

Handles of manipulable objects attract covert visual attention: ERP evidence



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ABSTRACT

Previous research has demonstrated that people are faster at making a manual response with the hand that is aligned with the handle of a manipulable object compared to its functional end. According to theories of embodied cognition (ETC), the presentation of a manipulable object automatically elicits sensorimotor simulations of the respective hand and these simulations facilitate the response. However, an alternative interpretation of these data is that handles preferentially attract visual attention, since attended stimuli and locations typically elicit faster responses. We investigated attentional biases elicited by manipulable and non-manipulable objects using event-related-potentials (ERPs). On each trial, a picture of a manipulable object was followed by a target dot that participants had to make a button-press to. The dot was located at either the handle or functional end of the object. Consistent with previous attentional cuing paradigms, we showed that the P1 ERP component was greater in response to targets cued by handles than by functional ends. These results suggest that object handles automatically bias covert attentional processes. These attentional biases may account for earlier behavioural findings, without any recourse to ETC.

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1. Introduction

Behavioural research has revealed an intimate link between the visual perception of manipulable artifacts and motor responses. These results suggest that viewing manipulable artifact induces a sensorimotor simulation of the action that the object affords, even though performing an action is incidental to the task. For instance, Tucker and Ellis (1998) reported that participants were faster at making button responses with the hand (either the right or left) that was compatible with the orientation of an object's handle. A similar 'potentiation effect' has been observed in a number of other studies, showing that large objects can potentiate 'power grips' (i.e. gripping with the whole hand) and small objects potentiate 'precision grips' (gripping with the thumb and index finger; e.g. Tucker & Ellis, 2001). More recently, Masson, Bub, and Breuer (2011) have shown that the presentation of objects can prime the production of actions associated with the handle (e.g., the presentation of a vertical beer mug primes a vertical power grasp), suggesting that that the presentation of objects automatically specifies the action the object affords (see also Bub, Masson, & Cree, 2008). To account for these effects, the theory of embodied cognition (ETC) suggests

that object representations are spread across modality-specific cortices, and that visual perception of objects automatically activates associated motor, auditory, and somatosensory processes (e.g. Barsalou, 2008). From an embodied perspective, the visual presentation of objects automatically activates these associated processes, which in turn facilitates cognitive performance.

However, despite the growing support for the ETC account of object representations, in particular from cognitive linguistic tasks (e.g. property generation; see Barsalou, 2008; see also Pulvermüller & Fadiga, 2010), the degree to which the visual presentation of manipulable objects automatically invokes motor processes, and the extent to which these processes are involved in cognitive tasks, is unclear. Though it is known that the visual presentation of an object activates neurons in the motor system (e.g. the 'canonical' neurons, see Fadiga, Fogassi, Gallese, & Rizzolatti, 2000), and though this type of activation provides some support for the general idea of distributed, modality-specific, object representations, a small number of behavioural studies have shown that motor potentiation effects (e.g. faster button pressing when the response hand is aligned with a manipulable object's handle) are best explained by low-level attentional effects. For instance, Anderson, Yamagishi, and Karavia (2002) showed participants images of scissors and clocks, and had participants judge the left–right orientation of the objects and press a corresponding key with their right/left hands.

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On different trials, the key press was spatially compatible with different regions of the object, either the handle of the scissors or the hands of the clock. They found that left/right-hand motor responses are faster when they are compatible with the scissor handles *and* when they are compatible with salient but non-manipulable clock hands. The latter effect cannot reasonably be explained by automatic activation of associated motor processes. According to the authors, this result likely reflects attentional processes that bias button responses to one region of space based on attended object features (i.e. object handles and clock hands). This finding is supported by research from our lab (Matheson, White, & McMullen, 2013) that has shown motor potentiation in response to artifact handles *and* animal heads. Other studies have shown that attention to irrelevant features (e.g. a dot that appears with the object) can eliminate the potentiation effect (Vainio, Ellis, & Tucker, 2007), which suggests that attentional processes may be generating the effect. Finally, Cho and Proctor (2010) showed potentiation effects to a frying pan handle when responses were made with the index finger of different hands (i.e. participants responded faster when the handle was compatible with the responding hand) and when the responses were made with the index and middle finger on the same hand (i.e. participants responded faster with the finger that was in the same relative left/right spatial position as the handle). Because potentiation effects were observed when participants made responses with a single hand, the authors concluded that the potentiation effect is likely the result of a general stimulus–response compatibility effect to different regions of objects. If these findings are explained by low-level visual attention, parsimony precludes the ETC account and would force scrutiny upon the theory.

1.1. Assessing covert visual attention in response to manipulable vs. nonmanipulable objects

Overall, behavioural results suggest that low-level visual attention plays a role in generating the potentiation effect, a finding that is often interpreted as evidence in favour of embodied object representations. However, all other things being equal, attention to a particular location will result in faster reaction times to that location. Because this explanation has consequences for the theory of embodied cognition, it is important to determine the role of attention during the perception of manipulable and non-manipulable objects. Event related potentials (ERPs) are well suited to addressing this issue. This technique has been instrumental in characterizing early visual attentional processes (see Luck, 2003). One ERP index of attention is the P1 component, which is the first large positive deflection observed in waveforms over occipito-parietal electrodes. The P1 is larger in response to target stimuli (e.g. dots) in the attended visual field compared to targets in the unattended visual field. It has been argued that this reflects an increased ‘gain’ of neurons in spatiotopically-organized extrastriate visual regions that map object features or extrapersonal space (see Hillyard, Vogel, & Luck, 1998; Luck, Woodman, & Vogel, 2000; Yantis & Serences, 2003). For example, Mangun and Hillyard (1991), adopting the widely used Posner attentional cueing paradigm (Posner, 1980), had participants respond to target bars that were presented in either the left or right visual fields. An arrow primed the location of the target ‘validly’ (i.e. by pointing towards it) or ‘invalidly’ (by pointing away from it). The authors reported larger P1s to validly cued targets. They interpreted this as reflecting sensory gain at early visual processing stages and suggested that this early attention to stimulus location accounts for faster behavioural responding to that location. This interpretation has been supported by other studies using the same Posner-type paradigm (e.g. Eimer, 1994).

Very few ERP studies have investigated early visual processing in response to manipulable artifacts and non-manipulable objects

using ERPs. In one study, Handy, Grafton, Shroff, Ketay, and Gazzaniga (2003) had participants respond to target gabor-gratings that appeared in either the right or left visual field by pressing a left button for left-targets and a right button for right-targets (i.e. target detection). Importantly, images of manipulable artifacts (i.e. tools) or non-manipulable objects (e.g. animals) appeared as cues on each trial, simultaneously presented in the right and left visual fields. The authors reported larger P1s (i.e. P1 enhancement) to targets cued by artifacts, primarily when artifacts cued right-targets in the right visual field. The authors suggested that manipulable artifacts attract attention automatically in the right visual field and this supports visually guiding reaching and grasping.

This finding shows that the P1 is a good candidate for measuring early attentional processes and demonstrates that manipulable artifacts may attract attention in a unique way. Further, it shows that attentional biases can be measured in the absence of a task that explicitly requires participants to process the identity of objects (i.e. automatic attention to objects). This study provides ‘proof of concept’ that objects can be used as ‘cues’ in target localization tasks, analogous to the typical symbolic arrowheads used in the Posner paradigm. However, the study by Handy, Grafton, Shroff, Ketay, and Gazzaniga (2003) does not address the *specificity* of the attentional bias they report. The authors showed that entire objects in the right (lower) visual field will bias visual attention, but it remains unclear whether the handles of the artifacts are particularly salient features and whether this feature attracts early visual attention *per se*. Because they used a heterogeneous stimulus set (with object handles oriented to the left or the right or presenting objects without handles all together) it is unclear how their effects map onto the hypothesis that handles attract attention.

1.2. The present study

The present study addressed the question of whether the facilitation of motor responses by the handles of manipulable objects is attributable to automatic activation of motor schemas by visual perception, or by attentional biases elicited by handles. We exploited the P1 as an index of early visual attention to explore the automatic distribution of covert attention in response to artifact and animal pictures. The advantage of using the P1 component is that it indexes visual attention without requiring an explicit motor response, thus allowing us to measure attentional effects that occur before a motor responses are initiated. According to the ETC account, the visual presentation of manipulable objects automatically elicits activity in multiple modality-specific cortices, including motor representations, which in turn speed motor responses. Alternatively, an attentional account suggests that speeded reaction times might reflect an attentional bias that is generated in response to particular parts of objects, including the handles of manipulable objects. Such a bias is expected to lead to faster responding to cued locations, regardless of whether the cue affords action. We tested the hypothesis that specific parts of visually-presented manipulable and non-manipulable objects bias attention.

1.3. Experimental design

We measured the P1 in response to target dots that were spatially cued by different features of manipulable and non-manipulable objects. On each trial, a picture of a manipulable artifact or an animal (the cue) was presented centrally, oriented facing the right or the left. Following this, a target (black dot) appeared near the left or right side of the object. Participants made a speeded response using either the left or right hand to indicate the side that the target appeared on. Thus, by virtue of object orientation, the target was cued by either (a) an artifact handle, (b) an artifact functional end (e.g. the blade of a saw), (c) an animal head, or (d)

an animal tail (see Methods for details). The P1 in response to the target dots was measured as an index of early attentional biases induced by object orientation.

Our hypotheses were as follows. According to the attentional account of the ‘potentiation effect’, handles draw visual attention. If P1 enhancement is an index of increased early visual attention, then we should observe P1 enhancement in response to targets cued by artifact handles compared to artifact functional ends. Similarly, because motor potentiation has been observed in response to animal heads (Matheson et al., 2013), and there are increased eye fixations on animal heads (Kovic, Plunkett, & Westermann, 2009a), we predicted P1 enhancement in response to targets cued by animal heads relative to their tail-ends. Conversely, because the ETC account attributes motor potentiation to the spread of visual object activity to motor cortex only in the case of manipulable objects, early attentional biases to both animals and artifacts would not be predicted.

This experimental set-up has a number of strengths. First, the paradigm borrows heavily from the well-established Posner cueing paradigm (Posner, 1980), in which target localization is validly cued (e.g. with an arrow pointing to the correct location) or invalidly cued (e.g. with an arrow pointing to the incorrect location). By analogy, we defined our object images as cues that ‘point’ to the target locations congruently or incongruently. Specifically, we defined the left–right asymmetry of our objects as ‘arrows’ pointing in the direction of the head or the functional-end. Second, we measured P1s in response to target dots that were the same on every trial, eliminating differences in ERP responses that could be caused by variation in the physical stimuli.

2. Method

2.1. Participants

22 participants were recruited from Dalhousie University or surrounding area (9 males; mean age = 21.87, all right-handed). Subjects were free of any history of neurological disorder. All gave written consent to participate.

2.2. Materials

In all experiments, 40 greyscale photographs of natural objects (i.e. animals) and 40 greyscale photographs of man-made objects (i.e. tools and other manipulable human artifacts) were obtained from various photographic databases available online (see Table 1 for list of objects, and Fig. 1 for examples). These images served as ‘cues’ on each trial. Animals were used as control stimuli because they are non-manipulable and, like our manipulable artifacts they have a high degree of left/right asymmetry when shown in profile. Each object was presented on a white background in a side/profile view. The raw images of the two categories were equated on

Table 1
List of individual objects used in experimental tasks. Numbers correspond to unique instances of objects.

Artifacts		Animals	
Axe 1	Kettle 2	Bear1	Giraffe 1
Coffeepot 1	Knife 1	Bear 2	Giraffe 2
Coffeepot 2	Knife 2	Cheetah 1	Horse 1
Coffeepot 3	Mug 1	Cheetah 2	Horse 2
Frying pan 1	Mug 2	Deer 1	Lion 1
Frying pan 2	Pitcher 1	Elephant 1	Lion 2
Handsaw 1	Pitcher 2	Elephant 2	Seagull 1
Handsaw 2	Plantwaterer 1	Elephant 3	Sheep 1
Iron 1	Saucepan 1	Fox 1	Zebra 1
Kettle 1	Saucepan 2	Fox 2	Zebra 2

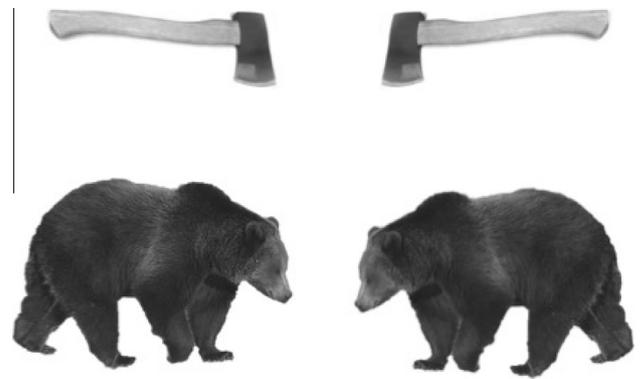


Fig. 1. Examples of the stimuli used in the present experiment from each category: artifacts (top); animals (bottom).

average area and average physical (i.e. pixel) luminance using graphics manipulation software. The stimuli were presented at approximately 10° of visual angle at a viewing distance of approximately 66 cm. In addition to the cues, solid black circles were used as ‘targets’. Targets were presented with a diameter of 1°, with their center 1° to either the left or the right of the lateral edge of each cue (i.e. they never overlapped with the image, with half a degree of white space between the edge of the target and the edge of the cue image). Fig. 2 shows the relative positioning of the cue and target.

Stimuli were presented on a 45 cm wide Asus LCD monitor with a refresh rate of 60 Hz and a screen resolution of 1440 × 900 pixels at 96 DPI. Presentation was controlled using a custom Python script running in Windows XP (Microsoft, Washington). Eye movement data were monitored with an Eyelink II Desk Mounted Eye-tracking system (v. 2.22, SR Research Ltd., Mississauga, ON) sampling at 500 Hz, with a spatial accuracy of .05 degrees. An eye movement was defined as whenever the recorded position of the eye moved 3 degrees in any direction from a central fixation; saccades were defined as eye movements that that reached a velocity of at least 22 degrees/s.

2.3. ERP recording procedures

Continuous EEG data was acquired from 32 Ag/AgCl electrodes using the BioSemi ActiveTwo recording system (Metting van Rijn,

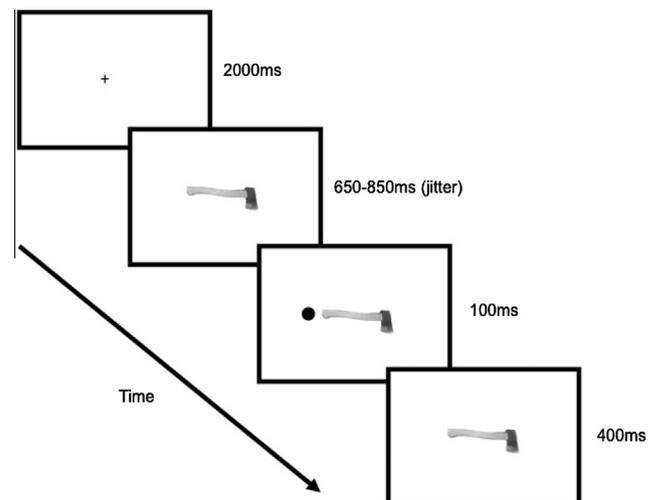


Fig. 2. Schematic representation of the timing and events of the experimental paradigm.

Peper, & Grimbergen, 1990) digitized at 2 kHz and stored offline for later analysis. The electrodes were embedded in an elastic nylon cap at their standard locations (according to the 10–20 coordinate system). To measure horizontal eye movements, additional electrodes were placed at both external canthi. Further, electrodes placed over the left eye (fronto-polar) and under the left eye (inferiorly) allowed us to detect any eye-movements that might not have triggered the Eyelink system. Two electrodes were placed directly over the mastoid bone bilaterally to be used as references in postprocessing.

2.4. Procedure

Participants were fitted with the electrode cap and electrodes were put into place. Next, the Eyelink monitor was calibrated using a 4-point calibration. To do so, participants put their chin in a chin rest mounted on the desk approximately 12 cm high (the chair was adjusted so this height was as comfortable as possible). Once calibrated participants completed a short practice session with images that were not used in the experiment. In the experiment, each trial began with the presentation of a fixation cross (.8 degrees wide) for 2000 ms. The cue object was presented centrally (facing either the left or the right) for a period between 650 and 850 ms (randomly chosen on each trial). The image remained on the screen and the target dot appeared for 100 ms. The cue image remained on the screen for an additional 400 ms. Participants were instructed to localize target dots by pressing the 'z' key if the target dot was on the left or the '/' key if it was on the right. Participants had 6000 ms to respond before an error would appear. The inter-trial interval was 1000 ms. Trials were self paced and initiated with the 'space bar' key. Participants were encouraged to take breaks when needed. See Fig. 2 for a schematic of the trial sequence.

The use of the chin rest ensured a constant viewing angle and reduced extraneous movement, facilitating eyetracking. Importantly, on any trial for which the Eyelink monitor detected a saccade outside of the predefined central region, or lost track of the pupil during an eye blink, an error message appeared encouraging participants not to move their eyes. These trials were "recycled", meaning that the ERP recorded for that trial was flagged to not be included in later analysis and the same trial was presented at a later, random point in the experiment.

2.5. ERP Data preprocessing and analysis

Data were re-referenced to the average of the two mastoids upon import to the EEGLAB toolbox (v. 9.0.8.6b Delorme & Makeig, 2004), as it is implemented in MATLAB software (v. 7.7.0.471; Mathworks, MA). Data were filtered (0.3–40 Hz bandpass) and visually inspected for artifacts. For a small number of subjects, an electrical artifact appeared in one electrode and was interpolated using the interpolation tool in EEGLAB. The raw data were epoched with the ERPLAB (<http://erpinfo.org/erplab>) toolbox with a 200 ms pre stimulus baseline and a 300 ms post stimulus time window. Epochs were generated with respect to the target-dot stimulus. Once epoched, artifacts were removed using a threshold-based rejection (any deflections larger than $\pm 100 \mu\text{V}$); because trials with eye blinks were eliminated during the experiment, very few trials (7.3% of all trials) were rejected (i.e. due to skin potentials or other movement artifacts). Epochs were visually inspected after artifact rejection to ensure no obvious artifacts remained in the data. Finally, ERPs from single trials were averaged for each subject.

2.6. P1 analysis strategy

The P1 was characterized as the mean amplitude of a preselected time window surrounding the peak of the first positive

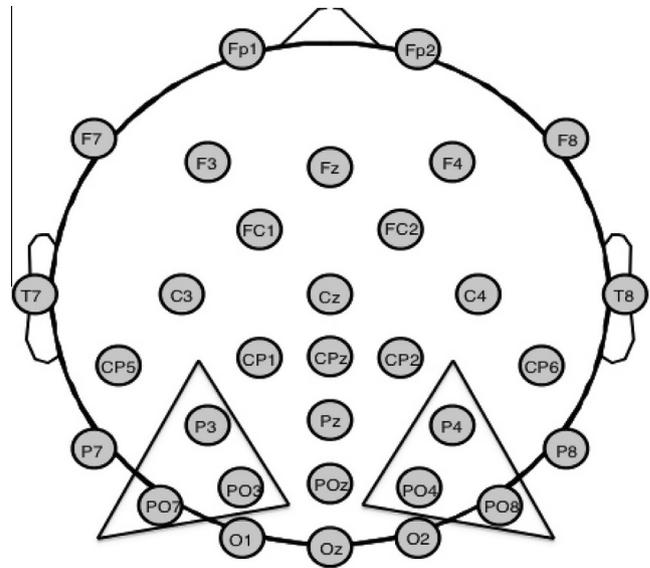


Fig. 3. Schematic of electrode placement (dorsal view, nose at top). Electrodes within triangles were analyzed as regions of interest.

deflection. We selected data between 120 and 160 ms for the P1 (see Mangun, Hillyard, & Luck, 1993). This peak was observed broadly over bilateral posterior occipitoparietal electrodes. To best characterize this peak and to increase statistical power we collapsed data from three electrodes in the left (P3, PO3, PO7) and right (P4, PO4, PO8) hemispheres. See Fig. 3 for electrode placement and regions of interest.

P1 data were aggregated and submitted to an Analysis of Variance (ANOVA), as it is implemented in the *ez()* package (v. 4.1.1; Lawrence, 2012) in R statistical computing software (v. 2.15.1; R Core Team, Vienna, Austria). To increase statistical power, we collapsed mean amplitude measures across hemispheres (i.e. targets that fell into the left and right visual fields) into ipsilateral and contralateral conditions. Thus, we used a 2 (category; animals vs. artifacts) \times 2 (cue; functional-end/head vs. handle/tail) \times 2 (hemisphere; contralateral vs. ipsilateral) repeated measures ANOVA. Fisher's Least Significant Differences are reported to compare conditions means. With this procedure, when an ANOVA effect is statistically significant, FLSD is a minimal value that is required for a statistically significant *t*-test at the alpha .05 level.

3. Results

3.1. Behavioural results

To verify that participants were on task and to explore motor potentiation, we submitted behavioural accuracy and reaction time data to a 2 (category; artifact vs. animal) \times 2 (compatibility; functional-end/head vs. handle/tail) Analysis of Variance (ANOVA).¹ For this analysis, compatibility was defined as a spatial compatibility with between the target and relevant object features (i.e. which features were cued by the target). For simplicity, we have defined the orientations of the two categories of objects such that the tail and the handle or the functional end and heads are grouped together. Thus, for targets appearing on the right or the left of center,

¹ As a measure of effect size we present the generalized eta squared. Unlike partial eta square (in which the number of factors in an experiment can influence the calculated size), generalized eta squared is designed to reduce the influence of the number of factors in an experiment, giving values that are easily comparable across experiments with different designs; however, the measure still follows conventional definitions for small, medium, and large effects (see Olejnik & Algina 2003).

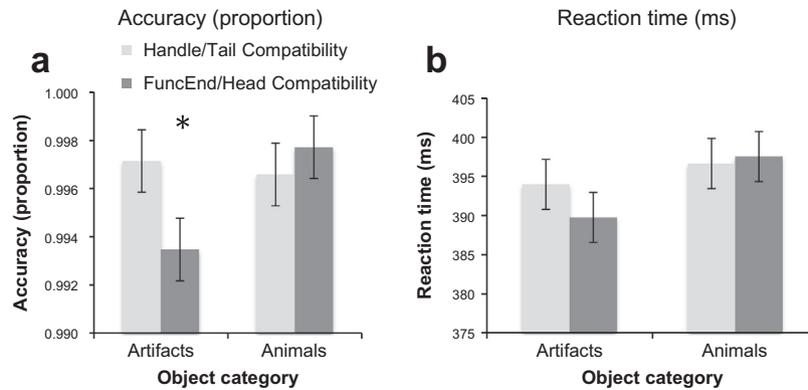


Fig. 4. Accuracy (proportion correct; left) and reaction time (ms; right) as a function of object category and target-cue compatibility. Error bars represent Fisher's Least Significant Difference.

they could cue the handle or the tail (i.e. 'Handle/Tail Compatibility') or (similarly for the right) the functional end or the head (i.e. 'Functional End/Head Compatibility').

Accuracy was overall very high (>.99%).² The ANOVA revealed a Category \times Compatibility interaction, $F(1,21) = 6.89$, $p = .002$, $\eta_c^2 = .03$. This interaction is due to a significant difference (Fisher's Least Significant Difference) between targets cued by handles ($M = .997$, $SD = .005$) compared to targets cued by functional ends ($M = .993$, $SD = .01$), while there is no significant difference between responses to targets cued by tails ($M = .996$, $SD = .006$) and targets cued by heads ($M = .997$, $SD = .006$). No other effects reached significance, $ps > .05$. See Fig. 4a.

To analyze reaction time, only correct trials were used. Additionally, reaction times less than 200 ms or greater than 2000 ms were excluded (this procedure removes extreme values that were due to responses that were too fast to have been processed and responses that were too slow). We then removed outlier RTs that were greater than 2.5 standard deviations from the mean on a subject-by-subject basis (2.35% of trials). The ANOVA revealed a significant effect of object category, $F(1,21) = 4.92$, $p = .004$, $\eta_c^2 = .0004$, due to faster responding to artifacts ($M = 391.88$, $SD = 126.43$) than to animals ($M = 397.10$, $SD = 132.94$). No other effects were significant, $ps > .05$. See Fig. 4b.

In summary, participants responded quickly and with high accuracy to targets cued by both artifacts and animals, though there is evidence that a target response is more accurate (but not necessarily faster) to targets cued with artifact handles. Further, we have revealed a general category effect, with artifact cues resulting in faster target localization overall.

3.2. P1 results

Grand average ERP waveforms from each of the three electrodes of interest, as well as the topoplots of voltage at 150 ms post stimulus, are shown in Fig. 5. In Fig. 5a, we've plotted ERPs in response to targets on the left from electrodes over the left occipitotemporal areas; in Fig. 5b, we've plotted ERPs in response to right targets over right occipitotemporal areas. The waveforms show a P1–N1–P2 component pattern typical of the response to visual stimuli. The waveforms suggest a P1 enhancement for targets cued by artifact handles relative to their functional ends; a slightly larger P1 was also observed for animal tails relative to heads, but this difference appeared smaller in magnitude than for artifacts and was not consistent across sites.

² Note that the high accuracy rate represents a ceiling effect, and therefore the interpretation of the pattern of results should be made with caution.

Fig. 5 also shows topoplots for each cue-target combination at 150 ms post stimulus. Note the evidence of a larger P1 positivity in the left hemisphere to left targets and in the right hemisphere to right targets. The 2 (category; artifacts vs. animals) \times 2 (cue region; head/functional end vs. tail/handle) \times 2 (hemisphere; contralateral vs. ipsilateral) repeated measures ANOVA revealed a significant main-effect of hemisphere, $F(1,21) = 15.88$, $p = .0007$, $\eta_c^2 = .102$, demonstrating larger P1s in response to ipsilateral ($M = 2.11$, $SD = 1.65$) compared to contralateral ($M = .61$, $SD = 2.31$) targets. The ANOVA also showed a marginal two-way Cue Region \times Category interaction, $F(1,21) = 4.06$, $p = .057$, $\eta_c^2 = .014$. This interaction appeared because of a greater effect of cue for the artifacts than the animals.³ Specifically, we observed P1 enhancement in response to targets cued by artifact handles ($M = 1.62$, $SD = 2.1$) compared to artifact functional ends ($M = .81$, $SD = 2.36$) (Fisher's Least Significant Difference = .77). Though the difference in the animals was in the hypothesized direction, with larger P1s in response to targets cued by animal heads ($M = 1.63$, $SD = 1.77$) than animal tails ($M = 1.39$, $SD = 2.01$), it failed to reach significance. See Fig. 6.

4. Discussion

We measured the P1 as an index of early visual attention to object features. In light of the growing evidence for 'embodied' object representations, it is important to investigate low-level attentional explanations of the potentiation effect (e.g. Matheson et al., 2013). We predicted P1 enhancement in response to targets cued by artifact handles compared to artifact functional ends. In support of our hypothesis, we showed greater P1 amplitudes to target dots cued by artifact handles than artifact functional ends (e.g. the head of an axe). In contrast, no reliable differences were found between targets cued by animal heads compared to animal bodies, failing to support this prediction. Consistent with these electrophysiological results, accuracy was higher for detecting targets cued by artifact handles compared to artifact functional heads, but not between animal heads and bodies.

These findings support the notion that covert visual attention is biased towards artifact handles. We argue that, because P1 is an

³ Because the interaction of interest was marginally significant, we conducted further inferential statistics based on the Bayes factor using the procedure recommended by Masson (2011; see also Wagenmakers, 2007). This procedure estimates the posterior probabilities of two competing models and converts them into a conditional probability that the full model (i.e. an interaction is present) is more likely than the null model (i.e. no interaction). In our analysis of the interaction, the probability favoring the interaction over the null was $p_{BIC} = .60$, which is considered evidence in favour of the hypothesis, though it is 'weak' (see Raftery, 1995). Because this interaction is predicted, we interpret this as evidence of a bias in the P1 response.

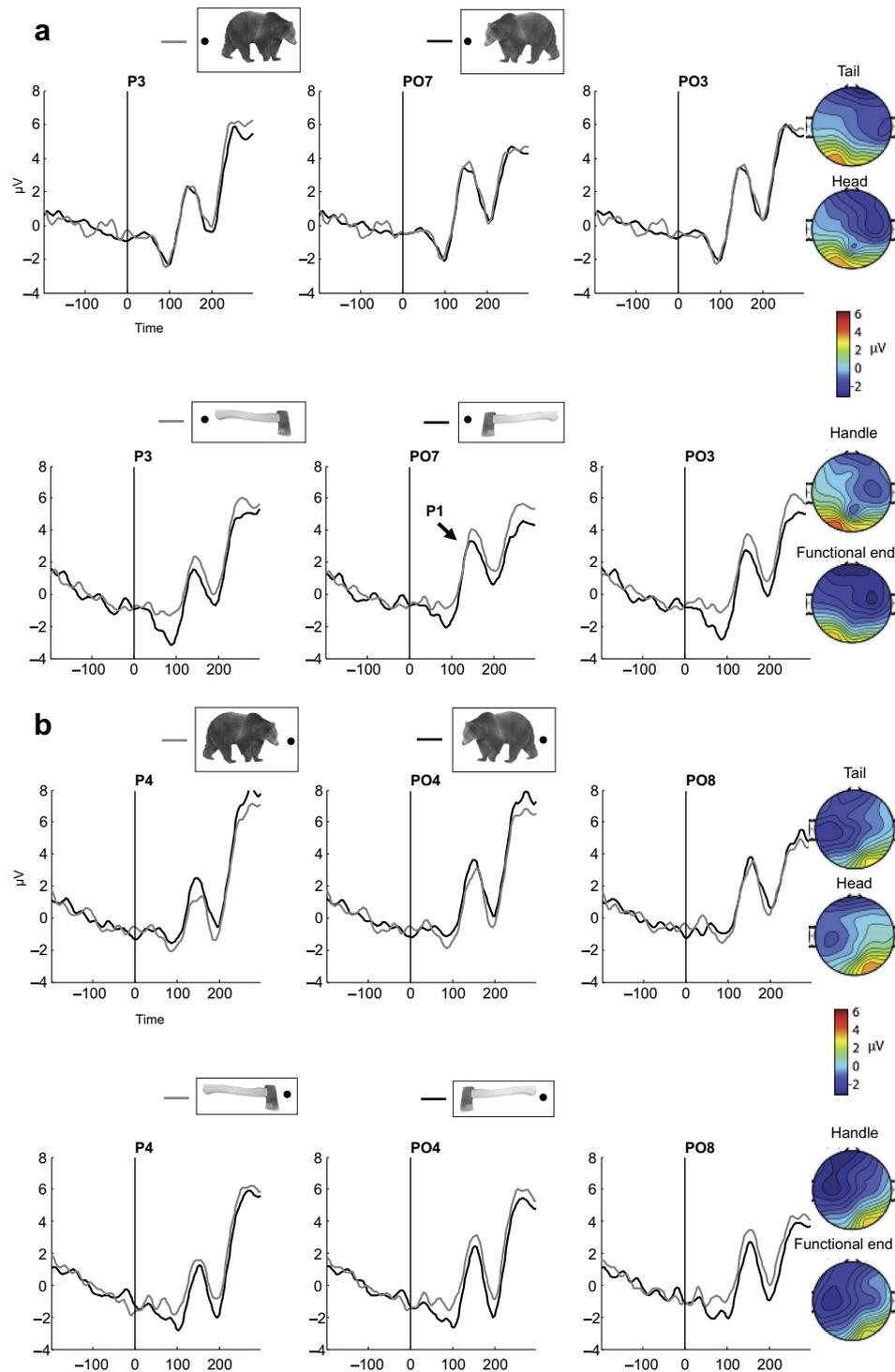


Fig. 5. Grand average waveforms and topoplots from electrodes of interest in response to targets presented in the left (5a) and right (5b) visual fields, for each of the four cues: Animal head (grey) animal tail (black), artifact functional end (grey), and artifact handle (black). Topoplots represent voltage distribution of the scale at 150 ms post stimulus onset.

early index of visual attention, it likely precedes activation of sensorimotor simulation in the motor or premotor cortices. Because of the latency of this effect, it is unlikely that the potentiation effect (faster responding to the same spatial location as a handle) reflects the ETC proposal of spreading activation from the visual system to the motor cortex; rather, this early effect suggests that handles automatically captures visual attention, and that this bias occurs early. Thus, low-level visual attention is a parsimonious account of the potentiation effect, and precludes the ETC account.

According to our view, categorization of the object cues led to visual attentional bias in early extrastriate cortex for artifact handles. However, we did not observe significant attentional bias to animal heads in the present experiment. One possible explanation is that animals are salient enough as an object category that they broadly attract attention, therefore eliminating a bias to one particular feature. Indeed, using a change detection paradigm, [New, Cosmides, and Toobey \(2007\)](#) have shown that animals do seem to broadly capture attention in visual scenes (but tools do

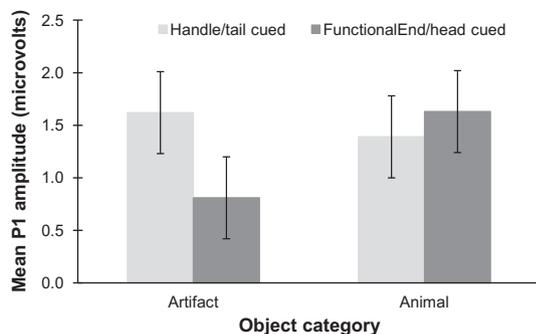


Fig. 6. Plot of the mean P1 amplitude as a function of category and cued region. Error bars represent Fisher's Least Significant Difference.

not), an effect they interpret as reflecting a category-specific tuning of low-level attention. If they are correct, we would expect no difference in P1 responses based on animal-head or animal-tail cues. Indeed, we did not show any evidence of a potentiation effect for animal heads (i.e. faster responding to with the hand that is compatible with the location of the animal head), failing to replicate other behavioural results (e.g. Matheson et al., 2013). One possible explanation for this difference comes from the obvious difference in the present task and the ones we used earlier. Indeed, in our previous studies, object categorization was an explicit task of participants; here, it was implicit. Future research should explore in more detail the task parameters that lead to attentional biases that facilitate manual responses that are compatible with different object features (e.g. head vs. tail vs. whole object). We suspect that these task differences alter attentional biases in object-specific ways, and may account for a number of effects that are often interpreted as 'embodied'.

The P1 results presented here support a growing body of behavioural research that has shown the ways in which visual attention speeds manual responses that are made with hands compatible with salient object features (Anderson et al., 2002; Cho & Proctor, 2010; Matheson et al., 2013; Vainio et al., 2007; see also Pellicano, Iani, Borghi, Rubichi, & Nicoletti, 2010). The growing consensus from this literature is that faster responding with the limb that is in the same spatial location as an object handle reflects an early attentional bias to that region of space. Our electrophysiological results suggest that this bias is automatic, occurring early in the visual processing of an object. We suspect that a history of reaching towards and grasping manipulable objects increases the saliency of this part of the object. Future research using novel objects can train individuals to use objects in particular ways to determine how these biases develop.

In summary, using the P1 as an index of early visual attention, we have shown that artifact handles automatically bias low-level visual attentional processes that are associated with superior target detection performance. This finding provides an alternative explanation of the ETC account of the potentiation effect and suggests covert visual attention plays a role in the early processing of manipulable vs. non-manipulable objects.

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