Two alternative target locations and object-based attention in Kanizsa Illusory and Amodal objects

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Abstract

Object-based attention refers to the effect that subjects are able to report the features of an object more efficiently on which attention has been focused than the features of an unattended object. It has been proposed that attention spreads more easily over an object surface than over other regions of space (Mattingley, Davis, & Driver, 1997). In the current paper, two experiments are reported in which (the distribution of) endogenously directed attention is studied in Kanizsa Illusory and Amodal objects. In the first experiment, subjects had to respond to letters which were presented either to the left or to the right of fixation. Informative or neutral endogenous cues (two arrowheads) were presented 500 ms before target presentation. Informative cues predicted the target location with a probability of 80% (valid trials). In the other 20% of the trials with informative cues the target was presented at the unexpected location (invalid trials). In case of neutral cues, the target was as likely to be presented at the left or right location. Cue and target were presented within a Kanizsa Illusory rectangle or within an Amodal rectangle. In Experiment 2, subjects were required to simply detect a sudden onset at left or right target positions. The targets were either presented within the end of a large rectangular object or within one of two square objects (again Kanizsa or Amodal objects). After presentation of the objects, the inducers at the left and at the right changed in different colours (e.g., blue at the left and red at the right), indicating the most probable target location. After 400 ms the target appeared in 67% of the cases at the cued location, and in 17% at the other location. In addition, 17% of the trials were catch trials, in which no target was presented and subjects had to withhold responding. In both experiments standard performance effects of spatial cuing were obtained, but these effects were completely independent of the type of object(s) in which the targets were presented. It is argued that object-based attention effects reflect a preference to shift attention within attended objects before attending other objects.

2.1 Introduction

Visual spatial attention is thought to act by modulating early visual information processing. Subjects selectively attending to a certain spatial area have a better representation of the visual information presented within that area as compared to information presented elsewhere. As a result, in tasks involving a speeded response, subjects show reduced reaction times and fewer errors when stimuli are presented at attended locations as compared to stimuli at other locations. For example, Posner (1980)
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cued subjects' spatial attention with arrowheads which predicted the most probable location of an upcoming peripheral (left or right) stimulus. A simple response had to be made to that stimulus. Responses were faster for validly cued stimuli than for invalidly cued stimuli. Posner (1980) also used a neutral cue which did not predict the location of the stimulus. RT to neutrally cued stimuli was intermediate to validly and invalidly cued stimuli, indicating that spatial attention both facilitates information processing at validly cued locations and inhibits information processing at invalidly cued locations.

Because of such findings and many others, theories of visual attention have heavily emphasized the spatial, location-based aspects of attention (e.g., Van der Heijden, 1993). Duncan (1984), however, showed that space-based attention cannot account for some performance differences when subjects responded to stimuli presented at the same spatial location. Subjects were presented with two objects: a box and a line struck through it. Participants had to report two of four features of these objects. In the situation in which the 'target features' belonged to the same object, performance was far superior to the situation in which the features belonged to different objects, even though the spatial distances between the features were identical in both situations.

The theoretical question is whether spatial attention is acting upon incoming elementary features before or after these are integrated into consistent object percepts. In the latter case, spatial attention also would be expected to be affected by the properties of the perceived objects. Mattingley, Davis, and Driver (1997) showed an elegant example of object-based attention effects. A patient with hemi-neglect performed a simple detection task. Hemi-neglect is considered as a syndrome mostly developed by patients with damage to the superior temporal sulcus (STC) in the right hemisphere. These patients seem to have ‘lost the left side of their world’. The patient in the study of Mattingley et al. (1997) had to detect 'pacmen' figures on the left, right or on both sides of fixation, which could be configured (in the case of four inducing pacmen) so that an illusory square was created (i.e. a Kanizsa rectangle). When four pacmen were presented in such a way that these did not create an illusory rectangle, the patient only reported the presence of the pacmen in the right visual field, a classical pattern known as extinction. Importantly, when the four pacmen were arranged as an illusory rectangle, the patient also reported the left pacmen also when the four pacmen were configured in an illusory contour display. It was argued that the percept of the illusory rectangle was created before attention was spatially distributed. Attention, it was proposed, 'spreads' over the illusory rectangle into the contralesional hemispace and consequently leads to a reduced extinction.

If attention tends to spread across perceived objects, this tendency might counteract efforts to direct attention selectively to parts of an object. In that case, it is expected that the attention effects as found by Posner will be diminished (or absent) by displaying the task within an illusory object, since the object is considered to be preattentively created and to alter the spatial distribution of attention. We report on two experiments using Kanizsa illusory figures in speeded response attention tasks. In the first experiment, participants were given a task similar to the Posner paradigm. A central double arrowhead cued the most likely position (left or right of fixation) of the upcoming target letter. In addition, in some trials there was a neutral cue, which specified that both positions were equally likely. This Posner task was displayed either within a Kanizsa illusory rectangle or within a Kanizsa violation (Amodal figures in which the inducing
circles were completed, see Fig 1). The purpose was to examine whether the display of the illusory objects altered the spatial distribution of attention. This would be evidenced by the finding that the RT effects which are usually obtained in the Posner paradigm would be reduced or absent in the illusory Kanizsa figure condition. We expected that the modulating effect of the embedding figure on the spatial attention effects would be larger with Kanizsa figures than with Amodal figures, since for Amodal figures the subjective experience of perceiving an illusory figure is much smaller. Other evidence also indicates that Kanizsa and Amodal figures are processed differently (Corballis, Fendrich, Shapley, & Gazzaniga, 1999).

In the second experiment, instead of the central double arrowhead cues, the inducer elements of the Kanizsa figure were used to cue spatial attention. This was an attempt to increase the importance of the illusory object itself in the orienting of attention. In Experiment 1, subjects could in principle ignore the illusory object and focus their attention completely to the central cue. Note though, that according to some of the ideas described above, this would not be possible, since the illusory object is processed preattentively, automatically modulating the distribution of spatial attention. Nevertheless, it could be that object-based attention effects are less obligatory than sometimes postulated, and that therefore task related factors might matter.

First, 8 pacmen inducers (2 vertical, 4 horizontal) were presented and configured in either two Kanizsa squares (1 left, 1 right of fixation) or one large Kanizsa rectangle, extending from the left to the right visual field. Again, in this design Amodal figures were used for comparison. The figures in this experiment could not be ignored, as in the first experiment, since spatial attention was cued by colouring the inducing pacmen. Subjects were instructed to attend to the location that was surrounded by inducers with a certain colour. Again, the probability that the stimulus appeared at the attended location was 80%. No neutral cues were used in the second experiment. Another difference between both experiments was that we used a discrimination task in Experiment 1, and a simple detection task in Experiment 2.

2.2 Experiment 1

2.2.1 Method

2.2.1.1 Participants

14 unpaid right-handed volunteers (age: 17-27) were positioned 0.75 meter in front of a computer screen and had normal or corrected-to-normal vision.

2.2.1.2 Procedure and Stimuli

A trial consisted of 5 displays. First, a fixation sign (‘+’) was shown at the centre of the screen for 400 ms. Second, a double arrowhead, cuing the likely location of the target (‘>>’ or ‘<<’), or a neutral cue (‘><’), substituted the fixation sign. Neutral cues were presented in 1/3 of the trials. After 500 ms, randomly, either a Kanizsa or an Amodal rectangular figure (width: 9.2 cm, height: 5.6 cm, see Figure 2.1) was presented. The centre of these figures was at fixation, and the figures extended to the left and right in
both visual half fields. The figures were induced by four pacmen, 4.5 cm in diameter each, placed on each corner of the rectangular figure. Amodal inducing pacmen were created by erasing a quarter of the circle, like in the Kanizsa figure, with the exception of the outer ring of the circle (1 pixel thick). The strength of the illusion is expressed by dividing the length of delimited rectangle line area by the total illusory line length (see Ringach & Shapley, 1996). For the illusory rectangle width this is 4.5/9.2=0.49, for height this is 4.5/5.6=0.8. 750 ms later the imperative stimulus (IS) was presented, either to the left or right (2.2 cm) of the double arrowhead, within the Kanizsa or Amodal rectangle. The IS was either an 'E' or an 'H' (.6 × .6 cm) and was presented for 110 ms. The Kanizsa or Amodal figure and the cue were presented for another 1000 ms. Responses were collected in the 1110 ms interval in which the stimulus and the poststimulus Kanizsa or Amodal figures were presented.

Subjects were instructed to attend to the location to which the arrowhead pointed. The probability of the IS appearing at the indicated location was 80 % (in case of a neutral cue 50 %). One half of the subjects was instructed to respond with a left keyboard key ('z' button) when the IS was an 'E' and with a right keyboard key ('/' button) when the IS was an 'H'. For the other half of the subjects the instruction was reversed. Subjects were instructed to respond as fast and accurately as possible. Ten blocks of 120 trials were presented to each subject.

2.2.1.3 Analyses

Reaction time (RT) and errors percentages were analyzed. A repeated measures MANOVA was calculated for two factors; cue validity (VALIDITY, three levels; valid, neutral, or invalid), and figure type (FIGURE-TYPE, two levels, Kanizsa or Amodal figure). In order to account for the violation of sphericity assumption in the application of the univariate approach, we used the Huynh-Feldt correction (Huynh & Feldt, 1976) in case of a Huynh-Feldt epsilon \( \geq 0.75 \), and the Greenhouse-Geisser correction (Greenhouse & Geisser, 1959) in case of an epsilon < 0.075 (Quintana & Maxwell, 1994).
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2.2.2 Results

The analyses showed significant RT- and error-effects of VALIDITY (F(2,26)=44.8, p<.001, and F(2,26)=9.5, p<.005, respectively). However, there was no main effect of FIGURE-TYPE, nor an interaction between FIGURE-TYPE and VALIDITY (RT: F(2,26)=.43, ns.; errors: F(2,26)=.57, ns.; see Figure 2.2).

Figure 2.2

In the upper panel the RTs on targets in Experiment 1, in the lower panel the accuracy data are presented. Error bars indicate standard error of mean.

It was observed that in RT there were no significant benefits, which is indicated by the contrast between valid and neutral conditions (F(1,13)=.2, ns.). However, more errors were made in the validly cued condition than in the neutral cued condition (F(1,13)=9.9, p<.05). The costs (indicated by the contrast between neutrally and invalidly cued conditions) in RT and errors were significant (F(1,13)=111.3, p<.001 and F(1,13)=10.8, p<.05). No effect of FIGURE-TYPE on either benefits or costs was found.
Another separate analyses of benefits compared to costs of cuing was performed to test the magnitude of the costs compared to the benefits. First, the difference between validly cued and neutrally cued conditions (indicating the benefits of attentional cuing) and the difference between neutrally and invalidly cued conditions (indicating the costs of attentional cuing) was calculated. The costs of attentional cuing in this experiment was higher than the benefits for RT ($F(1,13)=70.0, p<.001$) and for errors ($F(1,13)=11.4, p<.01$).

### 2.2.3 Discussion

We expected the spatial distribution of attention to be changed by presenting the spatial attention task in the context of an embedding illusory Kanizsa figure. In that case, first, we could have found that the validity effects were absent or much reduced as compared to similar studies without an embedding figural context. Clearly, this prediction could not be confirmed. We obtained robust effects of VALIDITY on both RTs and error percentages, and the size of the validity effect (valid as compared to invalid trials) is much comparable to other studies without embedding figures (e.g., Posner, Snyder, & Davidson, 1980; Posner, 1980). These VALIDITY effects indicate that subjects adequately shifted their attention to the cued position, despite the presence of the embedding illusory figure.

Second, we used Amodal figures as reference stimuli to the Kanizsa figures. Mattingley et al. (1997) found that Kanizsa figures but not Amodal figures largely improved left visual field performance of their extinction patient. Other research (Corballis et al., 1999) as well indicates that Kanizsa and Amodal objects are processed differently. Therefore, we expected that Kanizsa figures would have larger effects on spatial attention than Amodal figures. However, in contrast to expectation, the crucial FIGURE-TYPE by VALIDITY interaction was far from significant.

In the following part we discuss some possible explanations for the reason why we did not obtain the expected differential effects of Kanizsa and Amodal figures. First, Ringach and Shapley (1996) suggested that despite different perceptual outcomes in the formation of objects from Kanizsa configurations (strong illusory boundaries) and Amodal configurations (much weaker illusory boundaries), discrimination of object form of what would be rectangular shapes in our case, is the same. Possibly, the figural context did have an effect on the distribution of spatial attention, but similarly so for Kanizsa and Amodal figures. In fact, although we obtained robust validity effects (as determined by the difference in performance to validly and invalidly cued stimuli), the exact pattern of results was somewhat atypical. Contrary to previous studies (e.g., Posner, Snyder, and Davidson, 1980; Posner, 1980), attentional costs (performance in invalid versus neutral trials) were much larger than attentional benefits (performance in valid versus neutral trials). This might indicate that the embedding figural context was beneficial to task performance in the neutrally cued trials, helping the subjects to divide attention over the whole rectangular surface. Future investigations could use a condition without any figural context or a condition with pacmen in an orientation not forming an illusory figure.

Second, it could be that the subjects in experiment 1 did not perceive the Kanizsa figures at all. For instance, Lavie (Lavie and Tsal, 1994; Lavie, 1995) showed that when perceptual load is increased, irrelevant stimuli are processed only shallowly. In the
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In the present experiment, the introduction of the (irrelevant) inducing pacmen may have increased the perceptual load so that the processing of the individual pacmen was insufficient to produce an illusory object percept. However, this seems unlikely considering the literature on the processing of Kanizsa figures. There is ample evidence that irrelevant Kanizsa figures presented together with a visual attention task are processed extensively. For instance, subjects performing an attention task showed increased cerebral blood flow in area MT (an area known to be activated by the perception of motion) when rotating pacmen which induced illusory objects moved from top to bottom of the screen, in comparison with the same task in which the rotating pacmen did not induce illusory objects (Seghier et al., 2000). Furthermore, experiment 5 of Mattingley et al. (1997), in which the extinction patient had to detect dots presented within either a Kanizsa or an Amodal object, it was shown that she ignored a second dot on the left when the dots were presented in an Amodal object, but not in a Kanizsa object. This shows that a neglect patient strongly benefits from the context of an irrelevant Kanizsa figure, even though it has been demonstrated that neglect patients in general are highly vulnerable to even slight increases in perceptual load (Lavie, 1999).

Lastly, it is possible that the pacmen Kanizsa inducers have to play an active role in the attention task in order to influence spatial attention. In this task it is possible that subjects successfully ignored the Kanizsa object, because the pacmen inducers were always presented outside the focus of attention and could not be strategically used for improving performance. In comparison, Mattingley et al.’s (1997) patient had to actively search for pacmen inducers, or could profit from them in order to find a second dot on the left (Exp 5.), in which she only succeeded when the pacmen inducers formed a ‘good’ Kanizsa rectangle. Therefore, in Experiment 2, the pacmen inducers served as a predictive cue, indicating the most likely position of stimulus presentation.

2.3 Experiment 2

In the present experiment the pacmen inducers had to be used in order to optimally anticipate the upcoming target location. Pacmen inducers were changed from white to red on one side and from white to blue on the other side of fixation. These colours were predictive for the target location. In this way the pacmen inducers played a more prominent role in orienting attention, and possibly made it difficult for subjects to ignore the illusory figure(s). In addition we used a simple detection task instead of a discrimination task. The imperative stimulus was a bright white square placed in the illusory figure on either the cued (valid trials) or uncued side (invalid trials). Subject had to make a speeded response to the imperative stimulus. In catch trials no stimulus was presented and subjects had to withhold responding. In this design several figure displays were possible: eight pacmen inducers (four horizontally, two vertically) were either configured such that two illusory squares were presented (one left, one right) or such that one large illusory rectangular figure was presented, which covered left and right stimulus positions (see Figure 2.3).

The experiment of Egly et al. (1994) used a more or less similar design. Subjects had to detect a bright target square which was presented at one of the four ends of two rectangles. Before the stimulus was presented the subjects were exogenously cued to one the four rectangle ends by the brightening of the line which made up the rectangle end.
Egly et al. (1994) observed that when subjects were validly cued to a rectangle end, RT was fast relative to invalidly cued stimuli. Importantly, they observed that on invalidly cued trials, the RT was faster when a stimulus was presented at the opposite end of the cued rectangle than when the stimulus was presented at the other rectangle. Egly et al. (1994) concluded that apart from the obvious benefit of spatial cuing, there was also a benefit when the stimulus was presented at a location that was not itself directly cued, but belonged to the same perceptual object. The latter effect was interpreted as object-based attention.

In Experiment 2, we expected object-based attention to manifest itself particularly in the invalidly cued trials. In trials in which two illusory squares are presented and the stimulus is presented at the uncued square, the performance cost (relative to validly cued trials) will be large, since the stimulus is both spatially unexpected, and attention in addition has to switch to another object. In trials with a single illusory rectangle, on the other hand, an invalid stimulus is spatially unexpected, but is presented at a location within the cued object, so the performance cost should be smaller.

As in Experiment 1, Amodal figures were used as control stimuli. We expected object-based attention effects to be smaller for Amodal figures than for Kanizsa figures.

2.3.1 Method

2.3.1.1 Participants

13 Paid right handed volunteers (age: 19-29) were positioned 0.75 meter in front of a computer screen and had normal or corrected-to-normal vision.

2.3.1.2 Procedure and Stimuli

Each trial started with a fixation sign (‘+’) which was shown for 400 ms (see Figure 2.3). Then, for 1000 ms a display was presented containing 8 filled white circles (3.2 cm in diameter), four to the left and four to the right of fixation. Each set of four circles were arranged in a square configuration. Subsequently, a cue display was presented for 400 ms, in which parts of the circles were omitted to create pacman inducing a(n) illusory figure(s), or (an) Amodal figure(s). On half of the trials, the pacmen formed two square (illusory) figures (6.6 × 6.6 cm), one to the right and one to the left of fixation. In the other half of the trials the pacmen formed a single horizontal rectangle (19.2 cm width and 6.6 cm height), extending in both the left and right visual fields. For the Amodal figures, the pacmen inducers were configured the same as in Experiment 1. This stimulus also served as an attentional cue by presenting the four inducers in the left visual field in red, and the four inducers in the right visual field in blue, or vice versa. One of these colours (counterbalanced over subjects) indicated the location at which the subsequent imperative target would be presented with a probability of 80%. The imperative stimulus (IS) was presented for 100 ms, and consisted of a white square (3.3 × 3.3 cm), placed in the illusory space on the left or right of fixation between the inducing pacmen. 20% of the trials were catch trials without an IS. After the IS, there was an additional 800 ms response interval, in which the fixation sign and the coloured inducers remained visible.
Each subject was presented with 16 blocks of 48 trials. Mean RT was tested in a repeated measures analysis of variance (MANOVA) with factors VALIDITY (valid versus invalid), FIGURE-TYPE (Kanizsa versus Amodal figures), and CONFIGURATION (two squares versus one rectangle).

### 2.3.2 Results

Subjects used the coloured pacmen successfully as an attentional cue. On valid trials, the average RT was 243 ms and 298 ms on invalid trials (VALIDITY: $F(1,12)=32.6$, $p<.001$, see Figure 2.4). No further statistically significant effects were obtained. Error percentages were not analyzed, because too few errors were made.

![Figure 2.3](image)

**Figure 2.3**

Depicted is a schematic display of a trial of Experiment 2. Red and blue pacmen (see text) are depicted as light and dark in this figure.
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![Graph showing RTs on targets in Experiment 2.](image)

**Figure 2.4**

Presented are the RTs on targets in Experiment 2. The figure’s legend refer to the type of contextual object (Kanizsa or Amodal), and the number of objects used (1 rectangle or 2 squares). Error bars indicate standard error of means.

### 2.3.3 Discussion

We observed a robust spatial attention effect on RT. Importantly, the spatial attention effect was not modulated by the type of figures (Kanizsa versus Amodal), nor by the configuration of the figures (two squares versus one rectangle). Therefore, in contrast to what would be expected on the basis of existing literature (e.g., Egly, Driver, and Rafal, 1994; Moore, Yantis, & Vaughan, 1998), in the present experiment we were unable to demonstrate effects of object-based attention on the distribution of spatial attention.

In the present experiment the pacmen inducers were differently coloured in two groups of four, serving as an attentional cue. The purpose was that this stimulated the processing of the inducers and would lead to a stronger representation of the (illusory) figure(s). However, this procedure could have lead to an undesirable side-effect: possibly, object-based attention was guided more strongly by perceptual grouping on the basis of colour than by grouping on the basis of the induced illusory figures. In that case attention would be distributed over the group of pacmen in the relevant colour, independent of the type of figure presented. Possibly, in this situation no perceptual representation of the illusory figures is formed at all. Alternatively, it could be that despite the colouring of the inducers, Kanizsa figure representations were still built preattentively, but that the distribution of spatial attention is determined mainly by colour grouping.

### 2.3.4 General Discussion
Although we observed robust spatial attention effects in Experiments 1 and 2, we completely failed to obtain evidence for object-based attention effects. We could conclude from this that spatial and object-based attention concern two different processes which may sometimes interact (Egly, Driver, and Rafal, 1994; Mattingley, Davis, and Driver, 1997), but not in the experiments presented here. However, it remains unclear under what conditions object-based effects do or do not emerge.

Two considerations may be important. First, the influence of Kanizsa illusory figures on spatial attention might be weak and unreliable. It may be questioned whether the subjects in Experiments 1 and 2 actually perceived the (illusory) figures. However, results of the study of Mattingley et al. (1997) render this possibility rather unlikely, for they successfully modulated the distribution of spatial attention with similar Kanizsa figures. Furthermore, Moore, et al. (1998) replicated the experiment of Egly et al. (1994) with Kanizsa objects, and obtained similar object-based attention effects.

Second, it seems that object-based attention effects are hard to demonstrate in experiments with endogenous (symbolic) attentional cuing (Macquistan, 1997; but see Abrams & Law, 2000). Perhaps, when changes in the object-environment trigger reorienting of attention (e.g., by exogenous/peripheral cues), selection of some aspects of that environment occurs involuntary, resulting in object-based effects. On the other hand, it could be that selection of the environmental elements is suppressed when reorienting occurs without a change in the object-environment (by using endogenous cues).

Goldsmith and Yeari (2003) emphasized another important difference between exogenous and endogenous cuing in studies on object-based attention. They pointed out that before presentation of an exogenous cue, attention is presumably broadly distributed over both rectangles. However, before the presentation of an endogenous cue, attention is probably tightly focused at the position at which the endogenous cue is about to appear. The diffuse attentional state in the pre-cue interval in exogenous cuing conditions might promote object-based attention. Evidence for their stance was obtained in experiments in which it was attempted to induce a diffuse attentional state in the pre-cue interval in endogenous cuing conditions as well (by instruction and by auditory endogenous cuing). Indeed, clear object-based attention effects were obtained with such conditions. Unfortunately, these notions do not explain the absence of object-based attention effects in Experiment 2. The colouring of the left and right parts of the stimulus display in the cue interval was unpredictable, so that it seems reasonable to assume that subjects divided attention over the entire configuration in the pre-cue interval.

It could be that object-based attention mechanisms are only active during a short period of time after the initial focussing of attention, and that only space-based mechanisms are active following this time interval. Evidence for this was obtained in a study of Abrams and Law (2000). These authors used the Egly et al. (1994) paradigm with arrowheads as endogenous cues. They observed, like others (Macquistan, 1997), that with a cue-stimulus interval of 900 ms no object-based effects exist. Surprisingly however, they did observe these effects in a 300 ms cue-stimulus interval. This may indicate that object-based attention effects are short-living after reorientation of spatial attention. In Experiment 1 we used a 750 ms cue-stimulus interval, which might explain the absence of object-based attention effects in that experiment. However, in Experiment 2 we used a shorter (400 ms) cue-stimulus interval, and still did not obtain object-based effects.
A final consideration concerns another important difference between the present experiments and other studies on object-based attention (e.g., Egly, Driver, and Rafal, 1994). In other studies invalid targets could appear at two uncued locations, whereas there was just a single uncued location in our experiments. Shomstein and Yantis (2004) argue that object-based attention effects in fact reflect a search preference. If, on invalid trials, attention has to be reoriented towards uncued positions, subjects prefer to start searching for the invalid target in the same object. If there is just a single alternative target location, no preferential search strategy is possible, and therefore it doesn’t matter whether the single alternative location belongs to the same or to another object. This could explain why, in Experiment 2, we did not find differences between RT to the invalid targets presented in the same object (single rectangle trials) and RT to invalid targets presented in a different object (two-square trials).