel-centred stimuli and the alignment effects produced by object-centred stimuli are governed by distinct principles.

This distinction between the alignment effects is also present when observing how the effect changes across the RT distribution. For the pixel-centred version of the task used in Experiment 1 and 2, the alignment effect increases across RT distributions for high discriminability responses. For the responses that are less discriminable, the only instance where the alignment effect increased across the RT distribution was in experiment 2, with crossed-hand responses made to an inverted frying pan. In contrast, when using the object-centred stimuli in Experiment 3, the alignment effect did not increase across the RT distribution for any of the conditions.

Given all of these results, it is abundantly clear that the principles that produce the alignment effects are qualitatively distinct for the pixel-centred and object-centred version of the task. I argue that the handle alignment effect produced by the pixel-centered images resembles an object-based Simon effect, as proposed by Proctor et al. (2017), which is primarily based on a stimulus-response correspondence. In contrast to the typical Simon effect, which exhibits a rapid decrease in the effect across the RT distribution, object-based Simon effects tend to increase with increasing RTs (Proctor, Miles, & Baroni, 2011). This feature was present in the handle based alignment effects produced in Experiment 1 and 2, supporting the claim that the handle alignment effect is equivalent to an object-based Simon effect. In this setting, when the discriminability between responses is greater, the handle alignment effect is enhanced. More specifically, when the handle of the frying pan is aligned with the response key, the spatial cue of the handle provides an advantage for responding that is greater for highly discriminable responses. In contrast, when the handle is misaligned with the response key, the spatial cue of the handle produces a disadvantage for responding that is greater for highly discriminable responses. Further, the handle alignment effect is larger for inverted images than upright images. I suggest that this effect is based on the relationship between the location of the handle and the location of the task relevant depth cue embedded in the stimulus. The depth cue that I am referring to is a curved highlight present in the base of the pan. Since the task requires making an inverted/upright orientation judgement, it is likely that this depth cue is consulted to make this distinction. Crucially, this highlight is located closer to the handle for inverted images. This correspondence between the handle and the highlight works to enhance the influence of the handle, which leads to an increase in the alignment effect. When upright, the highlight is localized further away from the handle. This works to dampen the influence of the handle, which in turn reduces the alignment effect.

The body alignment effect exhibited in Experiment 3 produced an entirely different pattern of results, suggesting that different principles must be applied to account for this effect. The body alignment effect more closely resembles a stimulus-stimulus effect, similar to the effects found in the Stroop task. These effects arise with stimuli that are bivalent, such as a color word presented in an incongruent ink color (GREEN printed with red ink) (Egner, 2008). Given the direction of the body alignment effect, I have shown that attention is paid to the body of the frying pan, while the location of the handle is less salient. The relationship between the handle and the depth cue that determines upright/inverted judgments is now irrelevant, and indeed the handle has no influence on responses. Instead, I propose that the object-centred stimuli produce a left or a right stimulus code driven by the left/right asymmetry of the base of the frying pan. As a result of the centring of these stimuli, the body of the pan protrudes either to the left or the right of the midline. Further, the task relevant depth cue is presented on the body of the frying pan so that it correlates with the left/right location of the body. Concurrently, the stimuli are coded to the left or right response given the task instructions that assign an upright image to left key response and an inverted image to a right key response, or vice-versa. Therefore, the interference is present primarily at the stimulus level. Stimulus-stimulus effects such as the Stroop task have been known to produce *larger* effects when the discriminability between responses is low, consistent with the present findings from Experiment 3 and the current proposal that the body alignment effect is primarily a stimulus-stimulus effect (Egner, 2008; Chen & Proctor, 2014).

Clearly, distinct patterns of alignment effects occur depending on the centring technique. An important note can be made by revisiting Pappas's (2014) results as they stand in relation to the widely held claim that high quality images of graspable object trigger motor representations regardless of intentions. He successfully replicated the findings of Tucker & Ellis (1998), in which an alignment effect was found for between-hand responses, but not within-hand responses. In both of these experiments, the response mode manipulation was confounded with differences in the distance between the response keys. To dismiss key distance as a possible confound, Pappas (2014) cited evidence showing that Stroop effects are smaller when there is a large distance between response keys. While this claim is correct, it cannot be used to vindicate Pappas' claims. The stimuli were *pixel-centered* in his experiment, which I have established will produce alignment effects that are larger when response discriminability is high. Therefore, his dismissal of this confound does not stand. The modulation of the alignment effects by response mode was almost certainly due to the differences in discriminability between the response modes.

Finally, I conclude by noting a further result that re-affirms the fundamental role that intentions to engage in a reach-and-grasp actions play in evoking motor representations from pictures of handled objects (Bub & Masson, 2010; Masson, Bub & Breuer, 2011; Bub, Masson & Kumar, 2018). When the image of the frying pan is object-centred and subjects indicate their upright-inverted judgements by carrying out a speeded *reach-and-grasp action* on a single response element (a horizontal cylinder), robust alignment effects are induced by the handle of the object (Marshall, 2016). In other words, a left- or right-handed grasp action is faster when the *handle* of the object is aligned rather than misaligned with the hand. As shown by the present study, the very same object-centred image yields *reverse* alignment effects (i.e. a body-based rather than a handle-based effect) when orientation judgements are made via speeded key-press responses. This striking dissociation confirms what is now ample evidence that motor intentions, far from merely selecting between already active motor representations, are themselves the key to triggering constituents of actions from images of graspable objects.

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