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Brief article

Differential effect of one versus two hands on visual processing

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ABSTRACT

Hand position in the visual field influences performance in several visual tasks. Recent theoretical accounts have proposed that hand position either (a) influences the allocation of spatial attention, or (b) biases processing toward the magnocellular visual pathway. Comparing these accounts is difficult as some studies manipulate the distance of one hand in the visual field while others vary the distance of both hands, and it is unclear whether single and dual hand manipulations have the same impact on perception. We ask if hand position affects the spatial distribution of attention, with a broader distribution of attention when both hands are near a visual display and a narrower distribution when one hand is near a display. We examined the effects of four hand positions near the screen (left hand, right hand, both hands, no hands) on both temporal and spatial discrimination tasks. Placing two hands near the display compared to two hands distant resulted in improved sensitivity for the temporal task and reduced sensitivity in the spatial task, replicating previous results. However, the single hand manipulations showed the opposite pattern of results. Together these results suggest that visual attention is focused on the graspable space for a single hand, and expanded when two hands frame an area of the visual field.

1. Introduction

Recently, interest has grown on the impact of body position on perception and particularly on how objects within the graspable space of our hands are processed visually. It is intuitively sensible that items near the hands would be preferentially processed to facilitate object identification and action planning. Consistent with this intuition, placing the hands near a display influences performance in a number of visual tasks, resulting in slower visual search rates, increased magnitude of the attentional blink, improved change detection, and slower switching between global and local features (Abrams, Davoli, Du, Knapp, & Paull, 2008; Davoli, Brockmole, Du, & Abrams, 2012; Tseng & Bridgeman, 2011). These findings suggest that there is an increase in attentional dwell time for stimuli near the hands. Hand position also impacts figure-background discrimination, such that a surface near the hand is preferentially treated as the foreground object (Cosman & Vecera, 2010), and responses to targets appearing near a hand are faster than those to targets far from the hand (Reed, Betz, Garza, & Roberts, 2010; Reed, Grubb, & Steele, 2006). These latter effects are similar to those seen at spatially attended locations in attentional cuing studies (Downing & Pinker, 1985; Posner, Nissen, & Ogden, 1978; Posner, Snyder, & Davidson, 1980). One interpretation of these results is that visual attention is preferentially allocated towards the graspable space of the hand (Reed et al., 2006).

A recent proposal for the mechanism underlying the impact of hand position on perception is that there is shift in the type of visual processing being performed (Gozli, West, & Pratt, 2012). Specifically, for locations near the hands processing is biased towards the magnocellular

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visual pathway, which is sensitive to high temporal frequency (i.e., rapidly changing) and low spatial frequency information. Support for this magnocellular bias comes from evidence that when both hands are near the display, responses are more accurate in a temporal discrimination task than in a spatial discrimination task (Gozli et al., 2012). Placing both hands near the display also decreases the interference from object substitution masking, and decreases the response time for low spatial frequency compared to high spatial frequency stimuli, both of which are consistent with increased magnocellular processing (Abrams & Weidler, 2013; Chan, Peterson, Barense, & Pratt, 2013; Goodhew, Gozli, Ferber, & Pratt, 2013). Although the magnocellular bias theory provides an elegant explanation of these results, it is unclear whether the near hand visual processing differences found in single hand manipulation studies can be parsimoniously explained with this account (Cosman & Vecera, 2010; Reed et al., 2010, 2006).

One critical methodological difference in this literature is the use of one hand or both hands near a visual display. Based on this difference, we hypothesize that a single hand in the visual field may encourage a tightly focused area of attention directly within the graspable space of the hand and that a dual hand manipulation may instead encourage a larger window of attention encompassing the region between both hands. This spatial window account is analogous to theories of spatial attention that propose the size of the window of attention is adjusted to match the size of an object or cue (Castiello & Umiltà, 1990; Eriksen & St James, 1986). Further, the scale of attention might operate to bias processing toward either high temporal resolution (broad attentional focus) or high spatial resolution (narrow attentional focus). For example, a single hand near the screen may induce a focused area of visual attention. Studies using small exogenous cues have demonstrated that tightly focused attention leads to a bias towards high spatial resolution parvocellular processing (Yeshurun & Carrasco, 1998; Yeshurun & Sabo, 2012). Small exogenous cues have also been shown to reduce performance on tasks requiring high temporal resolution magnocellular based processing, suggesting that the bias towards parvocellular processing comes at the expense of magnocellular processing (Yeshurun & Levy, 2003; Yeshurun, 2004). Critically, the spatial resolution benefits and temporal resolution costs of small cues were demonstrated in contrast to large neutral cues that spanned the presentation array. This suggests that the larger cue may have led to a broad focus of attention, and that this may induced a bias towards magnocellular processing relative to the smaller cues. Further evidence of a magnocellular bias under a broad attentional window comes from demonstrations that the global-precedence effect is reduced or extinguished by reducing low spatial frequency information (Badcock, Whitworth, Badcock, & Lovegrove, 1990; Michimata, Okubo, & Mugishima, 1999; Shulman, Sullivan, Gish, & Sakoda, 1986). Placing two hands up near the screen may activate a similar underlying mechanism as a large exogenous cue or monitoring the global aspects of a stimuli, leading to a broad window of attention and subsequent bias towards the magnocellular processing pathway. An insufficient number of studies have compared single and dual hand manipulations on relevant tasks to determine if these lead to the same perceptual processing modes.

The current study was designed to directly test between the spatial window hypothesis of hand position effects and the magnocellular bias account. The tasks were an extension of those employed by Gozli et al. (2012). These tasks contrast the ability to discriminate a short temporal gap (temporal sensitivity) with the ability to discriminate a small spatial gap (spatial sensitivity). A strict magnocellular bias account predicts greater accuracy on temporal tasks for any condition in which stimuli appeared close to one or both hands. Our spatial window hypothesis makes the same prediction in the two hand near compared to two hands far comparison, but predicts improved spatial and reduced temporal sensitivity near compared to far from a single hand. Results consistent with this second prediction would indicate adjustments to the scope of the attended window leading to a bias towards spatial resolution in the single hand near condition and a bias towards temporal resolution in the two hands near condition.

2. Method

2.1. Participants

Participants were 60 University of Iowa undergraduates (41 female, 55 right handed). Half completed the spatial discrimination task, and half completed the temporal discrimination task. Participants provided informed consent prior to data collection and were compensated with course credit.

2.2. Stimuli

Displays consisted of a grey background (RGB = 55,55,55) with a white fixation dot at the center of the screen (Fig. 1A). The critical stimuli were white circles ($0.8^\circ \times 0.8^\circ$ of visual angle) presented one at a time with equal frequency on the left and right side of the fixation cross, with 4° from the center of the circle to fixation. Two types of circles were presented in both tasks, a gap circle (50%) and a no-gap circle (50%), depicted in Fig. 1B. The no-gap circle for both tasks consisted of an unbroken circle presented for 80 ms. For the spatial task, the gap circle had a small (0.14 radians) section removed from the top. For the temporal task, the gap circle was presented for 32 ms, blinked off for 16 ms, and then reappeared for another 32 ms. For both tasks, the gap and no-gap stimuli occurred with equal frequency on the left and right sides of fixation.

2.3. Procedure

Participants were seated facing a computer monitor at a distance of 55 cm. An instruction screen at the beginning of each block indicated the hand(s) held near the screen for that block: left hand, right hand, both hands, or no hands. For each hand condition, the hand(s) were placed near the screen such that the middle finger touched a green dot on

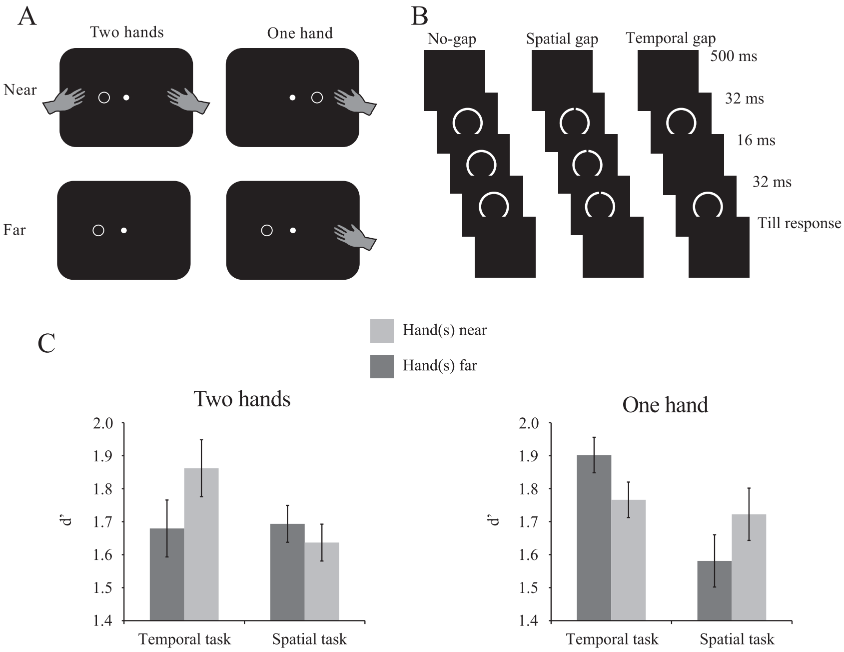

Fig. 1. Methodology and d′ data for all four hand positions. (A) The four hand positions used. (B) Series of event for trials, illustrating the gap trials for both spatial and temporal tasks, and the no-gap trials. (C) Mean d′ scores plotted separately for two and one hand configurations. Error bars are within subject 95% confidence intervals for the hand distance comparisons (Baguley, 2012; Loftus & Masson, 1994).

the ipsilateral side of the screen at a point 8° from fixation. Participants were instructed to keep their hands oriented so that their palms faced the center of the screen, towards the stimuli presentation locations. Hand(s) not near the monitor were rested on the table near the participant. On the side(s) of the screen not occupied by a hand, wooden dowels were placed pointing to the unoccupied hand position to provide a visual anchor.

For each trial, one circle was presented on either the left or right side of the screen. The task was to indicate whether a gap circle or a no-gap circle was presented using two foot pedals. The mapping of the left and right foot pedal to the type of response (gap/no-gap) was counterbalanced across participants. Responses were not speeded, and each response was followed by a 500 ms inter-trial interval. Each block consisted of 48 trials and lasted approximately 2 min. Each participant performed 24 blocks split equally between the four hand position, in a randomly selected order. Prior to beginning the experiment, all participants performed 24 practice trials in the two hands near the monitor condition. The experiment took approximately 1 h to complete.

The primary dependent variable of interest was the sensitivity (d') for discriminating the gap/no-gap items. Response times (RTs) for correct responses were also analyzed to assess speed accuracy tradeoffs. The three factors of interest were the task (spatial/temporal), the hand configuration (one hand/two hands), and hand distance (near/far). For the two hand configuration, hands near was defined as all stimuli in blocks with both hands up to the monitor, and hands far as blocks with both hands on the table. For the one hand configuration hand near was defined as the stimuli appearing on the same side of the monitor as the hand, and hand far as the stimuli occurring on the opposite side of the monitor. Task was a between-subjects factor, and hand configuration and distance were within-subjects factors.

3. Results

3.1. Sensitivity results

An initial set of comparisons assessed interactions between task and hand position in sensitivity (Fig. 1C). We found a three-way interaction between task, hand configuration, and hand distance indicating the impact of hand position on sensitivity differed between the two tasks, $F(1,58) = 10.3$, $p = .002$, $\eta_p^2 = .151$. We conducted planned comparisons for the single hand and two hands configurations separately. For the two hands condition, there was an interaction between hand distance and task, such that with both hands near the screen a higher d' was observed on the temporal task, and a lower d' was observed for the spatial task, $F(1,58) = 5.2$, $p = .027$, $\eta_p^2 = .082$, replicating previous results (Gozli et al., 2012). For the single hand condition there was also an interaction between hand distance and task, but in the opposite direction, $F(1,58) = 7.3$, $p = .009$, $\eta_p^2 = .112$. Specifically, for single hand configurations stimuli on the hand side of the screen had reduced sensitivity in the temporal task, and improved sensitivity in the spatial task compared to stimuli presented opposite the hand. These results demonstrate that the influence of

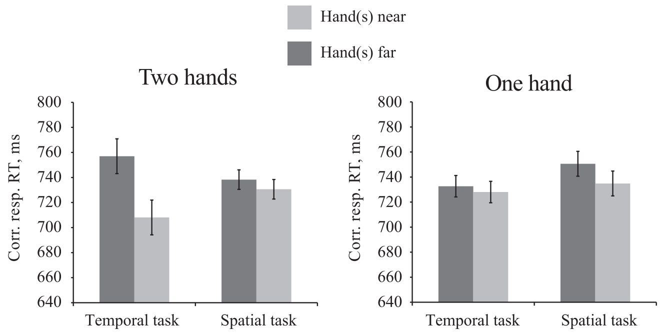

Fig. 2. Mean RTs for correct responses. Error bars are within subject 95% confidence intervals for the hand distance comparisons (Baguley, 2012; Loftus and Masson, 1994).

the hand on visual processing is strongly impacted by whether one or two hand(s) are placed near a display.

3.2. Response time results

RTs for correct responses were analyzed to determine whether the d' measurements indicated differences in sensitivity, or a speed accuracy tradeoff (Fig. 2). There was a three-way interaction between the task, hand distance, and hand configuration, $F(1,58) = 6.3$, $p = .015$, $\eta_p^2 = .098$. This interaction was driven by faster RTs in the temporal task when two hands were near compared to far from the display, $t(1,29) = 3.3$, $p = .002$, $d = .607$. None of the other main effects were significant, $ps > .05$. Critically, the pattern of the response time data did not indicate a speed accuracy tradeoff.

4. Discussion

The current results demonstrate that the type of hand manipulation used has a large impact on how visual stimuli near the hand(s) are processed. Using both single hand and two hand manipulations, consistent with the two dominant methods in the literature, we found that having two hands framing an area of the visual field increased temporal sensitivity and reduced spatial sensitivity relative to both hands distant. These results are consistent with previous findings that two hands near the monitor biases processing towards the magnocellular pathway (Gozli et al., 2012). Conversely, items near a single hand were perceived with an improved spatial sensitivity and worse temporal sensitivity compared to items opposite the hand, suggesting that processing was biased towards the parvocellular pathway. These findings highlight a previously unexplored complication in how hand position impacts vision, that for some tasks a single hand has the opposite effect on processing to those observed with two hand manipulations.

The current analyses focused on the near/far comparisons separately for single and two hand manipulations, as these were the planned comparisons based on the dominant methodologies in the literature. These comparisons demonstrate a relative bias towards spatial resolution near a single hand, and a relative bias towards temporal resolution near two hands. However, a visual inspection of the current data reveals additional patterns that could be of interest, such as a comparable temporal sensitivity between when an item is far from a single hand and when both hands are near the screen. These similarities may arise due to the proposed competitive relationship between the magnocellular and parvocellular pathways (Bocanegra & Zeelenberg, 2011; Yeshurun & Levy, 2003; Yeshurun, 2004). Manipulations that boost processing in one of these pathways tend to inhibit processing in the other pathway. Thus for locations opposite a single hand there may be improved temporal resolution commensurate with the reduction in spatial resolution. The mutually inhibitory relationship between the magnocellular and parvocellular pathway makes it difficult to interpret direct comparisons between a condition in the single hand manipulation and a condition in the two hand manipulation, and thus our analysis focused on the interactions observed within each hand manipulation.

Another interesting pattern observable in the data was that the spatial and temporal sensitivity near a single hand was similar to the sensitivity with both hands away from the screen. One way to interpret the two hands far condition is as a baseline to both the single and two hands near conditions. From this perspective the current pattern of results seems surprising, as it would be reasonable to predict that sensitivity near a single hand would be superior for the spatial task and reduced for the temporal task compared to when both hands are distant. However, this interpretation is based on the assumption that the presentation locations are not attended in the no hands near the screen condition. It is more likely that attention is allocated in the no hands condition in a manner best suited to the task and unconstrained by hand position. Comparing the data between items presented near a single hand and items presented when no hands were near the screen suggests a similar allocation of attention in these two conditions. Specifically, under our theoretical view this pattern suggests that when no hands are near the screen attention is divided into two focused windows at the presentation locations, leading to a bias towards parvocellular processing. Several studies support that spatial attention can be oriented to two non-contiguous focused regions, particularly when regions are split across visual hemifields

(Bichot, Cave, & Pashler, 1999; Kraft et al., 2007; McMains & Somers, 2004; Müller, Malinowski, Gruber, & Hillyard, 2003). This interpretation is based on a null result in a non-planned comparison and thus speculative, but the current data suggest that both presentation locations in the no hands distant condition are treated similarly to locations in the graspable space of a single hand.

Our study is not the first to examine differences between one hand and two hand configurations. Using a change detection task, Tseng and Bridgeman (2011) found better change detection performance when two hands were near the display compared to when a single hand was near the display. We propose that this result was due to a larger scope of attention in the two hands condition allowing analysis of more of the items in the display. This suggests that other manipulation that widen the attentional window may also produce higher change detection accuracy than manipulations that narrow the attentional window.

Both the attentional allocation theory (Reed et al., 2006) and the magnocellular processing theory (Gozli et al., 2012) of the impact of hand position on perception are supported in part by the current results, but each tells only half of the full story. We propose that in addition to orienting attention towards the hand, the scale of the window of attention is adjusted based on the hand configuration. When a single hand is positioned in the visual field attention is focused near the graspable space of the hand, coinciding with increased spatial discrimination and reduced rapid temporal discrimination. When a portion of the visual field is framed between two hands the window of attention is expanded with corresponding increases in rapid temporal discrimination and reduced spatial discrimination. We should note that this explanation relies upon the inference that changing the scope of attention shifts the dominant visual processing pathway. Although there is some support for this (e.g., Shulman et al., 1986), a fuller understanding of how spatial and temporal processing are impacted by the spatial distribution of attention is needed. However, it is clear that understanding the impact of hand position on perception will need to account for the differences between using one and two hands.

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