Illusory Objects Produce Substitution Masking Effects

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Abstract. Existing notions of what an object is mainly considered physical object features and properties. While there are growing interests in whether illusory objects carry similar functional properties as physical objects. Hirose and Osaka (2009) made an attempt but their design, we argue, cannot adequately eliminate the possibility of an attentional capture effect. The present study aimed to fill the gaps that Hirose and Osaka (2009) have left open, and to show direct evidence of functional similarities between illusory and physical objects. We present novel data suggesting that illusory objects are fully capable of functioning as physical masks. The idea that visual objects are representations in the mind is discussed.

Keywords: Object Substitution Masking; Mask Preview; ISI; Mask Configuration; Illusory Object

1. Introduction

Our perception is governed by the interaction among the objects present in our immediate visual environment[1]. To understand the basic units behind perception forms one of the most imperative goals in studies of visual cognition [1,7]. Masking paradigms are not only conveniently used to limit visual information available to observers; they allow also the examination of the mechanisms underlying phenomena in perception[2]. The general principle behind masking is to obstruct the perception of a target by presenting task-irrelevant objects in close spatial or temporal proximity[2]. While investigations have traditionally focused on physical properties of objects, there are growing interests concerning the similarities between physical and illusory objects. Mendola, Dale, Fischi, Liu and Tootell (1999) showed evidence using functional Magnetic Resonance Imaging that they are processed similarly. A question of interest is whether illusory objects can *function* like physical objects; whether illusory objects can mask as well as like their physical counterparts.

Yet, no one has adequately reported findings on the functional properties of illusory objects, although we noted Hirose and Osaka's (2009) recent suggestions. Hirose and Osaka used black filled inducers (shaped like Pacmen). Using an Object Substitution Masking (OSM) paradigm with the inclusion of the preview effect, they claimed evidence for illusory objects' ability in masking. According to Hirose and Osaka (2009), a preview of the inducers is necessary to successfully detect the masking effects of illusory objects as it eliminates the masking effect from the physical inducers. As such, any masking effect observed can inexorably be attributed to the illusory object. This is consistent with Tata and Giaschi (2004).

Upon close examination, because Hirose and Osaka (2009) had allowed illusory objects to appear abruptly, their results may have reflected an attentional capture (AC) effect instead. If so, their conclusion would be rendered void. Although Hirose and Osaka had cited Theeuwes (1991) and Yantis and Jonides (1990) to invalidate the AC interpretation, they are alas inadequate. They lacked the critical condition that examines the AC effect on simultaneously presented cue, target and mask as a function of proximity between abrupt onset and target which is the crux of Hirose and Osaka's paradigm. It is thus unconvincing that their data did not simply reflect AC. By extension, whether attention is unfocused in a simultaneous presentation condition or such a condition yields similar AC effects remained open empirical questions.

Moreover, comparing Hirose and Osaka's paradigm in mask position with other OSM studies[6,8], the intended mask in Hirose and Osaka's study differed in their onset position. To avoid a confounding interpretation with AC effects, studies that presented only one single mask to the intended target among distractor targets, always had these masks presented at the same spatial location as the intended target. The OSM argument must be such that it accounts for variance observed over and above attentional distractions. When the mask appears at the same spatial location as that of the target, even if attention is captured by the mask, it is unlikely that the target, at the same visual location, was not processed at all. However, this may not hold when the mask onsets at a different location since attentional shifts may be required. If this shift proves to require time longer than the target duration, the target is naturally not processed. This is clearly the case in Hirose and Osaka's paradigm, which opens itself to the possibility of an AC effect.

In light of these arguments, Lim and Chua's (2008) paradigm was employed to fill the gaps that Hirose and Osaka (2009) had left open and to test the masking property of illusory objects. In the present paradigm, the target and distractors were all assigned masks at the same spatial location. This manipulation would enable us to foreclose OSM effects *per se*, and prevent a confounding attention distraction interpretation.

2. Methods

2.1. Participants, apparatus and stimuli

15 undergraduates participated in the experiment. All had normal or corrected-to-normal vision. Participants sat approximately 57 cm away an assigned Pentium IV computer. Throughout the experiment, the monitor provided the only source of illumination. The visual display was composed of a grey-coloured (luminance – 80cd/m^2) background. The targets and distractors were Landolt Cs in darker grey (luminance – 40cd/m^2). All other stimuli were presented in black. A fixation cross (subtending 0.2^o of visual angle) was presented at the center at the start and end of each trial before the response frame, followed by four identical masks formed by four Pacmen inducers with mouths facing inwards (subtending 1.5^o of visual angle in diameter), black filled and positioned at the four corners of an imaginary square configuration (subtending 4.1^o of visual angle) forming one mask, enclosing either a distractor or target. Figure 1 shows the configuration in rotation of the original mask at 0^o, 90^o, and 180^o.

During each trial, each mask configuration had equal possibility to appear in the target array frame. During the preview frame, masks were always the 90^o masks (Figure 1b). The Landolt Cs (subtending 1.7^o of visual angle in diameter), with a gap (subtending 0.2^o of visual angle in width), were evenly distributed in a circular configuration (subtending 3.3^o of visual angle in radius) that surrounded the fixation cross. The gap in each Landolt C faced either north, south, east or west. A central arrow cue (subtending 1.8^o by 1.8^o of visual angle) will be presented simultaneously during the target array frame to randomly designate the target from the distracters; guess rate was 25%. The arrow designated the target equally frequent at all four Landolt C locations. Masks were always presented at the same spatial locations as that of the targets and distractors.

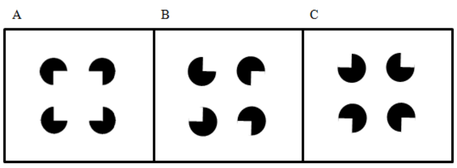

Fig. 1: A sample of the stimuli used in the experiment. A is the mask at 0^o configuration. B is the mask at 90^o counterclockwise configuration relative to A. C is the mask at 180^o configuration relative to A.

2.2. Task and design

Participants were tasked to identify the orientation of the designated Landolt C based on the location of its gap. Participants hit the corresponding keys [8, 2, 4, and 6 on the number pad (up, down, left, and right respectively)] on the keyboard to indicate whether the gaps were facing north, south, west, or east.

A single-factor, within subjects design was used. The independent variable was preview condition with five levels: (a) no preview, (b) preview with 90^o mask after an inter-stimulus interval (ISI) of 500ms, (c) preview with 180^o mask after 500 ms ISI, (d) preview with 180^o mask after 0 ms ISI, (e) preview with 0^o mask after 0 ms ISI. All preview frames were presented for 900 ms, and all the masks presented during preview were the 90^o versions. ISI was defined as the interval of presentation of a blank frame between offset of the preceding preview frame and the onset of the target-mask presentation frame (Figure 2b-e, frame iii). The dependent variable was response accuracy (the proportion of correct responses divided by the total number of trials for each condition). Each participant completed four blocks of 50 trials. Each trial's duration, defined as the presentation time from the onset of the first fixation cross at the beginning to the offset of the last fixation cross at the end of the trial, was fixed at 2570 ms across all conditions throughout the experiment to control for total trial duration. Each condition occurred equally often, resulting in the presentation of 40 trials per condition in a single experiment. The 0° mask (Figure 1a) was formed of black filled Pacmen facing inwards creating an illusory square within. Importantly, this illusion was not apparent in the other two mask configurations (Figure 1b and 1c).

2.3. Procedure

Participants were shown instructions on-screen before a computerised demonstration of a typical trial in the experiment. Participants completed one block of 30 practice trials and continued with the main blocks; a break interval was programmed in between each block of trials. The chronology of events for each condition is depicted in Figure 2. Each trial began with a fixation cross which appeared at the center of the screen and stayed on until it was replaced by the central arrow cue during target/distractor-mask presentation. It reappeared 300 ms before the appearance of the response frame. In condition (a), target, distractors, central arrow cue, and masks onset simultaneous at their respective locations after 1700 ms of presentation of the fixation cross. In condition (b), after previewing the masks, the fixation cross stayed on-screen for another 500 ms. On fixation cross offset, target, distractors, arrow cue and 90° masks (same as masks at preview presentation) onset. In condition (c), after previewing the masks, the fixation cross stayed on-screen for another 500 ms. On fixation cross offset, target, distractors, arrow cue and 180° masks (different at preview presentation) onset. In condition (d), masks preview onset after 800 ms of fixation cross onset, offset together, followed by the simultaneous presentation of the target, distractors, arrow and 180° masks (different at preview presentation). In condition (e), masks preview onset after 800 ms of fixation cross onset, terminated together, followed by the presentation of the target, distractors, arrow and 0° masks (different at preview presentation). In conditions (b) and (c), 90° masks appeared at their respective locations 300 ms after the onset of the fixation cross and terminated after 900 ms while the fixation cross stayed on. In conditions (d) and (e), 90° masks appeared at their respective locations 800ms after the onset of the fixation cross and together terminated after 900 ms. Across all conditions, targets' and distractors' presentation duration were fixed at 70 ms. with masks and the central arrow cue accompanying them. The target, distractors and central arrow terminate together, but the masks stayed on for another 500 ms. When ISI was 0 ms, target and distractors alone appeared as abrupt onsets but when ISI was 500 ms, masks also appeared as abrupt onsets. Participants were told to respond quickly and accurately.

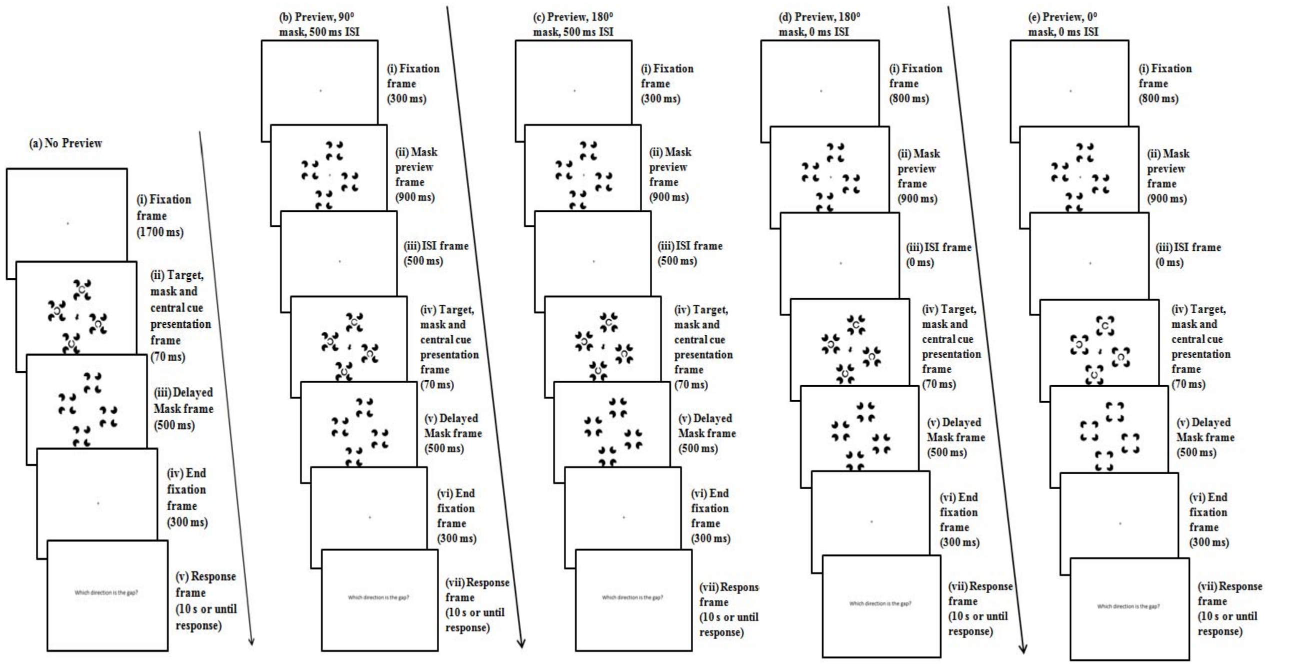

Fig. 2: Schematic of trials across experimental conditions.

3. Results

Figure 3 shows the percentage of correct responses per condition as a function of preview condition. The proportion of correct responses was calculated per condition for each participant and subjected to a one-way repeated measures analysis of variance. A main effect of the preview was found, $F(4, 56) = 9.91$, $MS_e = .056$, $p = .0001$, $\eta^2 = .41$. To determine whether preview enhanced performance, condition (a) was compared with (b). Performance at condition (b) ($M = .61$, $SD = .11$) was significantly better than (a) ($M = .55$, $SD = .12$), $t(14) = 2.70$, $p = .02$, $\eta^2 = .33$. Previewing the mask in (b) indeed enhanced performance compared to (a) when no previewing was administered. To determine whether a change between mask preview and actual mask presentation leads to the elimination of the preview effect, condition (b) was compared with (c). Performance at condition (b) was significantly better than (c) ($M = .55$, $SD = .15$), $t(14) = 2.53$, $p = .02$, $\eta^2 = .30$. This showed that when the masks previewed during the preview frame were different to the ones later presented during the target array frame, performance deteriorated as in (a); the preview effect was eliminated. To establish that when apparent motion is induced and thus the preview effect is sustained when the masks at preview and actual presentation were different, condition (c) was compared with (d). Performance at condition (d) ($M = .62$, $SD = .17$) was significantly better than (c), $t(14) = 3.10$, $p = .008$, $\eta^2 = .39$. Apparent motion eliminated mask configuration change, sustained the preview effect and masking was attenuated. To determine if the illusory object formed from the 0^o mask was indeed capable of masking the target object, condition (d) was compared with (e). Performance at condition (d) was significantly better than (e) ($M = .47$, $SD = .14$), $t(14) = 4.54$, $p = .0001$, $\eta^2 = .58$. When an illusory object was presented as a mask at the target array frame, performance deteriorated, showing that masking occurred. Interestingly, a comparison between conditions (a) and (e) revealed significantly different performance, $t(15) = 2.37$, $p = .03$, $\eta^2 = .27$. The implication is that an illusory object in fact masked more powerfully than a physical object did.

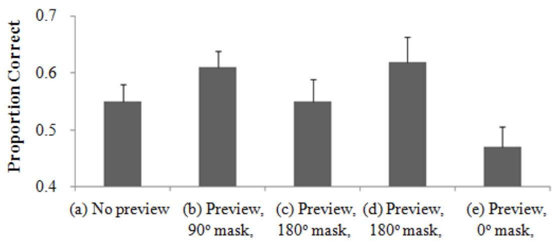

Fig. 3: Proportion of correct responses across the respective preview conditions in the experiment. Error bars represent standard errors

4. Discussion

The results indicate that previewing the mask before its presentation with the target array attenuated masking (comparison between (a) and (b)). However, this preview effect was not apparent when the masks in the preview and target array frames were different in configuration (condition (c)). By removing the ISI between the two frames, previewing was again able to attenuate masking by way of apparent motion (condition (d)). The change in configuration of the masks from preview to target array frames was a 90^o *counterclockwise* rotation of the individual black filled inducers in conditions (c) and (d). In condition (e), all features were the same as condition (d) except the rotation of the mask from preview to target array frames was at a 90^o *clockwise* direction. With virtually identical kinds of rotation, masking effects at both condition (d) and (e) should be attenuated to equal amounts, but masking was observed in condition (e). This masking effect is likely attributable to the illusory square that obtained in condition (e).

Condition (a) replicates a standard OSM trial. Condition (a) was composed of a standard OSM sequence that presented the target simultaneously with the mask, followed by a delayed offset of the mask. Since both mask and target appeared abruptly, they should both be new elements of high priority[10,11]. Given their equally prioritized status and close proximity, both objects ought to be processed simultaneously. A short presentation of the target-mask combination renders its representation in the visual system unstable. The delayed offset of the mask interferes by substituting the representation of the target-mask combination in these processes resulting in an OSM effect. When mask preview was administered across conditions (b) to (e), the mask was presumably processed before the target array frame. Because the mask was fully specified, the target received most of the attentional resources, stabilising its representation. Masking was attenuated.

While where the mask at the target array frame was different from the mask at the preview frame, these masks remained high-priority elements as they were treated as separate objects (comparison between (b) and (c)). Both conditions had a long ISI between the two frames, but masking was attenuated only in condition (b). Previewing the mask in a different configuration (condition (c)) failed to attenuate the masking effect. Condition (d) attenuated the masking effect despite having a configuration change between the preview and test frames. This was possible because removing the ISI between the two frames led to an apparent motion effect that linked the two masks across both frames as the same object[4]. Here, the first mask was perceived as having rotated into the second, so that the mask presented at test frame was treated as old. It should, thus, not compete with the target for attentional resources. As such, the previewing of the mask attenuated its masking effect. Condition (d) also showed that by previewing and removing the ISI between the two frames an apparent motion effect was established; the intended masking object should lose its ability to substitute the target object since it has become old. Condition (e) differed with condition (d) in the configuration of the mask used during the target array frame. The Pacmen inducers formed an illusory square during the target array frame. This feature was unique to condition (e). Nonetheless, an attenuation effect in condition (d) should also be apparent in condition (e). Yet, performance in condition (e) was significantly worse compared to condition (d). This difference can only be attributed to the illusory square that the inducers had created.

The present results suggest that illusory objects function similarly to physical objects in masking. It seems that what critically define an object are not simply physical features, but essentially *representation in the mind*. Importantly, it is shown that illusory objects influence visual processing as well. This study is the first to directly examine the functional similarities between illusory and physical objects in masking in an uncontested way. Illusory objects, although "virtual", can powerfully create visual masking. This affirms the philosophical notion of what a visual object is. Specifically, whether an object physically occurs is peripheral; so long as it is perceived and represented in cognition, its effects are comparable to physical objects.

5. References

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