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Target enhancement and distractor suppression in multiple object tracking

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In multiple object tracking (MOT), observers keep track of target objects that move haphazardly around a display in the presence of identical distractors. The typical result from this paradigm is that observers can accurately track up to about four objects, with performance declining precipitously beyond this number. However, recent evidence indicates that the number of objects that can be effectively tracked is not fixed but depends on factors such as speed and interobject distance (Shim, Alvarez, & Jiang, 2008).

Decreasing interobject distance reduces tracking performance, which is compatible with the idea that visual attention may be particularly important in MOT in order to maintain individuation of target objects in the face of nearby distractors. Previous research has shown that one source of errors during MOT arises when observers mistakenly begin tracking distractors that pass close to targets (O’Hearn et al., 2005; Pylyshyn, 2004). Therefore, a sensible strategy might be to suppress or inhibit distractors that pass close to and are confusable with targets. Consistent with this idea, Pylyshyn, Haladjian, King, and Reilly (2008) reported that probes appearing on distractors that were located in a different depth plane than the tracked objects were detected more frequently than same-depth plane distractor probes. According to them, objects in different depth planes are preattentively segregated, allowing observers to easily ignore different-depth plane distractors without the need to actively suppress them. This is consistent

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with the claim that suppression of nearby distractors by visual attention may be useful in preventing nearby distractors from being mistaken for targets.

520 In the present experiment we attempted to provide converging evidence for the role of inhibition in MOT by examining the N1 component of the event-related brain potential elicited by probes appearing on targets and distractors. Displays were arranged so that some distractors on each trial were relatively close to tracked targets while others were further away (Figure 1A). During each trial, irrelevant probe flashes appeared intermit-

525 tently on targets, nearby distractors, and far distractors. On average, near distractor probes were approximately 2.5° ($SD = 0.9^\circ$) from targets compared to 10.6° ($SD = 1.7^\circ$) for far distractor probes. Mean eccentricities were similar across conditions: Target, $M = 7.4^\circ$, $SD = 1.3^\circ$; near distractor, $M = 7.5^\circ$, $SD = 1.3^\circ$; far distractor, $M = 7.5^\circ$, $SD = 1.2^\circ$. If distractors that

530 are close to targets are inhibited, probe flashes appearing on them should result in a smaller N1 component compared to probe flashes appearing on targets. However, this pattern is ambiguous as it could also result from enhancement of the target without suppression of the distractor. Probes on far distractor objects can serve as a “neutral baseline” for disambiguating these results since far distractors should not be confusable with target

535 objects and should not, therefore, require suppression. “Pure suppression” of nearby distractors should result in equivalent N1s for probes appearing on targets and far distractors together with smaller N1s for near distractor probes. In contrast, the signature of “pure target enhancement” would be a large target N1 coupled with small and equivalent N1s for distractors

540 regardless of distance.

Two separate N1 components were observed in this experiment. The *posterior* N1, thought to be generated in the lateral occipital complex (LOC; Di Russo Martinez, & Hillyard, 2003; Martinez, Ramanathan, Foxe, Javitt,

545 & Hillyard, 2007), occurred over lateral posterior electrode locations and peaked approximately 175 ms poststimulus for contralateral stimuli (Figure 1B). Comparable posterior N1 components were observed for targets and far distractors and they were both larger than N1s for near distractors (Figure 1B and C), $F(2, 22) = 5.16$, $p < .05$ (see Figure 1C for p -values based on pairwise t -tests). This pattern is consistent with suppression of nearby

550 distractors. The *anterior* N1, thought to be generated in superior parietal areas near the intraparietal sulcus (IPS; Di Russo et al., 2003), occurred over frontocentral electrode locations and peaked approximately 155 ms poststimulus (Figure 1D). In contrast to the suppression pattern observed in the

555 posterior N1, the anterior N1 showed a pattern consistent with pure enhancement of target objects. N1 amplitude was larger for targets than both near and far distractors which did not differ (Figure 1D and E), $F(2, 22) = 4.96$, $p < .05$ (see Figure 1E for p -values based on pairwise t -tests).

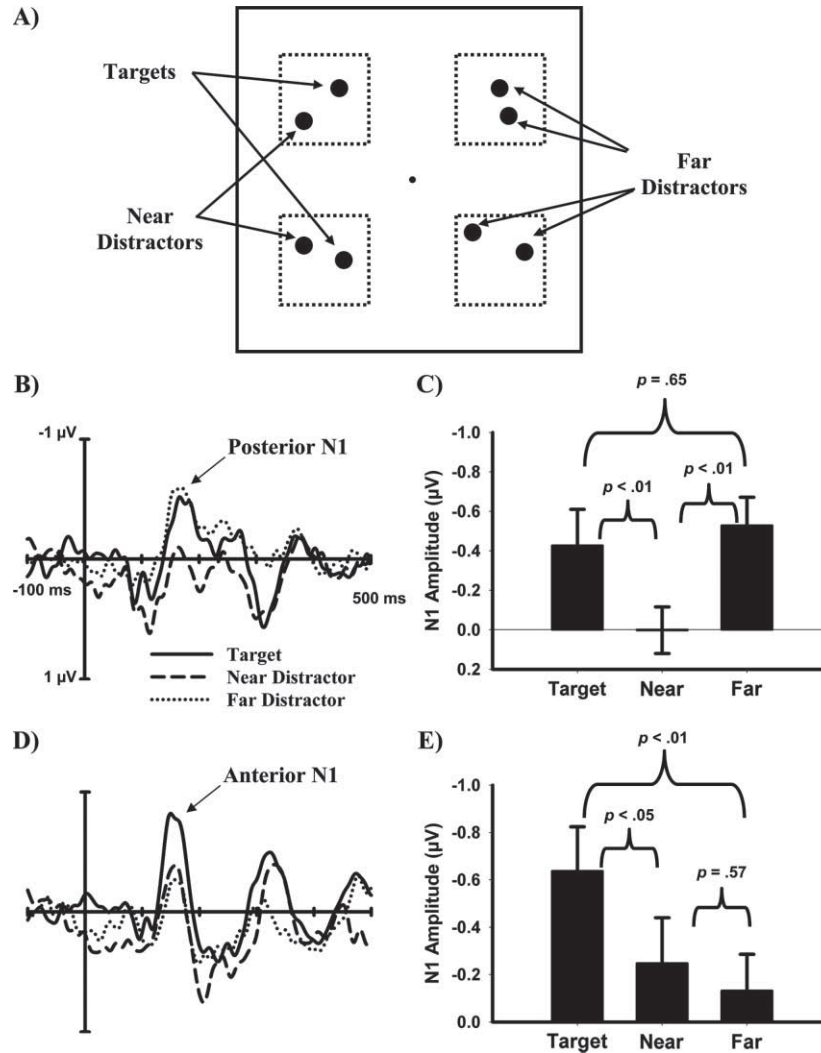


Figure 1. (A) Schematic of the MOT displays in this experiment. Objects were positioned so that two objects were located in each quadrant. During the motion phase of each trial, the objects reflected off of the boundaries of invisible “containers” (illustrated by the dotted squares) so that they remained in separate quadrants. Participants tracked two target objects that were positioned in adjacent quadrants such that there were always near distractors (i.e., distractors within the same quadrant as a target) and far distractors (i.e., distractors in the quadrants without targets). Probes were presented equally often on targets, near distractors, and far distractors. Note that the dotted boxes are for illustration purposes and were not visible to the observers. (B) ERP waveforms measured at occipitoparietal scalp locations illustrating the posterior N1. (C) Mean posterior N1 amplitude. (D) ERP waveforms measured at frontocentral scalp locations illustrating the anterior N1. (E) Mean anterior N1 amplitude. The posterior N1 shows distractor suppression; the anterior N1 shows only target enhancement.

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560 Apparently, visual attention can act at different levels of the visual system to both enhance target objects and suppress distractors during MOT.

The finding that target enhancement and distractor suppression appeared in different ERP components associated with different generators in the brain suggests that they are separate and distinct processes. The parietal system associated with the anterior N1 seems to primarily enhance attended locations (He, Fan, Zhou, & Chen, 2004). On the other hand, the extrastriate system associated with the posterior N1 seems to primarily suppress distractors perhaps by means of a winner-take-all competition (Desimone & Duncan, 1995). That suppression was only applied to nearby distractors is consistent with this sort of competition since distractors that share receptive fields with targets would be subject to suppression whereas far away distractors would not.

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Individual differences in overriding attentional capture

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Working memory capacity (WMC) is known to be severely limited, yet variable across individuals. Recent evidence suggests that high WMC

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