Attentional orienting to graspable objects: what triggers the response?

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We used event-related potentials to determine whether attentional orienting to graspable objects depends on the type of motor representation they implicitly activate – object and/or hand specific. Our paradigm was based on varying the visual hemifield location (left vs. right) of a task-irrelevant 'tool'. As our left-handed participants had object and hand-specific motor representations lateralized to their left and right cerebral hemispheres, respectively, the motor representation activated on each trial thus varied with the tool's hemifield. In question was whether attentional orienting would also vary with the tool's hemifield. Our ERP data, however, indicated that attention was drawn to the tool's location regardless of hemifield, suggesting that graspable objects can trigger attentional orienting via either an object or hand-specific motor representation. NeuroReport 18:941–944 © 2007 Lippincott Williams & Wilkins.

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Introduction

Objects that we associate with grasping – things such as cups, utensils, cell phones, and so on – appear to have a special hold on our visual attention. For example, brain lesion patients suffering a loss of awareness for objects in their left visual hemifield can overcome this awareness deficit if the object is graspable [1,2]. Likewise, not only do graspable objects automatically activate motor-related processing regions in cortex [3–5], but this can have a feedback influence on the orienting of visual attention to that object's spatial location [6] – all at an implicit, nonconscious level. But given this ability of graspable objects to automatically bias visual attention, how do they actually do it? What is it about a graspable object that can actually trigger a visual–spatial orienting response?

When a graspable object comes into view at least two specific motor representations are implicitly activated in cortex: one associated with the object's manual engagement characteristics (i.e. an ideomotor praxis representation), and one associated with the hand to be used for grasping [7–11]. As it is the generation of these object and hand-specific motor representations that appear to distinguish the processing of graspable from nongraspable objects in cortex, we hypothesized that their implicit activation [3–5] may play a key role in triggering attentional orienting responses.

To test this hypothesis, we turned to a consideration of where these motor representations are lateralized in cortex. Although hand-specific motor representations are strongly biased toward the cerebral hemisphere controlling the motor-dominant hand [12,13], ideomotor praxis representations are lateralized to the left cerebral hemisphere regardless of hand dominance [14–16]. The importance of this

point emerges when one considers Handy et al. [6], who reported that visual attention was drawn to a graspable object's location only when it was in the right visual field (RVF) – an asymmetry notable in that the participant cohort was right-hand dominant. Because each cerebral hemisphere has preferential access to a stimulus presented in the contralateral visual hemifield [17], attention was thus oriented only to graspable objects when they were in the visual hemifield optimal for activating both object and hand-specific motor representations in dextrals: the RVF. It thus remains uncertain whether activation of either or both of these representations may be the critical factor for triggering an attentional response. To address this issue we thus replicated the paradigm used by Handy et al. [6] in a left-hand dominant participant cohort – a cohort having object and hand-specific motor representations lateralized in the left and right hemispheres, respectively. In question was whether attention would get drawn to graspable objects in one, both, or neither visual field location(s).

Methods

Participants

Eight left-handed volunteers participated (five females; mean age: 22.4 years, range 19–31). All gave informed consent and had normal or corrected-to-normal vision. All protocols were approved by the UBC Clinical Research Ethics Board. To qualify, volunteers had to respond 'left-hand only' on at least seven of the first 10 items on the Edinburgh Handedness Inventory [18], those items that concern unimanual grasping (mean: 9.1 items; range: 7–10 items).

Stimuli and procedures

On each trial, participants maintained fixation while two task-irrelevant objects were presented, one in each upper visual hemifield. The objects were from a canonical set of line drawings [19] and were onscreen for 650–850 ms before the presentation of a square-wave target that was briefly (100 ms) superimposed over one of the two objects. The objects remained onscreen for another 400 ms, followed by an intertrial interval of 2500 ms when only the fixation point was present. Participants were instructed to ignore the objects and signal the target location by making a button press with the left thumb for targets over the left visual field (LVF) object and the right thumb for targets over the RVF object. Unknown to the participants, the objects came from two different categories: 'tools', or the kinds of items shown previously to activate motor schemata in cortex (e.g. utensils) and 'nontools', or items less likely to be associated with motor schemata (e.g. animals).

Participants were run in a total of 15 trial blocks of 64 trials each. Within each run there were 48 trials with a tool in one visual hemifield location and a nontool in the opposite hemifield location (24 trials with a tool in the LVF, 24 trials with a tool in the RVF), eight trials with tools in both locations, and eight trials of nontools in both locations. These latter two trial types were included to help prevent participants from 'guessing' the true purpose of the object displays, and were not included in analyses because of low trial numbers and the ambiguity of prediction about how attention would be biased under such conditions. The same square-wave target was presented on every trial, with its location (LVF vs. RVF) counterbalanced with respect to all object conditions. The objects and target were presented in black against a gray background. The target was a square-wave grating of two cycles/degree, forming an approximately 1° square. The objects never exceeded approximately 2° in either width or height, and were presented approximately 3° to center from fixation in the given visual hemifield. Fifty different objects were present in each of the two object categories, and based on normative ratings provided for each object, tools and nontools were equated for familiarity (3.60 vs. 3.60, respectively) and complexity (2.49 vs. 2.59). Postexperiment debriefing confirmed that all participants remained naïve as to this distinction in object categories.

Measuring attention

We relied on two complementary event-related potential (ERP) measures of attentional orienting. First, the amplitude of the lateral occipital P1 ERP component is larger when a stimulus is presented in a spatially attended location, relative to when the same stimulus is presented in the same location but attention has been oriented elsewhere in the visual field [20]. A change in P1 amplitude between experimental conditions can thus be interpreted as indicating a change in attention at the location of the ERP-eliciting stimulus [20]. We thus examined the ERPs time locked to the onset of the square-wave targets as a function of the target location (RVF vs. LVF) and the object type in the target's location (tool vs. nontool). Second, when visual attention is oriented covertly to a lateralized visual field location, there is an increased negativity over contralateral temporal-parietal electrode sites beginning between 200 and 250 ms after the onset of the attentional orienting – an ERP

component known as the N2pc [21]. Given that in the current paradigm attention is oriented in response to the onset of the bilateral object displays [6], this response – if present – should generate an N2pc in ERPs time locked to the onset of the bilateral object displays. Our determination of whether attention was drawn to a tool in the RVF and/or LVF thus required that both a P1 attention effect be present in the target-locked ERP and that an N2pc effect be present in the corresponding display-locked ERP.

Electrophysiological recording

Electroencephalographic data were recorded from 17 posterior scalp electrode locations at 256 samples per second (National Instruments PCI-6170e, Austin, Texas, USA), with a bandpass of 0.1–30 Hz and a gain of 50 000 (Grass Instruments Model 12, West Varwick, Rhode Island, USA), all relative to the left mastoid. Electrooculograms were also recorded in the horizontal and vertical dimensions. Offline, trials with eye movement and blink artifacts were rejected before signal averaging within each participant, the ERP waveforms were rereferenced to the average of the left and right mastoids, and digitally low-pass filtered (25.6 Hz half-amplitude cutoff). For P1 measurement, peak amplitude results reported below were based on the latency of the P1 peak in the group waveforms at each electrode site and condition of interest. For N2pc measurement, the mean amplitude was based on a 100 ms time window, starting 250 ms poststimulus. A-200 to 0 ms prestimulus baseline was used for all P1 and N2pc measurements and waveform displays.

Results
Behavior

Reaction times (RTs) to targets in the LVF were slightly faster with a tool in that location, relative to a nontool [328 ms (SD=37 ms) vs. 335 ms (42 ms)]. Conversely, for targets in the RVF, RTs were slightly slower with a tool in that location, relative to a nontool [327 ms (31 ms) vs. 316 ms (25 ms)]. A repeated-measure analysis of variance (ANOVA) showed a significant interaction between the target location and the object in that location [F(1,7)=5.91, P < 0.05], but no main effect of visual field [F(1,7)=2.08, P=0.19] or object type in the target location [F(1,7)=0.36 P=0.57]. Accuracy of identifying target location (LVF vs. RVF) was determined via a percentage correct measure and was at ceiling across all conditions.

Target-locked event-related potentials: the P1

Statistical analysis of the P1 data was restricted *a priori* to lateral occipitotemporal scalp electrode sites contralateral to the visual field of the target (OR and T6 for LVF targets, OL and T5 for RVF targets), the scalp electrode locations where the visual P1 and its attentional modulation are maximal for lateralized stimuli [20]. We found that independent of the target's visual field, the peak amplitude of the P1 was greater when a tool was in the target's location relative to a nontool (Fig. 1a). This was confirmed via a repeated-measures ANOVA on the peak P1 amplitude with factors of target visual field (LVF vs. RVF) and object in that location (tool vs. nontool) that showed a main effect of object [F(1,7)=12.04, P=0.01], but no main effect of visual field [F(1,7)=1.13] or object × visual field interaction [F(1,7)=0.27]. To ensure that our statistical result was not
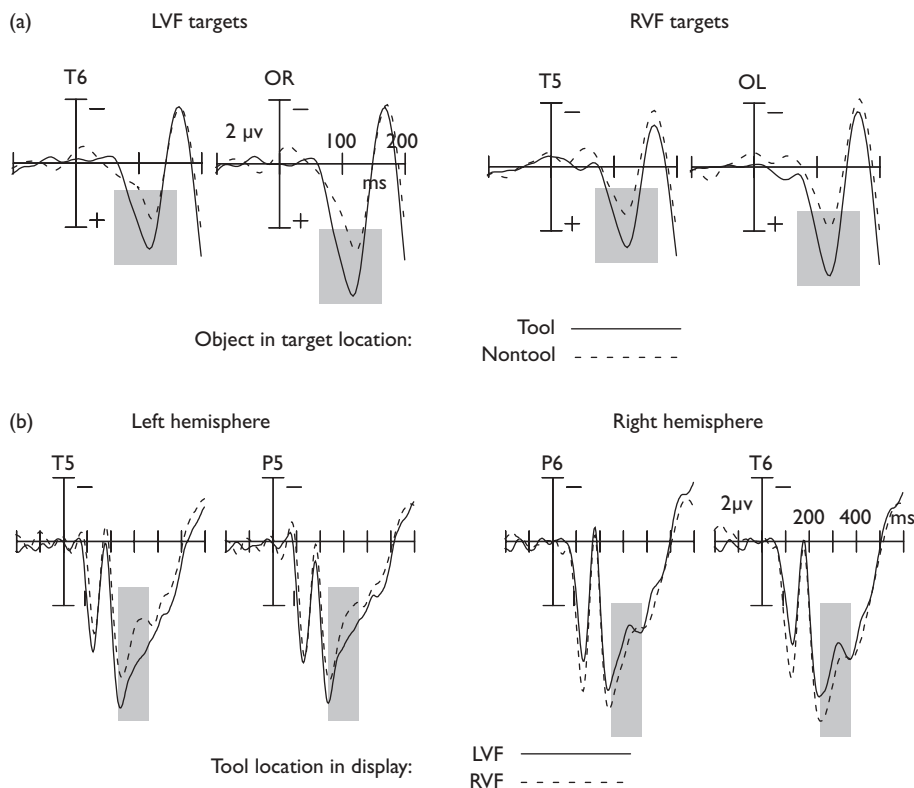
Fig. I (a) For targets in both the left and right visual fields, the peak amplitude of the PI ERP component (shaded in gray) was larger when a tool was in the target's location, relative to a nontool. (b) When the object displays were presented, the participants showed an N2pc component (shaded in gray) for displays having a tool in either the LVF or RVF location. LVF, left visual field; RVF, right visual field.

idiosyncratic to a peak amplitude measure, a mean amplitude measure of the P1 (40 ms time window, centered on peak) produced an identical statistical result: a main effect of object [$F(1,7)=7.54$, $P<0.05$], but no main effect of visual field [$F(1,7)=0.80$] or object × visual field interaction [$F(1,7)=0.01$].

Display-locked event-related potentials: the N2pc
If attention was indeed biased in response to the object displays, an N2pc over right temporal-parietal sites would be expected for displays with tools in the LVF, and an N2pc over left temporal-parietal sites would be expected for displays with tools in the RVF [21]. When the ERPs to the object displays were analyzed, this N2pc pattern was in fact evident (Fig. 1b). This data pattern was confirmed via repeated-measures ANOVA on the mean N2pc amplitude at temporal-parietal electrode sites T5/T6 and P5/P6, with factors of tool location in the display (LVF vs. RVF) and hemisphere of recording (left vs. right). Results revealed a significant interaction between tool location and recording hemisphere [$F(1,7)=24.68$, $P<0.005$] with no main effect of either tool location [$F(1,7)=0.03$] or recording hemisphere [$F(1,7)=0.41$]. Given this interaction, separate ANOVAs within each hemisphere revealed an increased negativity over the right hemisphere electrode sites when a tool was on the left side of the display [$F(1,7)=6.03$, $P<0.05$], and an increased negativity over the left hemisphere electrode sites when a tool was on the right side of the display [$F(1,7)=9.88$, $P<0.05$].

Discussion
Using a paradigm and participant cohort designed to dissociate activation of object vs. hand-specific motor representations by the visual field location of a graspable object we found that visual–spatial attention was drawn to graspable objects regardless of their visual field of presentation. When taken in conjunction with the findings of Handy *et al*. [6], the current data suggest that activation of either an object or hand-specific motor representation may alone be sufficient for an attentional orienting response to arise. Although our results do not unambiguously establish object and hand-specific motor representations as the attentional triggers *per se*, they do support the hypothesis that the cascade of events associated with an orienting response to a graspable object can proceed when only one of these two representations is activated.

Critically, our conclusion rests on the assumption that different motor representations were in fact activated as a function of the visual field location of the graspable object. Is the assumption valid? To the point, RTs to targets in the RVF were slower when a tool was in that location, a signature of response interference that would be expected if the tool activated an object specific motor representation in the left cerebral hemisphere that was incompatible with the manual button press required by the target. By contrast, RTs to targets in the LVF were faster when a tool was in that location, a facilitation in RT that would be expected if the graspable object activated or primed a more general, hand-specific motor representation in the right cerebral hemisphere. One caveat to note here is, however, that visual

attention itself would not be expected to directly influence RTs to targets via perceptual facilitation typically associated with events at spatially attended locations [6] – a position supported not only by the functional independence of perceptual and motor representations in cortex [22,23], but the finding that stimulus-driven motor priming can obscure attention-related perceptual facilitation in RTs [24].

Conclusion

In conclusion, it is important to note that there may be some object motor representations that remain lateralized to the motor-dominant hemisphere. For example, recent fMRI evidence has revealed that when right and left-handed participants actively discriminate between sounds made by tools vs. animal vocalizations, the task is strongly associated with higher-level motor areas in the hemisphere controlling the dominant hand [25]. Although the use of auditory stimuli and a task requiring explicit motor-related processing makes comparisons to this study difficult at best, what this highlights is the central importance of grasping objects in everyday human behavior and the variety of different motor representations in cortex that support these actions. Given this context, it is thus perhaps less than surprising to find evidence suggesting that not only can graspable objects automatically draw visual attention to their spatial locations, but that these visual–motor interactions may be linked to either object or hand-specific motor representations.

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