Further Evidence that Object-Based Correspondence Effects are Primarily Modulated by Object Location not Grasping Affordance

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Further Evidence that Object-Based Correspondence Effects are Primarily Modulated by Object Location not Grasping Affordance

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Abstract

Tipper, Paul, and Hayes (2006) found object-based correspondence effects for door-handle stimuli for shape judgments but not color. They reasoned that a grasping affordance is activated when judging dimensions related to a grasping action (shape), but not for other dimensions (color). Cho and Proctor (2011, 2013), however, found the effect with respect to handle position when the bases of the door handles were centered (so handles were positioned left or right; the base-centered condition) but not when the handles were centered (the object-centered condition), suggesting that the effect is driven by object location, not grasping affordance. We conducted an independent replication of Cho and Proctor's design, but with behavioral and event-related potential measures. Participants made shape judgments in Experiment 1 and color judgments in Experiment 2 on the same door-handle objects. Correspondence effects on RT and errors were obtained in both experiments for the base-centered condition but not the object-centered condition. Effects were absent in the P1 and N1 data, which is consistent with the hypothesis of little binding between visual processing of grasping component and action. These findings question the grasping affordance view but support a spatial coding view, suggesting that correspondence effects are modulated primarily by object location.

Further Evidence that Object-Based Correspondence Effects are Primarily Modulated by Object Location not Grasping Affordance

For many years, researchers have attempted to outline the connection between visual perception and action, and how it determines our performance (see Humphreys & Riddoch, 2005, for a review). Some studies have claimed that visual processing of objects is primarily driven by the potential action offered by the object, known as the *affordance view* (e.g., Bub & Masson, 2010; Goslin, Dixon, Fischer, Cangelosi, & Ellis, 2012; Handy, Grafton, Shroff, Ketay, & Gazzaniga, 2003; Iani, Baroni, Pellicano, & Nicoletti, 2011; Tucker & Ellis, 1998). For instance, Tucker and Ellis had participants identify the orientation (upright or inverted) of graspable objects (e.g., a frying pan) and respond with left and right keypress (using the index fingers of the respective hands). They found that response times (RTs) were shorter when the handle corresponded with the response hand than when it did not. This *object-based correspondence effect* has been attributed to a grasping affordance: the viewed object automatically activates the hand on the same side as the handle, just as if one were actually to try to grab the handle.

Studies supporting the affordance view further suggested that attention is required to construct the grasping affordance (e.g., Vainio, Tucker, & Ellis, 2007) and, more specifically, that the task must require attending to an object property relevant to grasping (e.g., Pellicano, Iani, Borghi, Rubichi, & Nicoletti, 2010; Tipper, Paul, & Hayes, 2006). Pellicano et al. (2010) obtained a correspondence effect, albeit small, for the handle end of a torch (flashlight) when participants were to make upright/inverted judgments (features assumed to be relevant to grasping action), but not when they were to make color judgments (features assumed to be irrelevant to grasping action). However, Song, Chen, and Proctor (2014) provided evidence that this effect is due to asymmetries in the visual properties of the stimuli rather than to the grasping affordance of the handle. Other studies also revealed that response activation by a grasping affordance did not occur automatically (see Proctor & Miles, 2014, for a review).

Additional evidence challenging the affordance view comes from the study of Simon effects, indicating that our action is strongly driven by stimulus location (see Proctor & Vu, 2006, for a review). That is, responses are faster and more accurate when irrelevant stimulus location corresponds with response location, which has been attributed to stimulus location, rather than object grasping affordance, producing "automatic" activation of the corresponding response-location code when the responses (most often keypresses) are spatial locations along the same dimension (e.g., Kornblum, Hasbroucq, & Osman, 1990; Yamaguchi & Proctor, 2012). According to the *spatial coding view*, the object-based correspondence effect may have been caused by object location rather than grasping affordance.

Of greatest interest for the present study is that Tipper et al. (2006) reported a correspondence effect for door-handle stimuli that differed in shape (rounded or squared) and color (blue or green), but only when the participants made shape judgments (i.e., features primed to process affordance). Additionally, the correspondence effect was larger when the handle was in an active, operated state (i.e., depressed, rotated downward from the base 45°; the estimated effect from their Figure 3A was 35 ms) compared to when it was in a passive state (i.e., horizontally aligned; the effect about 14 ms). Tipper et al. argued that the active state implies action to be underway, which momentarily activates visual-motor systems and prompts the inferred grasp and depression action. Such visual-action binding was much weaker for the passive objects.

Although Tipper et al.'s (2006) findings can be easily explained by the grasping affordance view, their results were not replicated in Cho and Proctor's (2011, 2013) studies, which used the same stimuli. In Tipper et al. (2006), the whole door-handle stimulus was displayed in a centered location on the screen such that the handle was at approximately the same position on all trials (i.e., an object-centered condition). Cho and Proctor (2011, 2013) made several attempts to replicate Tipper et al.'s pattern of results with the object-centered condition, but found no effect of correspondence between the handle location and the response location for either color judgments or shape judgments. In Experiment 4, using the color judgment task only, Cho and Proctor (2011) also presented the base of the door handle centrally (so that the handles were positioned left or right; i.e., the base-centered condition). They observed a correspondence effect in this particular condition and subsequently concluded that the correspondence effect was primarily driven by the object location, supporting the spatial coding view.

Since Tipper et al. (2006) found evidence that a grasping affordance is activated when making shape judgments but not color judgments, and Cho and Proctor's (2013) negative results for shape judgments in the object-centered condition involved accepting the null hypothesis, it seemed prudent to conduct other, separately-programmed experiments to resolve these conflicting findings. Such an attempt at replication is critical in research practice (e.g., Brandt et al., 2014). As emphasized by Roediger (2012), "if we replicate our results routinely, we do not need to worry so much about the poor logic of null hypothesis statistics or using Bayesian statistics to try to determine what happened in a single experiment or study. If you obtain an effect, just replicate it (perhaps under somewhat different conditions) to be sure it is real." Thus, one purpose of the present study was to do so.

In addition, Cho and Proctor's (2011) evidence for the spatial coding view is from the base-centered condition of their Experiment 4, which used color judgments only. It remains to be determined whether a similar pattern of correspondence effects would also be observed for shape judgments in the base-centered condition. It is possible that both spatial coding and grasping affordance (if it has any effect) act jointly when making shape judgments but not color judgments. If this is the case, then one might expect a much larger correspondence effect for shape judgments than color judgments in the base-centered condition. Therefore, a second purpose of the present study was to determine whether Cho and Proctor's finding of a correspondence effect in the base-centered condition for color judgments extends to shape judgments as well (the present Experiment 1) and whether there is any evidence of a joint effect of spatial coding and grasping affordance.

The third purpose of the present study was to look for another source of possible evidence for an effect of grasping affordance. For that purpose, we used event-related potential (ERP) measures, which can provide a valuable converging source of evidence concerning whether activation of the grasp-afforded response is occurring. Following Goslin et al. (2012), we focused on the early visual processing ERP components of P1 and N1 at parietal and occipital sites. These components are typically studied using a spatial cuing paradigm (e.g., Luck & Hillyard, 1995). An object in a cued location (attended) is assumed to elicit a large P1 (during the time window 100-130 ms after stimulus onset) and N1 (during the time window 150-200 ms after stimulus onset) relative to an object in the uncued (unattended) location (e.g., Hillyard, Hink, Schwent, & Picton, 1973; Luck, Heinze, Mangun, & Hillyard, 1990; Müller & Hillyard, 2000). Since the P1 and N1 ERP components reflect early visual processing of a stimulus feature on the basis of its location, Goslin et al. (2012) argued that the intended action triggered by the visual processing of handle orientation should be evident in the P1 and N1 (i.e., an ERP correspondence effect). In other words, attention would be directed to the handle orientation, eliciting larger P1 and N1 components for the corresponding trials than the non-corresponding trials. They indeed found a small correspondence effect from object handle orientation on P1 and N1 when classifying a variety of objects as tools or kitchen utensils, which they took as evidence supporting the grasping affordance view. However, Lien, Jardin, and Proctor (2013) were unable to replicate their P1/N1 findings in three experiments with centrally located objects similar to those used by Goslin et al. (2012). Regardless of the discrepancy between these two studies, examining P1 and N1 ERP components could still offer some insight into the issue regarding the possible role of a grasping affordance (although not definitive evidence).

Experiment 1

Experiment 1 adopted Tipper et al.'s (2006) tasks but used both behavioral and ERP measures. Colored door-handle objects from Cho and Proctor (2011, Experiment 4; 2013; identical to those of Tipper et al., 2006) were used. The same video of door-handle operation as in Cho and Proctor (2013; Figure 1, Panel A; see also Tipper et al., 2006) was shown to participants prior to the experiment, since it has been suggested that such a video may be necessary to activate a grasping affordance when making keypress responses (Bub & Masson, 2010; but see Cho & Proctor, 2013).

Two object display conditions were included – a base-centered condition (in which the base of the handle was centered and the handle location varied around it) and an object-centered condition (in which the entire object was centered, and the base therefore changed location from one trial to the next). Figure 1, Panel B shows an example of these two conditions. As in previous studies, presentation was blocked by object display condition. However, instead of using a between-subject design for the object display condition as in previous studies, we used a within-subject design (to avoid possible perceptual confound in the EEG measures).

In Experiment 1, participants made a left or right keypress response to the shape of the door handle (square or round). The door handle was active (the position was in the middle of the normal range of motion) or passive (no action). The door handle orientation, though irrelevant to the task, was toward the left or right which could correspond to the response location or not. We measured the correspondence effect (noncorresponding minus corresponding) between door handle orientation and response hand on both behavioral and ERP data.

Method

Participants. Twenty-three undergraduate students from Oregon State University participated in exchange for extra course credit. Data from three participants were excluded from the final analyses due to excessive artifacts in the electroencephalographic (EEG) data (see below) for one participant and the failure of recording EEG data for two participants. The remaining 20 participants (13 females) had a mean age of 21 years (range: 18-33). Two were left handed and 18 were right handed. All reported having normal or corrected-to-normal acuity.

Apparatus, stimuli, and procedure. Stimuli, displayed on a 19-inch monitor, were viewed from a distance of about 55 cm. The complete set of 32 colored pictures of door handles (half for each display condition) from Cho and Proctor (2013) was used. The door handles were 3.33^0 (width) × 14.28^0 (length) for the square shape and 2.71^0 (width) × 14.87^0 (length) for the round shape. The base was 5.71^0 in diameter. Within each display condition, there was one object for each of handle orientation (left vs. right), shape (round vs. square), color (blue vs. green), and object state (active vs. passive).

Prior to the experimental trials, participants were first shown a video clip adopted from Cho and Proctor (2013) – a person's left or right hand reaching toward and operating a door handle (Figure 1, Panel A). The experiment then started with a fixation cross in the center for

1,000 ms. The stimulus appeared in the center screen immediately after offset of the fixation cross and remained present until participants made a response or when a 1,500-ms deadline was reached. The participants' task was to indicate whether the door handle was square or round by pressing the leftmost response-box button with their left-index finger or the rightmost button with their right-index finger. As a result, the response hand and response location were always compatible. Therefore, we used the term "response hand" rather than "response location" to simplify our descriptions below. The mapping between shape and response key was counterbalanced between participants. Feedback (a tone for an incorrect response or the fixation display for a correct response) was presented for 100 ms. The next trial then began with the fixation display (see Figure 1, Panel B).

Each participant completed two sessions, one with each of the two display conditions (base-centered vs. object-centered). Session order was counterbalanced between participants. Within each session, participants performed one practice block of 32 trials, followed by 8 experimental blocks of 96 trials each (a total of 768 experimental trials for each session). For 50% of the trials, the response hand was corresponding with the orientation of the door handle. For the remaining 50% of the trials, they were noncorresponding. Participants completed these two sessions within a single visit and were given breaks between blocks and between sessions.

<u>EEG Recording.</u> The EEG activity was recorded from F3, Fz, F4, C3, Cz, C4, P3, Pz, P4, P7, P8, PO7, PO8, O1, and O2. These sites and the right mastoid were recorded in relation to a reference electrode at the left mastoid. The ERP waveforms were then re-referenced offline to the average of the left and right mastoids (see Luck, 2005). The horizontal electrooculogram (HEOG) was recorded bipolarly from electrodes at the outer canthi of both eyes, and the vertical electrooculogram (VEOG) was recorded from electrodes above and below the midpoint of the

left eye. Electrode impedance was kept below 5 kΩ. EEG, HEOG, and VEOG were amplified using Synamps2 (Neuroscan) with a gain of 2,000 and a bandpass of 0.1-40 Hz. The amplified signals were digitized at 500 Hz.

Trials with artifacts were identified in two steps. First, trials with artifacts were rejected automatically using a threshold of ± 75μV for a 1,000 ms epoch beginning 200 ms before stimulus onset and ending 800 ms after stimulus onset. Second, each of these candidate artifact trials was then inspected manually. One of the original 23 participants was eliminated because of artifact rejection on more than 25% of trials. EEG data for two of those participants failed to record. Thus, only 20 participants' data were included in the final analyses.

Results

We intended to exclude trials from the final analyses of behavioral data (RT and proportion of error [PE]) and ERP data if RT was less than 100 ms, but no trials were in that range. Rejection of trials with EEG artifacts led to the elimination of 7% of trials, with no more than 17% rejected for any individual participant. Trials were also excluded from the RT and ERP analyses if the response was incorrect (note that the trials were considered as incorrect if participants failed to respond within the 1,500-ms deadline). An alpha level of .05 was used to ascertain statistical significance. Reported confidence intervals were based on a 95% confidence interval, shown as the mean ± the confidence interval half-width.

Behavioral Data Analyses

An analysis of variance (ANOVA) was conducted including the within-subject variables of object display condition (base-centered vs. object-centered), object state (active vs. passive), and response-hand/handle-orientation correspondence (corresponding vs. noncorresponding). Table 1 shows the mean RT and PE for each of these conditions.

Mean RT was 17 ms longer for the base-centered display condition (454 ms) than the object-centered display condition (437 ms), $F(1, 19) = 4.63$, $p < .05$, $\eta_p^2 = .20$. The mean RT was 4 ms longer for the passive state (447 ms) than the active state (443 ms), $F(1, 19) = 19.83$, $p < .001$, $\eta_p^2 = .51$. The overall correspondence effect was 9±5 ms on RT, $F(1, 19) = 13.70$, $p < .01$, $\eta_p^2 = .42$. The correspondence effect on RT interacted significantly with display condition, $F(1, 19) = 69.49$, $p < .0001$, $\eta_p^2 = .79$, being large and positive for the base-centered display condition (22±6 ms) but small and negative for the object-centered display condition (-5±6 ms). Most important, the three-way interaction of object display condition, object state, and correspondence was significant, $F(1, 19) = 16.14$, $p < .001$, $\eta_p^2 = .46$. For the base-centered display condition, the positive correspondence effect was smaller for the active state (16±6 ms) than the passive state (28±8 ms), $F(1, 19) = 7.29$, $p < .05$, $\eta_p^2 = .28$. Further *t*-test analyses revealed that those positive correspondence effects were significantly different from zero, $t(19) = 5.71$, $p < .0001$, and $t(19) = 6.86$, $p < .0001$, for the active state and the passive state, respectively. For the object-centered display condition, the negative correspondence effect did not differ significantly for the active state (-1±6 ms) and the passive state (-8±8 ms), $F(1, 19) = 3.12$, $p = .09$, $\eta_p^2 = .14$. Further *t*-test analyses revealed that only the latter correspondence effect approached being significant, $t < 1.0$, and $t(19) = -2.00$, $p = .0601$, respectively.

For the PE data, an overall correspondence effect of .011±.006 was observed, $F(1, 19) = 14.64$, $p < .01$, $\eta_p^2 = .44$. The correspondence effect was much larger for the base-centered display condition (.024±.009) than for the object-centered display condition (-.002±.008), $F(1, 19) = 18.08$, $p < .001$, $\eta_p^2 = .49$. No other effects were significant.

ERP Data Analyses

To quantify the overall magnitude of the P1 and N1 effects, we focused on the time windows 100-130 ms and 150-200 ms after stimulus onset, respectively, and calculated the mean amplitude from parietal and occipital electrodes: P7, P8, O1, and O2 (see also Lien et al., 2013). Figure 2 shows the scalp distribution of brain potentials during the critical time windows used to measure the P1 and N1. All ERP data were adjusted relative to the mean amplitude during a 200-ms pre-stimulus onset baseline period. Note that if the P1 and N1 are modulated by the correspondence between response hand and door handle orientation, corresponding trials should produce larger ERP amplitudes than noncorresponding trials (i.e., more positive for corresponding than noncorresponding trials). To ensure consistency, we measured the correspondence effect for ERPs using the same equation as the behavioral data (noncorresponding minus corresponding). Thus, we would expect the correspondence effect to be negative in value in ERP measures (P1 and N1) while being positive in behavioral measures (RT and PE).

We analyzed the P1 and N1 data as a function of object display condition (base-centered vs. object-centered), object state (active vs. passive), door handle orientation (left vs. right), response hand (left vs. right), electrode site (parietal [P7, P8] vs. occipital [O1, O2]), and electrode hemisphere (left [P7, O1] vs. right [P8, O2]). All factors were within-subjects variables. Figure 3 shows the mean P1 and N1 amplitude averaged across the P7, P8, O1, and O2 electrodes for the base-centered and the object-centered display conditions as a function of object state (active vs. passive). Our primary interest was whether the P1 and N1 were modulated by the correspondence between door handle orientation and response hand. Therefore, we report only these effects below. The complete summary of the ANOVA is given in Appendix A.

Both P1 and N1 data analyses revealed that neither the correspondence between response hand and door handle orientation nor its interactions with other variables were significant. For the P1 data, the correspondence effect was negligible (0.046 μV) and non-significant, $F < 1.0$. The correspondence effect was not significantly different between the base-centered display condition (-0.110 μV) and the object-centered display condition (0.203 μV), $F(1, 19) = 1.97$, $p = .18$, $\eta_p^2 = .09$. Further *t*-test analyses revealed that the correspondence effect was not significantly different from zero for either display condition, $|ts(19)| \leq 1.20$, $ps \geq .25$. The correspondence effect was not significantly different between the active condition (0.005 μV) and the passive condition (0.088 μV), $F < 1.0$. The difference in the correspondence effect between the active and passive conditions was similar for the base-centered display condition (-0.086 μV vs. -0.133 μV, respectively) and the object-centered display condition (0.097 μV vs. 0.309 μV, respectively), $F < 1.0$. Further *t*-test analyses revealed that none of the correspondence effects was significant, $|ts(19)| \leq 1.46$, $ps \geq .16$.

As in the P1 data, the N1 data showed that neither the interaction of response hand and handle orientation (i.e., the correspondence effect) nor its interaction with object display condition was significant, $Fs < 1.0$. Further analysis also revealed that the correspondence effect was not significant for either the base-centered display condition (-0.022 μV) or the object-centered display condition (0.060 μV), $|ts(19)| < 1.0$. The correspondence effect was not significantly different between the active condition (-0.136 μV) and the passive condition (0.174 μV), $F(1, 19) = 2.83$, $p = .11$, $\eta_p^2 = .13$. The difference in the correspondence effect between the active and passive conditions was similar for the base-centered display condition (-0.104 μV vs. 0.059 μV, respectively) and the object-centered display condition (-0.169 μV vs. 0.209 μV, respectively), $F(1, 19) = 1.69$, $p = .21$, $\eta_p^2 = .08$. Further *t*-test analyses revealed that none of the correspondence effects was significant, $|ts(19)| \leq 1.40$, $ps \geq .18$. To sum up, these findings suggest that both P1 and N1 were not modulated by the correspondence between response hand and handle orientation.

Discussion

As noted in the Introduction, Cho and Proctor (2011) did not include shape judgments in the base-centered condition. Therefore, it remained to be determined whether their finding of a correspondence effect with color judgments in the base-centered condition but not in the object-centered condition can be extended to shape judgments. The present Experiment 1 provided such a comparison between these two display conditions for shape judgments. We found a correspondence effect on RT and PE in the base-centered display condition (22±6 ms and .024±.009, respectively), where the handles were clearly positioned to the left or right of center. This finding extended Cho and Proctor's finding with color judgments (a 33-ms correspondence effect) to shape judgments. However, the effect on both RT and PE was absent in the object-centered display condition (-5±6 ms and -.002±.008), where there was no left or right location code for the object handles. The absence of a handle-response correspondence effect with centered objects when making shape judgments is similar to the findings of Cho and Proctor (2013, Experiments 1 and 2), and the entire result pattern resembles that Cho and Proctor (2011, Experiment 4) obtained for color judgments, which showed a positive correspondence effect on RT only for a base-centered display condition and not for an object-centered one (33 ms vs. -9 ms, respectively; see their Table 2). Thus, even with different apparatus and programs (e.g., E-prime in the present study vs. MEL in Cho & Proctor, 2011) and participant pools at different universities, we did not replicate Tipper et al.'s (2006) finding with the same stimuli and procedures.

Furthermore, the P1 and N1 ERP components (assumed to reflect early visual processing) were not modulated by the correspondence between response hand and handle orientation for the active and passive objects in both the base-centered and the object-centered display conditions. These results provide little evidence that the orientation of the object handles affects early visual processing and the intended keypress action (i.e., visual-action binding).

Experiment 2

It should be noted that Tipper et al. (2006) observed the correspondence effect with shape but not color discriminations and argued that the effect was caused by the action affordance elicited by the object rather than the low-level visual features such as color. Nevertheless, Experiment 1 with shape judgments produced a correspondence effect only in the base-centered condition (22±6 ms) but not in the object-centered condition (-5±6 ms) that was similar to the one used by Tipper et al. Furthermore, the effect in the base-centered condition seemed to be smaller than the 33-ms effect with color judgments in Cho and Proctor (2011), which is in the opposite direction of that predicted from the grasping affordance view. Experiment 2 therefore was conducted similarly to Experiment 1 but with color judgments to the door handle (blue vs. green) instead of shape judgments. This experiment, similar to Cho and Proctor's design, allowed us to directly compare the effect sizes observed by shape judgments (Experiment 1) and color judgments (Experiment 2). In this experiment, based on the grasping-affordance account, we should expect no correspondence effect in either the base-centered or the object-centered display condition because the color judgment task on the door handle was used. Nevertheless, if the correspondence effect with keypresses is primarily driven by object location, as suggested by the spatial coding view, rather than the orientation of grasping component, then we should expect the effect to be present in the base-centered display condition (due to the explicit left and right location codes for the object) but not in the object-centered display condition (due to the lack of location codes for the object).

Method

Participants. There were 19 new participants, from the same participant pool as in Experiment 1. One participant's data were excluded because of EEG artifact rejection rate more than 25% of trials. Therefore, data from 18 participants (8 females), mean age of 20 years (range: 18-22), were included in the final data analyses. Two were left handed and 16 were right handed. All reported having normal or corrected-to-normal acuity. They also demonstrated normal color vision using the Ishihara Test for color deficiency.

Apparatus, stimuli, and procedure. The tasks, stimuli, and equipment were the same as in Experiment 1, except that participants made color judgments instead of shape judgments. They indicated whether the door handle was blue or green by pressing the leftmost response-box button with their left-index finger or the rightmost button with their right-index finger. The mapping between color and response key was counterbalanced between participants.

Results

The data analysis was similar to that of Experiment 1. Application of the pre-determined RT cutoff (< 100 ms) eliminated only .02% trials (note that the 1,500 ms response deadline was also used in Experiment 2 as in our Experiment 1). Rejection of trials with EEG artifacts led to the further elimination of 12% of trials, but no more than 25% for any participant.

Behavioral Data Analyses

As in Experiment 1, the behavioral data were analyzed as a function of object display condition (base-centered vs. object-centered), object state (active vs. passive), and response-hand/handle-orientation correspondence (corresponding vs. noncorresponding). Table 2 shows the mean RT and PE for each of these conditions.

Mean RT was similar for the base-centered display condition (407 ms) and the object-centered display condition (401 ms), $F < 1.0$. The mean RT was 3 ms longer for the passive state (405 ms) than the active state (402 ms), $F(1, 17) = 4.62$, $p < .05$, $\eta_p^2 = .21$. The overall correspondence effect was 7±4 ms on RT, $F(1, 17) = 12.93$, $p < .01$, $\eta_p^2 = .43$. As in Experiment 1, the correspondence effect interacted significantly with display condition, $F(1, 17) = 91.15$, $p < .0001$, $\eta_p^2 = .84$, being larger and positive for the base-centered display condition (27±6 ms) but smaller and negative for the object-centered display condition (-13±6 ms). Again, the three-way interaction of object display condition, object state, and correspondence was significant, $F(1, 17) = 22.18$, $p < .001$, $\eta_p^2 = .57$. For the base-centered display condition, the positive correspondence effect was smaller for the active state (19±5 ms) than for the passive state (35±8 ms), $F(1, 17) = 14.44$, $p < .01$, $\eta_p^2 = .46$. Further *t*-test analyses revealed that those positive correspondence effects were significantly different from zero, $t(17) = 6.78$, $p < .0001$, and $t(17) = 8.56$, $p < .0001$, for the active state and the passive state, respectively. For the object-centered display condition, although the correspondence effect was negative, it was also smaller for the active state (-7±5 ms) than for the passive state (-19±7 ms), $F(1, 17) = 16.47$, $p < .001$, $\eta_p^2 = .49$. Further *t*-test analyses revealed that those negative correspondence effects were significantly different from zero, $t(17) = -2.32$, $p < .05$, and $t(17) = -5.11$, $p < .0001$, respectively.

For the PE data, an overall correspondence effect of .009±.006 was observed, $F(1, 17) = 8.42$, $p < .01$, $\eta_p^2 = .33$. The correspondence effect was positive for the base-centered display condition (.037±.014) and negative for the object-centered display condition (-.021±.013), $F(1, 17) = 26.06$, $p < .0001$, $\eta_p^2 = .61$. The three-way interaction of object display condition, object state, and correspondence was also significant, $F(1, 17) = 34.86$, $p < .0001$, $\eta_p^2 = .67$. For the base-centered display condition, the positive correspondence effect on PE was smaller for the active state (.022±.011) than for the passive state (.053±.017), $F(1, 17) = 29.29$, $p < .0001$, $\eta_p^2 = .63$. For the object-centered display condition, the negative correspondence effect was also smaller for the active state (-.006±.010) than for the passive state (-.035±.018), $F(1, 17) = 11.44$, $p < .01$, $\eta_p^2 = .40$. No other effects were significant.

ERP Data Analyses

As in Experiment 1, we analyzed the P1 and N1 data (the time window 100-130 ms vs. 150-200 ms after stimulus onset, respectively) as a function of object display condition (base-centered vs. object-centered), object state (active vs. passive), door handle orientation (left vs. right), response hand (left vs. right), electrode site (parietal [P7, P8] vs. occipital [O1, O2]), and electrode hemisphere (left [P7, O1] vs. right [P8, O2]). All factors were within-subjects variables. Figure 4 shows the mean P1 and N1 amplitude averaged across the P7, P8, O1, and O2 electrodes for the base-centered and the object-centered display conditions as a function of object state (active vs. passive). As in Experiment 1, we report only effects involving the correspondence between handle orientation and response hand. A complete summary of the ANOVA results is given in Appendix B.

Replicating the results in Experiment 1, both P1 and N1 data analyses revealed no evidence of correspondence effects (between response location and handle orientation) and of the effect being modulated by object display condition and object state. For the P1 data, the overall correspondence effect was negligible (-0.023 μV) and was similar for the base-centered display condition (-0.022 μV) and the object-centered display condition (-0.024 μV), *F*s < 1.0. Further *t*-test analyses revealed that the correspondence effect was non-significant for both display conditions, $|ts(17)| < 1.0$. The correspondence effect was not significantly different between the active condition (0.095 μV) and the passive condition (-0.141 μV), $F < 1.0$. The difference in the correspondence effect between the active and passive objects was not statistically significant for the base-centered display condition (0.216 μV vs. -0.260 μV, respectively) and the object-centered display condition (-0.025μV vs. -0.022 μV, respectively), *F*s(1, 17) ≤ 1.41, *p*s ≥ .25, η_p^2s ≤ .08. Although there seems to be a trend for a correspondence effect on P1 for the active and passive objects in the base-centered display conditions, further *t*-test analyses revealed that neither effect was significantly different from zero, |*t*s(17)| ≤ 1.0. Likewise, the correspondence effects on P1 for the active and passive objects were not significant in the object-centered display condition (-0.025μV vs. -0.022 μV, respectively), |*t*s(17)| ≤ 1.0.

As in the P1 data, the N1 data showed no evidence of the correspondence effect, *F*(1, 17) = 1.57, *p* = .23, η_p^2 = .08. The effect was not modulated by the object display condition, *F* < 1.0. Further *t*-test analysis revealed that the correspondence effect was not significant for both the base-centered display condition (-0.267 μV) and the object-centered display condition (-0.146 μV), |*t*s(17)| < 1.02, *p*s ≥ .32. The correspondence effect was not significantly different between the active object (-0.053 μV) and the passive object (-0.360 μV), *F*(1, 17) = 1.05, *p* = .32, η_p^2 = .06. The further *t*-test analyses revealed that the correspondence effect on N1 was not significantly different from zero for both active objects, |*t*(17)| < 1.0, and passive objects, *t*(17) = -1.78, *p* = .09. The difference in the correspondence effect between the active and passive conditions was similar for the base-centered display condition (-0.024 μV vs. -0.510 μV, respectively) and the object-centered display condition (-0.083 μV vs. -0.209 μV, respectively), *F* < 1.0. Further *t*-test analyses revealed that none of the correspondence effect was significant, |*t*s(17)| <1.0, except that the passive object in the base-centered display condition approached being significant, *t*(17) = -2.06, *p* = .0545. This trend in fact was in an opposite direction than the affordance view would predict; that is, active objects should have produced larger correspondence effects than passive objects due to the action state of the viewed object (Tipper et al., 2006).

<u>Discussion</u>

Experiment 2 used a color discrimination task instead of a shape discrimination task on the same door handle stimuli in Experiment 1. Despite the task change (note that otherwise the stimulus display and procedures were the same for these two experiments), both behavioral and ERP data replicated the major findings of Experiment 1. That is, the object-centered display condition produced no positive correspondence effect on RT and PE (the 95% confidence interval was -13±6 ms vs. -.021± .013, respectively, averaged across both active and passive states). On the contrary, the base-centered display condition elicited a large correspondence effect on RT (27±6 ms) and PE (.037±.014), similar in size of the effects obtained in Cho and Proctor's (2011, 2013) studies with the same door handle stimuli. Thus, the presence or absence of the correspondence effect strongly depends on the object display location, which is inconsistent with the grasping affordance view and, instead, supports the spatial coding view.

The ERP data provide no indication of a role of grasping affordance. P1 and N1 showed no modulation by the correspondence between response hand and handle orientation in both the object-centered and base-centered display conditions. In addition, the effect on P1 and N1 was not modulated by object state (active vs. passive). Consistent with the behavioral data, the absence of the correspondence effects on the early visual processing components of ERPs indicates little activation of action triggered by the visual processing of the object grasping component.

The more striking finding of Experiment 2 is how the action state of the door handle (active vs. passive) influenced the correspondence effect. The active state of the door handle (i.e., the handle was depressed by 45°, implying the action was underway) clearly did not enhance the grasping affordance in the base-centered display condition (19±5 ms and .022±.011 for the active state vs. 35±8 ms and .053±.017 for the passive state), as would be predicted by the grasping affordance view. In fact, the effect was in an opposite direction. In the object-centered display condition, the active state of the door handle similarly resulted in a smaller negative correspondence effect than the passive state (the correspondence effect was -7±3 ms and -.006±.010 vs. -19±7 ms and -.035±.018, respectively). One might suggest in this case that, for the active state, a grasping affordance countered the overall negative correspondence effect, even though it did not lead to responses being faster for the corresponding trials than for the noncorresponding ones. However, note that the absolute value of the difference in effect between the active and passive states is similar to that for the base-centered display, $F < 1.0$, which implies that, for both types of displays, the horizontal images of the passive displays yield stronger left-right coding than the angled images of the active displays. In the case of the object-centered display, this coding would be of the changing left vs. right position of the salient base (see Cho & Proctor's, 2013, Experiment 2, for similar results and conclusions with regard to the object-centered displays).

The pattern of correspondence effects for the color judgments in Experiment 2 was similar to that for the shape judgments in Experiment 1, being negative in the object-centered condition and positive in the base-centered condition. This qualitative similarity seems counter to Tipper et al.'s (2006) argument that action affordances are activated only when attending to stimulus features related to grasping actions (e.g., shape). However, one could argue that, in addition to spatial coding, a grasping affordance elicited by the shape contributes to the correspondence effect. Such an effect of grasping affordance would benefit the response to the handle side, reducing the negative correspondence effect for the shape task in the object-centered condition but increasing the positive correspondence effect in the base-centered condition.[1] To examine this possibility, we conducted an ANOVA on the correspondence effect as a function of Experiment (shape in Experiment 1 vs. color in Experiment 2) and Object Display Condition (base-centered vs. object-centered). The main effect of experiment, $F < 1.0$, which would be expected on the basis of a grasping-affordance contribution, was not significant, but the interaction of the two variables was, $F(2, 26) = 6.22$, $p < .05$, $\eta_p^2 = 0.15$. Although there was a marginally-significant trend toward a less negative correspondence effect for shape than color judgments in the object-centered condition (-5 ms vs. -13 ms, respectively), $t(36) = 1.95$, $p = .0596$, there was a nonsignificant trend in the opposite direction in the base-centered condition (22 ms vs. 27 ms, for the shape and color tasks, respectively), $t(36) = -1.23$, $p = .2282$.

While there was no evidence in the between-experiment ANOVA for any affordance effect in the base-centered condition, the data from the object-centered condition lean in the right direction, but the trend is small. One could surmise that the object-centered condition provides a more sensitive test for the presence of a small affordance effect, because spatial coding effects should be weaker and thus less able to overwhelm affordance effects. This idea provides a faint ray of hope for the affordance view that could be investigated in future studies. However, note that it is a post-hoc explanation based on a trend that did not attain statistical significance. The statistically significant term, the interaction, coupled with the absence of a main effect of experiment (shape vs. color judgments) on the correspondence effect is consistent with a simpler alternative explanation: The correspondence effect produced by the part of the object that varies in left or right position (the base in the object-centered condition; the handle in the based-centered condition) tends to be larger for color than shape judgments (see Cho & Proctor, 2013, p. 627, for elaboration of this account).

General Discussion

Tipper et al. (2006) found a correspondence effect elicited by the grasping component of the door handle when making shape judgments, suggesting that visual perception is modulated by the degree to which an object affords a particular action. This finding, supporting the affordance view, later was questioned by Cho and Proctor (2011, 2013), where they found no effects for shape judgments using the same procedures and stimuli. The effect was only observed when the base of the door handle was centrally located, so that the handle was clearly located to the left or right side of the screen (i.e., the base-centered condition), not when the whole door handle was centrally located (i.e., the object-centered condition). These results, supporting the spatial coding view, led them to conclude that the correspondence effect is primarily due to object location, not object affordance.

The present study attempted to replicate previous studies and also take a step further by looking for converging evidence of grasping affordance effects using electrophysiological measures, which provide more sensitive, direct indexes of perception and action processing. We used the same procedures and stimuli as Cho and Proctor (2013; see also Tipper et al., 2006). Participants performed a shape judgment task in Experiment 1 and a color judgment task in Experiment 2. In addition to the behavioral data (RT and PE) of correspondence effect between the orientation of a door handle and the response hand, we measured the ERP components of P1 and N1. These two components relate to early visual processing of a stimulus feature, which have been found to be larger for the cued (attended) object than the uncued (unattended) object (e.g., Hillyard et al., 1973; Luck & Hillyard, 1995; Müller & Hillyard, 2000). As argued by

Goslin et al. (2012), if the object handle provides a visual cue for the intended grasping action, then one might expect a correspondence effect between the orientation of a door handle and the response hand to be evident in both P1 and N1. Observing a correspondence effect on P1 and N1 would therefore provide converging evidence for the grasping affordance view, as reported in Goslin et al.'s study.

We found a correspondence effect between handle-orientation and response hand on both RT and PE only when the object handle was positioned to left or right (the base-centered condition), not when it was centrally located (the object-centered condition). This pattern held across Experiments 1 and 2 with shape and color judgments on the door handle, respectively.[2] In fact, compared to the shape judgments, the color judgments produced much larger differences on RT and PE between these two display conditions, Fs(1, 36) ≥ 5.96, ps < .05, η_p^2s ≥ .55. The overall effect on RT was 22 ms vs. -5 ms, for the base-centered vs. the object-centered display conditions, respectively, with shape judgments (Experiment 1). However, the effect was 27 ms vs. -13 ms, respectively, with color judgments (Experiment 2). Likewise, the effect on PE was .024 vs. -.002, for the base-centered vs. the object-centered display conditions with shape judgments, and was .037 vs. -.021 with color judgments. Given that the only difference between the base-centered display condition and the object-centered display condition was the relative location of the door handle with respect to the center of the display, those findings ubiquitously support the spatial coding view and suggest that the correspondence effect is driven primarily by the activation of object location, not the activation of object affordance.

The P1 and N1 ERP data further support this conclusion. There was no correspondence effect elicited by the visual processing of the door handle orientation in both the base-centered and object-centered display conditions. The sensory-evoked visual P1 and N1 components have been assumed to reflect the visual processing of the object within the focus of attention (e.g., attention gate control, Luck, 1995; Mangun, 1995; a discrimination process, Vogel & Luck, 2000). Some studies have even found that they are modulated by non-spatial object features such as color and orientation (e.g., Karayanidis & Michie, 1997). Thus, the absence of the correspondence effect on P1 and N1 components in our Experiments 1 and 2 suggests that the visual cue provided by the door handle orientation did not induce any intended grasping action. We should note that the only evidence from P1 and N1 ERP components for the grasping affordance view was from Goslin et al.'s (2012) single experiment. The null results for P1 and N1 effects in the present two experiments, as well as in three experiments reported by Lien et al. (2013), suggest that both ERP components are not tied to grasping action, contrary to Goslin et al.'s (2012) claim.

One could suggest that our failure to find the correspondence effect on P1 and N1, as well as on RT and PE in the object-centered condition, was due to low statistical power. For instance, Goslin et al.'s (2012) single-experiment study showed a correspondence effect on RT (5 ms) and P1/N1 with a total of 65 participants (5 out of 70 were excluded from their final analyses). With a pooled sample of 68 participants from three experiments (26, 20, and 22 for Experiments 1-3, respectively) using with Goslin et al.'s (2012) task, Lien et al. (2013) still did not obtain the correspondence effect on RT (95% confidence interval: 1±3 ms), $F < 1.0$, and P1/N1, Fs ≤ 1.38, in the object-centered condition. Using G*Power 3 analyses (Faul, Erdfelder, Lang, & Buchner, 2007), Lien et al. estimated that the power to observe Goslin et al.'s (2012) effect with the pooled sample size of 68 was .94 with a two-tailed test and an α level of .05.

In addition, there were only 15 participants in Tipper et al.'s (2006) Experiment 1 where the correspondence effect (45 ms, estimated from their Figure 3) was observed in the active state of the shape discrimination task. In the present study, there were a total of 38 participants across the two experiments (20 in Experiment 1 and 18 in Experiment 2). The pooled data from the object-centered condition of both experiments produced a correspondence effect on RT in the opposite direction from what the affordance view predicts (95% confidence interval: -8±4 ms), $|t(37)| = 3.94$, $p < .001$. Consistent with the RT data, the pooled P1 and N1 data showed no effect of correspondence (0.096±0.228 μV vs. -0.037±0.248 μV, respectively), $|ts| < 1.0$.

Furthermore, there were a total of 1008 trials (504 per mapping) in Lien et al.'s (2013) study and 1536 trials (768 per display) for each participant in the present study, compared to only 504 trials (252 per mapping) in Goslin et al. (2012) and 128 trials in Tipper et al. (2006). Overall, even with more participants and at least 2-3 times more trials, we were still not able to find any evidence for RT and ERP data being modulated by the grasping affordance. Given the non-replication of Goslin et al.'s single-experiment finding, as well as Tipper et al.'s (2006) results, in our 5 experiments (three in Lien et al., 2013, and two in the present study), it is difficult to attribute the lack of grasping affordance effect on RT and P1/N1 in the present study to inadequate power to detect an effect of meaningful size.

The close replication of Tipper et al.'s (2006) design in our present two ERP experiments yielded no evidence for the grasping affordance view. As mentioned above, one notable difference between their study and the present study is the total number of trials (128 trials in theirs; 768 trials per display condition in ours due to the need for minimizing ERP noise). It is possible that the grasping affordance effect occurred initially but dissipated over blocks. To evaluate this possibility, we analyzed the correspondence effect on RT as a function of block (2-9; Block 1 was a practice block), object display condition (base-centered vs. object-centered), and object state (active vs. passive). In Experiment 1, neither the main effect of block nor its interactions with object display and state were significant, $Fs(7, 133) \leq 1.66$, $ps \geq .1241$, η_p^2s $\leq .08$. The correspondence effect averaged across the active and passive state conditions was 21, 26, 23, 18, 25, 18, 23, and 24 ms from Blocks 2 to 9, respectively, for the based-centered condition, and was -8, -6, -7, -23, -23, 5, 6, and -2 ms, respectively, for the object-centered condition. Similar results were observed in Experiment 2 – neither the main effect of block nor its interactions with object display and state were significant, $Fs(7, 119) \leq 1.51$, $ps \geq .1703$, η_p^2s $\leq .08$. The correspondence effect averaged across the active and passive state conditions was 36, 28, 25, 21, 25, 32, 29, and 20 ms from Blocks 2 to 9, respectively, for the based-centered condition, and was -11, -16, -24, -18, -8, -16, -2, and -7 ms, respectively, for the object-centered condition. Thus, there was no evidence that the grasping affordance effect occurred early in the experiment.

One noteworthy finding in our study concerns the nature of action state of the object. According to the affordance view, a larger correspondence effect should have been observed in the active object state than the passive object state because the active object state implies the on-going action (e.g., Tipper et al., 2006). We did not find any evidence in the behavioral and EEG data supporting this argument for both the base-centered and object-centered display conditions. Our results in the base-centered display conditions actually showed an opposite pattern – larger correspondence effects for the passive object state than the active object state in both Experiment 1 (28 ms vs. 16 ms, respectively) and Experiment 2 (35 ms vs. 19 ms). The larger correspondence effect for the passive state likely is due to the more explicit object location information (left vs. right) conveyed by the horizontal alignment in that state compared to the angled alignment when the object was depressed and rotated downward (the active state; see Cho & Proctor, 2013). Thus, these findings indicate that the action state of the object did not highlight the grasp-afforded object feature and subsequently enhance the intended response/action.

Despite the non-replication of Tipper et al.'s (2006) finding, one could still propose that affordance effects do occur but are relatively weak in the present study. It is possible that when spatial-location information is salient, as in the base-centered condition where the handles were positioned left or right side of the central fixation point, the strength of the spatial-location effect could overshadow the affordance effect, leaving the latter effect difficult to detect. In contrast, when there is no explicit spatial-location information, as in the object-centered condition where the handles were displayed in a centered location on the screen, the affordance effect might be easier to detect. Although we are skeptical of this view, it nevertheless provides one possibility for future efforts to demonstrate an affordance effect.

<u>Conclusions</u>

Across two experiments, we observed that the object-based correspondence effect was modulated by the object location but not the object affordance in behavioral data (RT and PE). The effect does not appear to be due to a visual-action binding of the grasp-afforded object feature. It remains unclear for why Tipper et al. (2006) observed an effect of grasping affordance, whereas our two experiments as well as several experiments of Cho and Proctor (2011, 2013) showed no effects using the same stimulus display condition (the object-centered condition) and procedures. We emphasize that the present experiments were programmed and conducted completely separately from those of Cho and Proctor (2011, 2013) and thus represent an independent replication. Our additional measures of P1 and N1 ERP data also provide little converging evidence that perceptual judgments about an object (such as whether the door handle was square or round or blue or green) are affected by the orientation of the grasping component with respect to the effector used for the response. Together, our findings are counter to the view that grasping affordances contribute substantially to the performance of tasks requiring keypress responses. Instead, they support the view, advocated by Proctor and Miles (2014) from a detailed review of the literature, that spatial coding is the primary determinant of the obtained object-based correspondence effects.

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Footnotes

1. We thank one anonymous reviewer for suggesting this possibility.
2. One anonymous reviewer suggests that including both left- and right-handed individuals could bias the grasping affordance effect. We believe that this bias was unlikely to be present in the current study since the correspondence effect was averaged across left and right hands for each participant. Therefore, participant's handedness should have little influence on the results. Nevertheless, we followed the reviewer's suggestion and analyzed the data including only right-handed individuals (2 were excluded from both Experiments 1 and 2). The results were very similar as the overall analyses reported in the main text. In Experiment 1, the critical three-way interaction between the display condition, object state, and correspondence was still significant, $F(1, 17) = 19.19$, $p < .001$, $\eta_p^2 = .53$. The correspondence effects were 16 ms and 30 ms for the active and passive objects, respectively, in the base-centered display condition and were -1 ms and -8 ms, respectively, in the object-centered display condition. Similarly, the three-way interaction was still significant in Experiment 2, $F(1, 15) = 24.40$, $p < .001$, $\eta_p^2 = .62$. The correspondence effects were 19 ms and 35 ms for the active and passive objects, respectively, in the base-centered display condition and were -8 ms and -21 ms, respectively, in the object-centered display condition.

Table 1. Mean Response Time (RT) in Milliseconds and Proportion of Errors (PE) as a Function of Object Display Condition (Base-Centered vs. Object-Centered), Object State (Active vs. Passive), and Response-Hand/Handle-Orientation Correspondence (Corresponding vs. Noncorresponding) in Experiment 1.

Object State	Correspondence				*Correspondence Effect*	
	Corresponding		Noncorresponding			
	RT	PE	RT	PE	*RT*	*PE*
Base-Centered Display Condition						
Active	444 (15)	.021 (.004)	460 (15)	.041 (.006)	*16 (3)*	*.020 (.004)*
Passive	442 (16)	.020 (.004)	470 (14)	.049 (.008)	*28 (4)*	*.029 (.007)*
Object-Centered Display Condition						
Active	435 (15)	.025 (.006)	434 (14)	.027 (.005)	*-1 (3)*	*.002 (.005)*
Passive	443 (16)	.035 (.007)	435 (14)	.027 (.004)	*-8 (4)*	*-.008 (.005)*

Note: The standard error of the mean is shown in parentheses.

Table 2. Mean Response Time (RT) in Milliseconds and Proportion of Errors (PE) as a Function of Object Display Condition (Base-Centered vs. Object-Centered), Object State (Active vs. Passive), and Response-Hand/Handle-Orientation Correspondence (Corresponding vs. Noncorresponding) in Experiment 2.

Object State	Correspondence				*Correspondence Effect*	
	Corresponding		Noncorresponding			
	RT	PE	RT	PE	*RT*	*PE*
Base-Centered Display Condition						
Active	396 (12)	.035 (.007)	415 (13)	.057 (.010)	*19 (3)*	*.022 (.005)*
Passive	391 (12)	.024 (.006)	426 (14)	.077 (.012)	*35 (4)*	*.053 (.009)*
Object-Centered Display Condition						
Active	403 (12)	.044 (.008)	396 (11)	.038 (.008)	*-7 (3)*	*-.006 (.005)*
Passive	412 (12)	.062 (.011)	393 (11)	.027 (.006)	*-19 (4)*	*-.035 (.009)*

Note: The standard error of the mean is shown in parentheses.

Figure Captions

Figure 1. Panel A shows the video clip presented to participants prior to the task in Experiment 1. Panel B shows an example of event sequence used for the base-centered, active condition and the object-centered, passive condition in Experiment 1. The base-centered condition and the object-centered condition were varied between blocks, whereas the active and passive conditions were varied from trial to trial within blocks. Only right handle, round objects are shown.

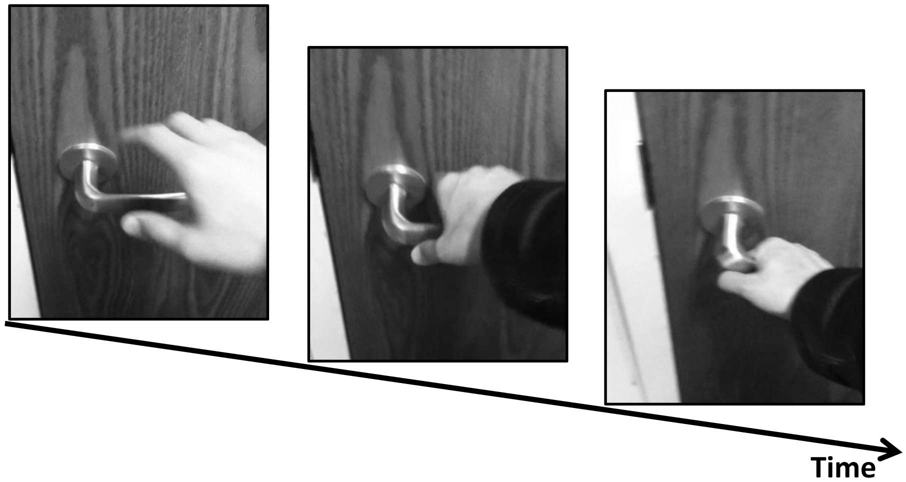
Figure 2. The scalp distribution of event-related potentials for every 24-ms interval during the time window 100-200 ms after stimulus onset in Experiment 1. These topographies indicated increased activity for parietal and occipital sites during this time window.

Figure 3. Grand average P1 and N1 waveforms across P7, P8, O1, and O2 electrodes as a function of object display condition (base-centered vs. object-centered) and object state (active vs. passive) in Experiment 1. Data are plotted as a function of whether the response hand and the door handle orientation were corresponding (both left or both right) or noncorresponding (one left and one right). The unfilled rectangular boxes indicate the time window used to assess the P1 effect (100-130 ms after stimulus onset) and the N1 effect (150-200 ms after stimulus onset). Negative is plotted upward and time zero represents stimulus onset.

Figure 4. Grand average P1 and N1 waveforms across P7, P8, O1, and O2 electrodes as a function of object display condition (base-centered vs. object-centered) and object state (active vs. passive) in Experiment 2. Data are plotted as a function of whether the response hand and the door handle orientation were corresponding (both left or both right) or noncorresponding (one left and one right). The unfilled rectangular boxes indicate the time window used to assess the P1 effect (100-130 ms after stimulus onset) and the N1 effect (150-200 ms after stimulus onset). Negative is plotted upward and time zero represents stimulus onset.

Figure 1

Panel A



Panel B

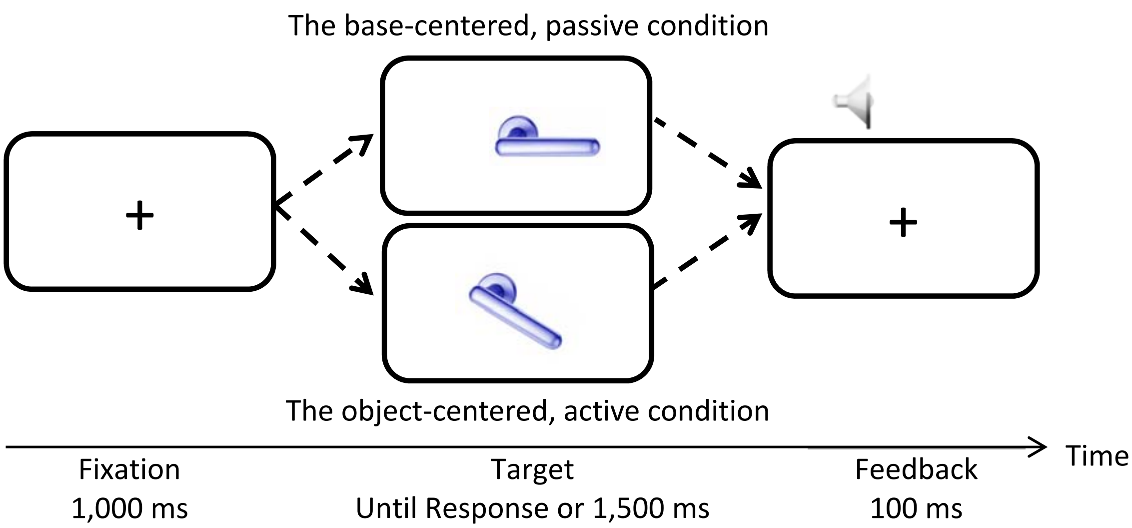


Figure 2

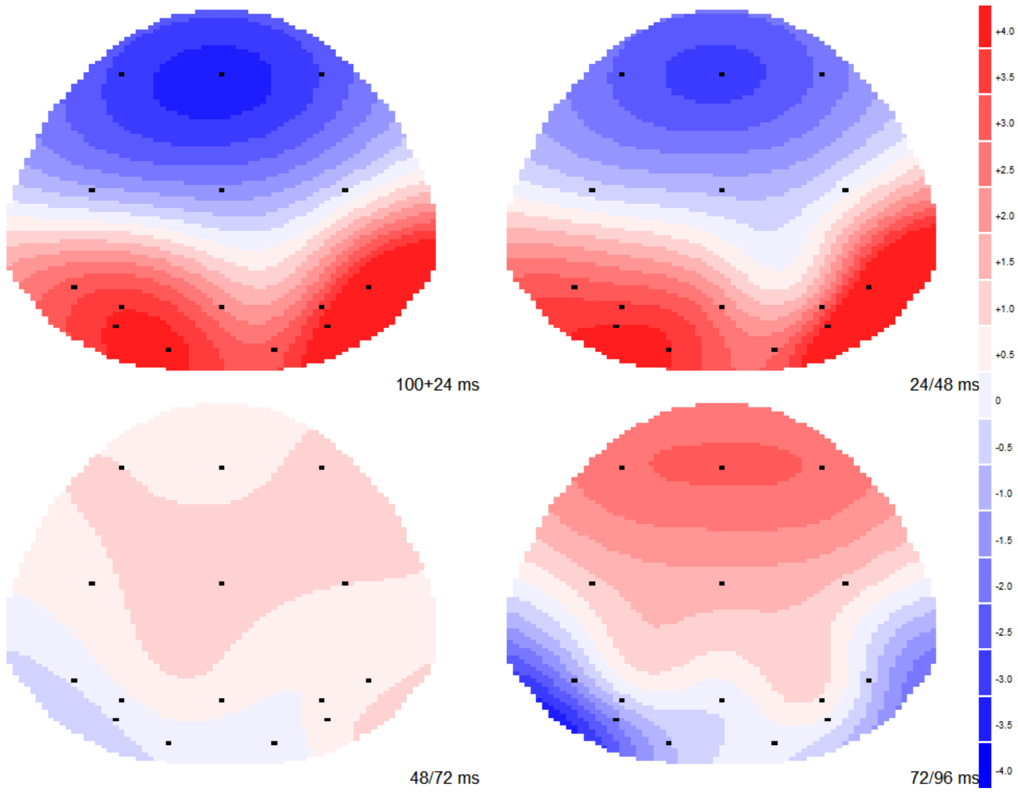
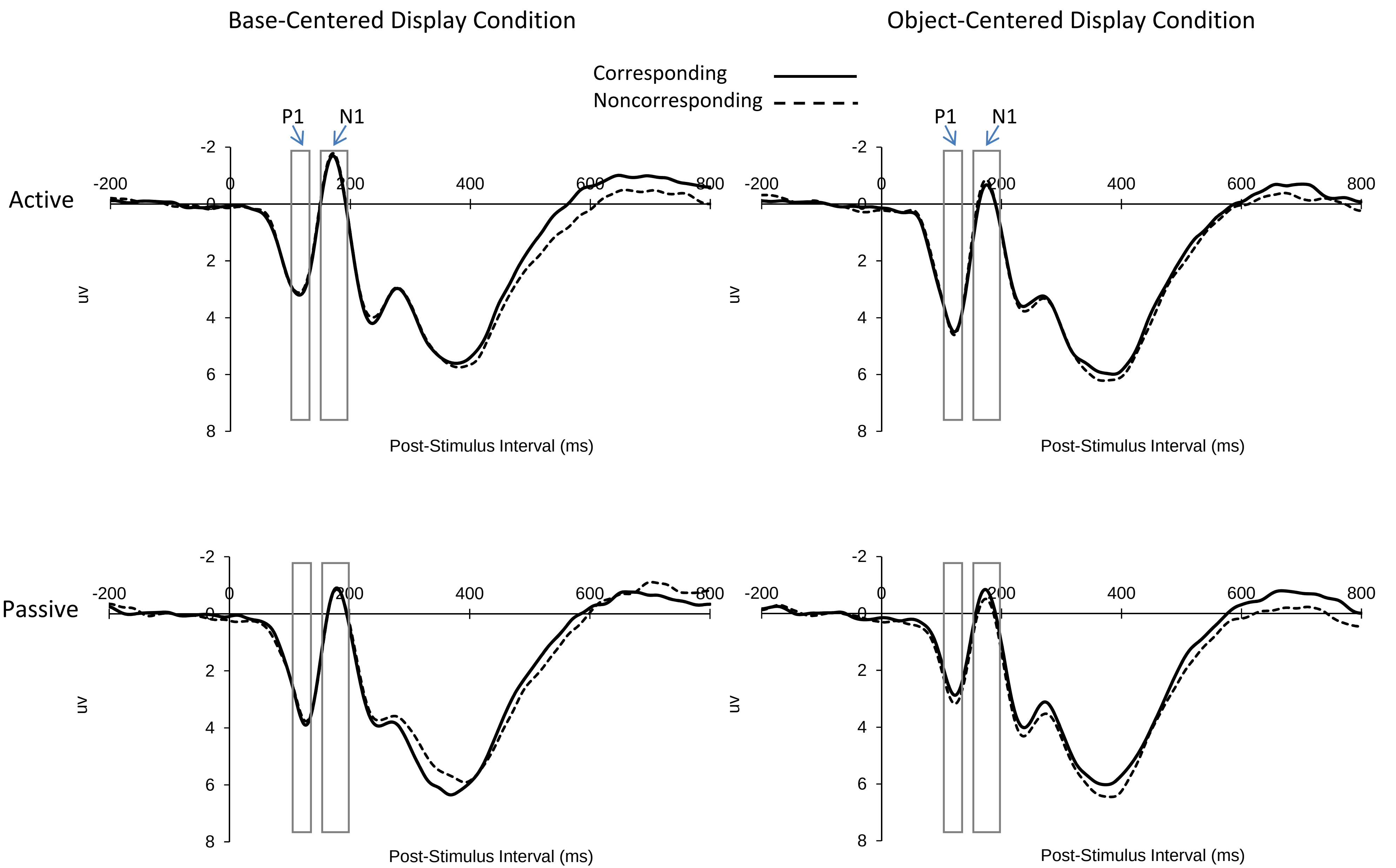
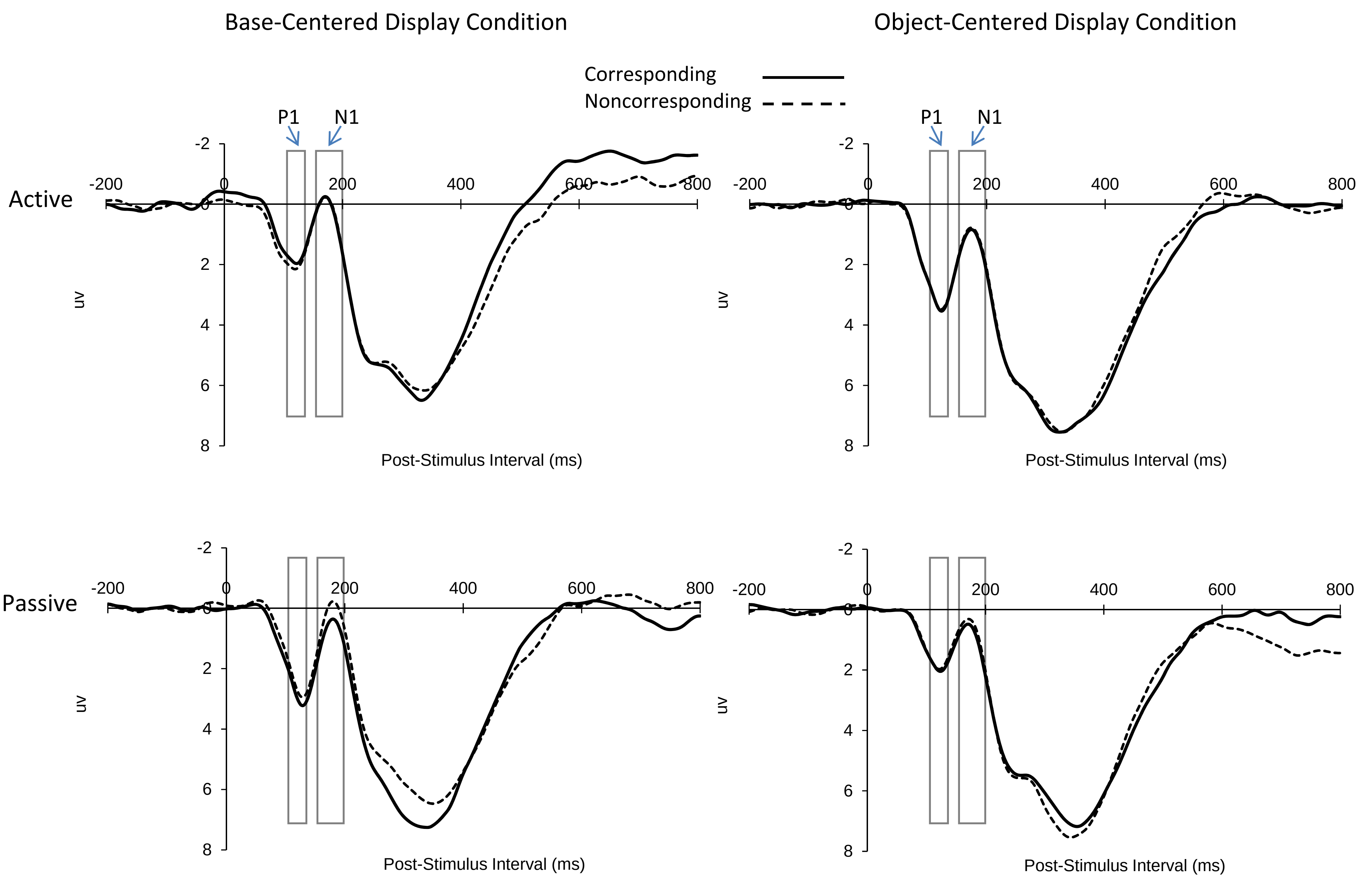

100+24 ms
24/48 ms
48/72 ms
72/96 ms
+4.0
+3.5
+3.0
+2.5
+2.0
+1.5
+1.0
+0.5
0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0

Figure 3



Base-Centered Display Condition
Object-Centered Display Condition
Corresponding
Noncorresponding
P1
N1
Active
Passive
-2
0
2
4
6
8
-200
200
400
600
800
uv
Post-Stimulus Interval (ms)

Figure 4



Base-Centered Display Condition
Object-Centered Display Condition
Corresponding
Noncorresponding
P1
N1
Active
Passive
uv
Post-Stimulus Interval (ms)
-200
0
200
400
600
800
-2
2
4
6
8

Appendix A

A Summary Table for ANOVAs on Average P1 and N1 as a Function of Object Display Condition (Base-Centered vs. Object-Centered), Object State (Active vs. Passive), Door Handle Orientation (Left vs. Right), Response Hand (Left vs. Right), Electrode Site (Parietal vs. Occipital), and Electrode Hemisphere (Left vs. Right) in Experiment 1.

Effect	*df*	P1			N1		
		F	*p*	η_p^2	*F*	*p*	η_p^2
Object Display (D)	1,19	2.22	.15	.10	4.08	.06	.18
Object State (S)	1,19	16.48	<.001	.46	5.37	<.05	.22
Handle Orientation (H)	1,19	<1.0	—	—	<1.0	—	—
Response Hand (R)	1,19	<1.0	—	—	<1.0	—	—
Electrode Site (Es)	1,19	3.06	.10	.14	1.64	.22	.08
Electrode Hemisphere (Eh)	1,19	1.78	.20	.09	2.1	.12	.12
D × S	1,19	26.55	<.0001	.58	8.52	<.01	.31
D × H	1,19	5.58	<.05	.23	2.09	.16	.10
D × R	1,19	<1.0	—	—	<1.0	—	—
D × Es	1,19	<1.0	—	—	17.57	<.001	.48
D × Eh	1,19	3.87	.06	.17	7.20	<.05	.27
S × H	1,19	<1.0	—	—	1.74	.20	.08
S × R	1,19	2.36	.14	.11	4.83	<.05	.20
S × Es	1,19	<1.0	—	—	26.19	<.0001	.58
S × Eh	1,19	<1.0	—	—	<1.0	—	—
H × R	1,19	<1.0	—	—	<1.0	—	—
H × Es	1,19	<1.0	—	—	<1.0	—	—
H × Eh	1,19	<1.0	—	—	2.59	.12	.12
R × Es	1,19	3.18	.09	.14	<1.0	—	—
R × Eh	1,19	42.64	<.0001	.69	8.37	<.01	.31
Es × Eh	1,19	23.36	<.0001	.55	<1.0	—	—
D × S × H	1,19	<1.0	—	—	<1.0	—	—
D × S × R	1,19	<1.0	—	—	<1.0	—	—
D × S × Es	1,19	13.92	<.01	.42	10.15	<.01	.35
D × S × Eh	1,19	<1.0	—	—	1.20	.29	.06
D × H × R	1,19	1.97	.18	.09	<1.0	—	—
D × H × Es	1,19	<1.0	—	—	1.93	.18	.09
D × H × Eh	1,19	<1.0	—	—	3.86	.06	.17
D × R × Es	1,19	13.04	<.01	.41	<1.0	—	—

D × R × Eh	1,19	35.68	<.0001	.65	<1.0	—	—
D × Es × Eh	1,19	<1.0	—	—	<1.0	—	—
S × H × R	1,19	<1.0	—	—	2.83	.11	.13
S × H × Es	1,19	1.58	.22	.08	<1.0	—	—
S × H × Eh	1,19	2.23	.15	.11	1.29	.27	.06
S × R × Es	1,19	5.52	<.05	.23	<1.0	—	—
S × R × Eh	1,19	7.25	<.05	.28	<1.0	—	—
S × Es × Eh	1,19	<1.0	—	—	2.83	.11	.13
H × R × Es	1,19	<1.0	—	—	<1.0	—	—
H × R × Eh	1,19	<1.0	—	—	<1.0	—	—
H × Es × Eh	1,19	<1.0	—	—	<1.0	—	—
R × Es × Eh	1,19	11.89	<.01	.38	6.69	<.05	.26
D × S × H × R	1,19	<1.0	—	—	1.69	.21	.08
D × S × H × Es	1,19	<1.0	—	—	1.31	.27	.06
D × S × H × Eh	1,19	<1.0	—	—	<1.0	—	—
D × S × R × Es	1,19	3.45	.08	.15	<1.0	—	—
D × S × R × Eh	1,19	<1.0	—	—	2.06	.17	.10
D × S × Es × Eh	1,19	4.86	<.05	.20	2.09	.16	.10
D × H × R × Es	1,19	2.95	.10	.13	1.28	.27	.06
D × H × R × Eh	1,19	<1.0	—	—	<1.0	—	—
D × H × Es × Eh	1,19	<1.0	—	—	<1.0	—	—
D × R × Es × Eh	1,19	28.09	<.0001	.60	<1.0	—	—
S × H × R × Es	1,19	1.12	.30	.06	<1.0	—	—
S × H × R × Eh	1,19	<1.0	—	—	1.89	.19	.09
S × H × Es × Eh	1,19	<1.0	—	—	<1.0	—	—
S × R × Es × Eh	1,19	1.40	.25	.07	<1.0	—	—
H × R × Es × Eh	1,19	1.82	.19	.09	2.87	.11	.13
D × S × H × R × Es	1,19	<1.0	—	—	1.21	.28	.06
D × S × H × R × Eh	1,19	<1.0	—	—	<1.0	—	—
D × S × H × Es × Eh	1,19	<1.0	—	—	<1.0	—	—
D × S × R × Es × Eh	1,19	<1.0	—	—	<1.0	—	—
D × H × R × Es × Eh	1,19	1.57	.23	.08	<1.0	—	—
S × H × R × Es × Eh	1,19	<1.0	—	—	<1.0	—	—
D × S × H × R × Es × Eh	1,19	4.69	<.05	.20	<1.0	—	—

Appendix B

A Summary Table for ANOVAs on Average P1 and N1 as a Function of Object Display Condition (Base-Centered vs. Object-Centered), Object State (Active vs. Passive), Door Handle Orientation (Left vs. Right), Response Hand (Left vs. Right), Electrode Site (Parietal vs. Occipital), and Electrode Hemisphere (Left vs. Right) in Experiment 2.

Effect	*df*	P1			N1		
		F	*p*	η_p^2	*F*	*p*	η_p^2
Object Display (D)	1,17	<1.0	—	—	2.22	.15	.12
Object State (S)	1,17	2.40	.14	.12	<1.0	—	—
Handle Orientation (H)	1,17	1.91	.19	.10	<1.0	—	—
Response Hand (R)	1,17	<1.0	—	—	<1.0	—	—
Electrode Site (Es)	1,17	<1.0	—	—	8.49	<.01	.33
Electrode Hemisphere (Eh)	1,17	<1.0	—	—	<1.0	—	—
D × S	1,17	30.34	<.0001	.64	2.54	.13	.13
D × H	1,17	<1.0	—	—	<1.0	—	—
D × R	1,17	1.31	.27	.07	2.64	.12	.13
D × Es	1,17	<1.0	—	—	2.07	.17	.11
D × Eh	1,17	<1.0	—	—	<1.0	—	—
S × H	1,17	<1.0	—	—	<1.0	—	—
S × R	1,17	<1.0	—	—	<1.0	—	—
S × Es	1,17	<1.0	—	—	19.00	<.001	.53
S × Eh	1,17	<1.0	—	—	<1.0	—	—
H × R	1,17	<1.0	—	—	1.57	.23	.08
H × Es	1,17	1.54	.23	.08	<1.0	—	—
H × Eh	1,17	<1.0	—	—	<1.0	—	—
R × Es	1,17	<1.0	—	—	2.84	.11	.14
R × Eh	1,17	30.11	<.0001	.64	13.83	<.01	.45
Es × Eh	1,17	4.27	.05	.20	3.63	.07	.18
D × S × H	1,17	<1.0	—	—	<1.0	—	—
D × S × R	1,17	2.13	.16	.11	<1.0	—	—
D × S × Es	1,17	17.07	<.001	.50	<1.0	—	—
D × S × Eh	1,17	13.15	<.01	.44	1.62	.22	.09
D × H × R	1,17	<1.0	—	—	<1.0	—	—
D × H × Es	1,17	<1.0	—	—	<1.0	—	—
D × H × Eh	1,17	<1.0	—	—	1.62	.22	.09
D × R × Es	1,17	2.08	.17	.11	<1.0	—	—

D × R × Eh	1,17	12.68	<.01	.43	9.62	<.01	.36
D × Es × Eh	1,17	1.39	.26	.08	<1.0	—	—
S × H × R	1,17	<1.0	—	—	1.05	.32	.06
S × H × Es	1,17	<1.0	—	—	<1.0	—	—
S × H × Eh	1,17	1.20	.19	.07	2.03	.17	.11
S × R × Es	1,17	2.29	.15	.12	3.28	.09	.16
S × R × Eh	1,17	<1.0	—	—	<1.0	—	—
S × Es × Eh	1,17	3.67	.07	.18	6.59	<.05	.28
H × R × Es	1,17	<1.0	—	—	1.42	.25	.08
H × R × Eh	1,17	<1.0	—	—	<1.0	—	—
H × Es × Eh	1,17	1.13	.30	.06	3.34	.09	.16
R × Es × Eh	1,17	3.26	.09	.16	1.99	.18	.11
D × S × H × R	1,17	<1.0	—	—	<1.0	—	—
D × S × H × Es	1,17	<1.0	—	—	<1.0	—	—
D × S × H × Eh	1,17	2.50	.13	.13	1.45	.24	.08
D × S × R × Es	1,17	10.74	<.01	.39	3.40	.09	.17
D × S × R × Eh	1,17	<1.0	—	—	2.93	.11	.15
D × S × Es × Eh	1,17	1.13	.30	.06	6.58	<.05	.28
D × H × R × Es	1,17	1.87	.19	.10	<1.0	—	—
D × H × R × Eh	1,17	<1.0	—	—	<1.0	—	—
D × H × Es × Eh	1,17	<1.0	—	—	<1.0	—	—
D × R × Es × Eh	1,17	10.28	<.01	.38	1.03	.32	.06
S × H × R × Es	1,17	<1.0	—	—	1.48	.24	.08
S × H × R × Eh	1,17	<1.0	—	—	<1.0	—	—
S × H × Es × Eh	1,17	<1.0	—	—	1.19	.29	.07
S × R × Es × Eh	1,17	<1.0	—	—	1.14	.30	.06
H × R × Es × Eh	1,17	<1.0	—	—	<1.0	—	—
D × S × H × R × Es	1,17	<1.0	—	—	<1.0	—	—
D × S × H × R × Eh	1,17	2.15	.16	.11	1.30	.27	.07
D × S × H × Es × Eh	1,17	<1.0	—	—	1.85	.19	.10
D × S × R × Es × Eh	1,17	<1.0	—	—	1.38	.26	.08
D × H × R × Es × Eh	1,17	8.28	<.05	.33	3.86	.07	.19
S × H × R × Es × Eh	1,17	<1.0	—	—	<1.0	—	—
D × S × H × R × Es × Eh	1,17	<1.0	—	—	<1.0	—	—