Early ERP components show cued object advantage in Kanizsa and Amodal subjective figures

Jurjen van der Helden, Berry Wijers, and Ritske de Jong.

Abstract

We used Kanizsa and Amodal rectangles to test whether the spatial distribution of attention was influenced by subjective figures, analogue to the seminal experiments of Egly, Driver, & Rafal (1994). We precued one of four ends of two (subjective) rectangles before subjects had to detect a luminant target. This target was either presented at the position of the precue (Valid trial), within the precued rectangle but opposite to the cued position (Cued Within trial), or at the uncued rectangle (Cued Between trial). By comparing these three classes of trials we investigated space-based (Valid versus Cue Within trials) and object-based (Cued Within versus Cued Between trials) attention effects on performance and event-related potentials (ERPs, Experiment 2). In two experiments we replicated the findings of Egly et al. (1994) with Kanizsa figures. RTs were faster for Valid Trials than for Cued Within trials, and RTs were fasted for Cued-Within trials than for Cued Between trials. Overall (Valid versus Cued Between trials) attention enhanced early components (P1/N1) in the event-related potential (ERP), reflecting modulated sensory processing (‘sensory gain’). The contralateral P1 (100-140 ms) only showed a space-based effect, whereas the contralateral N1 (150-200 ms) showed both a space-based and an object-based effect. These RT and ERP effects were similar for Kanizsa and Amodal rectangle figures. These results indicate that object-based attention was active both for Kanizsa and Amodal rectangles and resulted in sensory gain for stimuli presented within the cued object, although at a later stage of processing than purely space-based sensory gain.

3.1 Introduction

In everyday life, we navigate in a rich environment with moving and static, coloured and monochrome, living and non-living objects. To navigate properly, we should be able to filter out the relevant events from the irrelevant ones. Visuospatial attention provides us with a tool that enables us to do so. Attended objects can be described more precisely and remembered longer and better. Posner (1980) suggested that information presented at an attended location is selected for further processing. A way to manipulate spatial attention is to present a short visual flash in the peripheral visual field, which is assumed to attract attention (‘exogenous attentional cue’). Shortly thereafter a target is presented, either at the position of the attentional cue or at the opposite position, in the other visual field, and subjects have to detect or discriminate the target as fast as possible. Usually it is found that when the locations of the target and the cue overlap (valid trials) performance is better as compared to when the target and the cue were on different positions (invalid
trials). Duncan (1984) showed that space is not the only critical feature on the basis of which selection operates. He presented subjects with two superimposed objects (a box and a line) which varied both on two visual features (size and gap-side for the box and tilt and texture for the line). Subjects were required to identify two of those features. When the subjects had to identify two of the features of the same object, detection was superior as compared to the situation in which subjects had to identify two features of different objects. This indicates that selection is biased towards selecting whole objects even when they share the same location.

Although space-based and object-based accounts of attention can be seen as rival, it is also possible to view space-based and object-based attention as complementary. Results from an experiment by Egly, Rafal, & Driver (1994) can be taken as supportive for the latter view. In this experiment two rectangles were presented vertically to the left and right of fixation or horizontally above and below fixation. Subsequently a peripheral cue was presented in one of the four rectangle ends. This cue was either valid (the stimulus appearing a short time later was at the same location) or invalid. Validly cued stimuli were detected faster than invalidly cued stimuli. Invalidly cued stimuli could be presented either in the cued rectangle but at the opposite end (Cued Within), or in the uncued rectangle (Cued Between). The spatial distance between the valid and invalid positions was identical for the Cued Within and Cued Between trials. Importantly, subjects responded slower to the Cued Within stimuli than to the validly cued stimuli, but faster than to the Cued Between stimuli. The latter difference was considered an object-based attention effect, whereas the former difference can be considered as an additional effect of space-based attention.

Many later studies on object-based attention used variations of the experimental design of Egly et al. (1994). Moore, Yantis and Vaughan (1998) used rectangular illusory Kanizsa figures instead of real outlined rectangles. Kanizsa figures are typically configured by placing pacman on the corners of an illusory occluding object (see Figure 3.1, middle). Moore et al. (1998) observed object-based attention effects similar to Egly et al. (1994), indicating that the spatial distribution of attention was altered by the illusory objects.

In another experiment Moore et al. (1998) presented two outlined rectangles with another rectangle placed on top of the two rectangles so that this gave the impression of two rectangles appearing behind an occluding rectangle. When an object is partly occluded, but is seen as one whole object, it is said to be amodally completed. The occluding rectangle had no effect on the object-based attention effect. Moore et al. (1998) concluded that perceptual completion of objects is accomplished before objects influence the spatial distribution of attention, since object-based attention effects occurred even when the occluded rectangles had to be amodally completed (for a computational account see Behrmann, Zemel, and Mozer, 1998).

Vecera and Behrmann (1997) studied task performance in the Egly et al. (1994) paradigm in a patient with apperceptive agnosia. They observed that the patient did show the usual space-based cuing advantage, but failed to show an object-based cuing advantage. Abrams, and Law (2002) found that the object-based attention advantage was also eliminated by adding random visual noise to the stimulus displays. Abrams and Law (2002) concluded that object-based attention effects depend on successful segmentation of a scene into objects in an early stage of visual processing. Since the objects were still
clearly visible in the noise condition, Abrams and Law (2002) hypothesize that the segmentation that is accessible for conscious report may differ from the (earlier) representation that is operated upon by object-based attentional mechanisms.

Chen (1998) used two coloured ‘V’-shaped objects as a background for target presentation. The Vs were aligned so that they formed two differently coloured upper and lower parts of a large ‘X’. Similar to the Egly et al. (1994) design, one of the ends of this background object was cued, and subsequently subjects had to discriminate targets that were presented either at the cued position or at the other uncued positions. When Chen (1998) referred to these objects as two aligned ‘V’-shaped objects, subjects showed an object-based advantage: the RT for targets on the uncued location within the cued object (V) were faster than when targets were presented on the uncued object (differently coloured V). Importantly, when he referred to the objects as one (two-coloured) large ‘X’-shaped object, subjects no longer showed this object-based advantage. This suggests that subjective organization is an important factor in the manifestation of object-based attention effects.

Similarly, Iani, Nicoletti, Rubichi, & Umiltá (2001) showed that the object-based attention effect was eliminated when two of the rectangle ends used by Egly et al. (1994) were connected, resulting in one unitary ‘U’-shaped object. The conclusion which can be drawn from this is that whenever the subject is able to perceive an object (even occluded or illusory), spatial attention will be distributed preferably over the cued object. The internal representation on which selective attention operates depends on subjective interpretation (Chen, 1998) and experience (Behrmann, Zemel, and Mozer, 1998; Zemel, Behrmann, Mozer, & Bavelier, 2002).

Numerous experiments have shown that Kanizsa illusory objects alter the distribution of spatial attention as real objects do. Davis and Driver (1994) showed that visual search of Kanizsa illusory objects in a display with up to six clusters of pacmen was parallel. Later, they showed that search for a Pacmen figure among circular distractors was impaired when the Pacmen was placed on a corner of an illusory occluding Kanizsa object (Davis & Driver, 1998). They concluded that because the subjects amodally completed the Pacmen into an intact circle, placed behind the occluding illusory surface, it did not pop-out anymore. Similarly, search on occluded (amodal object surfaces is disrupted by distractors in occluding object surfaces (Ricciardelli, Bonfiglioli, Nicoletti, & Umilta, 2001; Davis & Driver, 1997).

Results from Mattingley, Rafal, & Driver (1997) provided another demonstration of the fact that illusory objects can exert strong effects on the distribution of visuospatial attention. They showed that their visual extinction patient could detect simultaneous changes on the left and right of a visual display when these changes produced a Kanizsa illusory object, but failed to detect any changes on her contralesional side when these did not produce a proper Kanizsa object. For instance, when two dots were presented (left and right) within a Kanizsa object, she was able to detect them both, but she could not do this (she only reported the right dot) when these dots were presented on a Kanizsa-like object in which the outer rim of the inducing pacmen were closed (often referred to as amodal objects, see Figure 3.1, lower). Corballis, Fendrich, Shapley, & Gazzaniga (1999) showed in two split-brain patients that the perception of Kanizsa illusory objects could be performed by both hemispheres, whereas discrimination between differently shaped amodal objects could be performed accurately by the right hemisphere only. So, Kanizsa
Early ERP components and Object Based Attention

figures and amodal figures are apparently perceived differently and have different effects on spatial attention (Mattingley, Davis, and Driver, 1997; see Ringach and Shapley, 1996, however). Alternatively therefore, it could be argued that the patient of Mattingley et al. was impaired in perception of the amodal object, because of the damage of her right hemisphere (which, according to Corballis et al. is important in perception of amodal objects). Note also that these 'amodal' objects do not have the effect on spatial attention (Mattingley, Davis, and Driver, 1997; Davis and Driver, 1994) as do occluded objects (Moore, Yantis, and Vaughan, 1998; Behrmann, Zemel, and Mozer, 1998; Zemel et al., 2002).

It has been suggested that object-based attention is dominantly a function of the left hemisphere. Patients with hemi-neglect due to right temporoparietal damage often fail to detect targets in contralesional hemispace, but less frequently so when targets are part of or are presented within an object extending into contralesional hemispace (Mattingley, Davis, and Driver, 1997; Egly, Driver, and Rafal, 1994). Egly, Rafal, Driver, & Starreveld (1994) used the same stimuli as Egly et al. (1994) but now presented either to the left or right visual fields. Egly et al. (Egly, Rafal, Driver, & Starreveld, 1994) found that a split-brain patient showed large object-based attention effects with right visual field presentation, but significantly reduced object-based effects with left visual field presentation. Neuroimaging research has provided supportive evidence for the idea that the left hemisphere is dominant for object-based attention. Arrington, Carr, Wayer, & Rao (2000) showed that several left hemisphere structures showed increased activation when subjects oriented spatial attention to an area bounded by object contours (object-based spatial attention) as compared to when subjects oriented to an unbounded region of space (location-based spatial attention). More specifically, increased activation with object-based spatial selection was found in left lateralized dorsolateral frontal, parietal, temporal, and thalamic structures. Arrington et al. (2000) suggest that these are the same brain areas that are known to be involved in spatial attention on the basis of previous research, and that these structures are more intensively activated in the left hemisphere when spatial attention is tightly focused by the boundaries of an object.

In the present experiment we investigated the time course of the processes involved in space-based and object-based attention using event-related brain potentials (ERPs). ERPs provide an excellent opportunity to examine the temporal aspects of space-based and object-based attention. Space-based attention has already been extensively studied with event-related potentials (ERPs). Numerous studies have shown that spatial attention modulates early exogenous ERP components, namely P1 (100-140 ms) and N1 (150-200 ms) (Wijers, Lamain, Slopsema, Mulder, & Mulder, 1989; Mangun & Hillyard, 1991; Eimer, 1993; Eimer, 1994a; Eimer, 1994b; Yamaguchi, Tsuchiya, & Kobayashi, 1995).

Only few studies investigated object-based attention using ERPs. In a study of Valdes-Sosa and colleagues (Valdes-Sosa et al., 1998), the stimuli consisted of two superimposed sets of dots in rigid rotation around fixation, each set of a different colour and direction of motion. These stimuli generated the percept of two transparent surfaces sliding across each other. At random intervals, the dots of one colour were linearly and simultaneously displaced, while the other set continued to rotate. Subjects were instructed to attend to one of these surfaces (and to ignore the other surface) in order to discriminate the direction of the displacements within that surface. Attended as compared to
unattended displacements induced an increase of P1 and N1 amplitudes. Although the attended and unattended stimuli occupied the same spatial positions, attending one of the ‘objects’ (surfaces) modulated these early visual components.

In the present experiment, we aimed at a direct comparison of space-based and object-based selection. For this reason, the temporal dynamics of both types of selection was our main interest, rather than which specific ERP components are modulated. Important effects were expected to be found not only at occipital sites (e.g., P1/N1 effects), but also at other midline and more frontal electrodes. For instance, Weber et al. (1997) showed that the P300 is also modulated by object-based selection (see also Czigler and Balazs, 1998).

Czigler and Balazs (1998) used the same stimuli as Duncan (1984, see above) and measured ERPs. Stimuli with two specific features were denoted as targets. In different conditions these two features belonged to the same object or to different objects. The ERPs in single-object versus two-object conditions condition diverged earlier than the onset of the ERP differences between the target versus nontarget stimuli. Czigler and Balasz (1998) interpreted this finding as showing that the allocation of attention to a particular object precedes (and might facilitate) the identification of the stimulus features. In a second experiment Czigler and Balasz (1998) used identical stimuli, with the exception that the two objects were spatially separated. Although the authors did not statistically compare the results from the two experiments, visual inspection of their data (Figure 4, p.122) suggests that the single versus two-object differences emerged earlier with separated objects (Experiment 2) than with spatially overlapping objects. This suggests that a spatial separation between objects speeds up the allocation of attention to one of the objects.

Objectives

The first experiment was an attempt to replicate the object-based effect reported by Egly et al. (1994), using illusory rectangular objects formed by illusory contours. We directly compared this condition with a condition with rectangles formed by real contours (identical to Egly et al., 1994). A replication of object-based effects with illusory contours would pave the way for Experiment 2, in which we aimed to trace the time-course of illusory object-based and space-based attentional processes using ERPs.

3.2 Experiment 1

Moore, Yantis, & Vaughan (1998) already showed object-based attention benefits in an experiment with objects (rectangles) formed by illusory contours. However, in that experiment the task consisted of searching a target letter (either ‘T’ or ‘L’) at one of the rectangle ends among distractors at the other rectangle ends. In order to compare space-based and object-based ERP-effects it is necessary to stimulate a single spatial location. Therefore, we investigated whether we would obtain similar results using a simple detection task instead of the search/discrimination task used by Moore et al. (1998). If an object is cued by a peripheral cue, the allocation of attention to that object will cost a certain amount time. Therefore, it could be that the latency of the response relative to the moment of cuing might be an important factor determining whether or not object-based
Early ERP components and Object Based Attention

effects will be found. Since reaction times are much faster in simple detection tasks than in search/discrimination tasks, it seemed essential to verify that object-based effects would be obtained using a simple detection task. Additionally, we compared attentional effects with illusory rectangles with the effects with real rectangles as used by Egly et al. (1994).

3.2.1 Method

3.2.1.1 Participants

Twelve subjects (4 female, 8 male, age M=23.6) were recruited from the Groningen University population and paid for their participation. Informed consent was obtained before the experiment. Their vision was normal or corrected-to-normal.

3.2.1.2 Stimuli

Subjects sat 1 m in front of a computer screen. A fixation cross was presented on the centre of the screen (+), which remained visible throughout the entire block. A trial began with the presentation of two rectangles on either side (either horizontally, below and above, or vertically, right and left) of fixation. These rectangles were made up of real contours (Real rectangles) or of illusory contours (Illusory, Kanizsa rectangles). The real rectangles were two boxes of $15 \times 5$ cm made up from 2 pixels wide lines. The Kanizsa Illusory Rectangles were produced in the following way: first 16 white circles (diameter 2.5 cm) were placed in four rows of four with 2.5 cm space between them. Then the space of two horizontal or vertical rectangles of $15 \times 5$ cm was cleared on either side of the centre (see Figure 3.1, middle). The illusory rectangles had a support ratio of 0.5 (see Ringach and Shapley, 1996). After 1000 ms presentation of these figures, a peripheral cue was presented for 50 ms. The cue was a line of 8 pixels wide along the border of one of the rectangle ends (5 cm in length). In 80% of the trials a target stimulus (a white square of 42 mm in diameter) was presented at one of three possible positions (either at the cued position: Valid, or at the opposite end of the cued rectangle: Cued Within, or opposite to the cued position in the uncued rectangle: Depicted are used objects in Experiment 1 and 2. In Experiment 1 real (top figure) and Kanizsa objects (middle figure) were used. In Experiment 2 Amodal objects (bottom figure) were contrasted with Kanizsa objects. In this example the rectangular objects are oriented horizontally, although we also used vertical rectangles.
Cued Between), after a variable interval between 250 and 340 ms (10 ms steps). The remaining trials were catch trials in which no target was presented. 75% of the target-present trials were valid. 12.5% of the target-present trials were Cued Within trials, and 12.5% were Cued Between trials. After 1000 ms the target and rectangles disappeared. The next trial began after 500 ms presentation of a screen with only the fixation cross.

### 3.2.1.3 Procedure

Subjects were instructed to respond when a target was presented by pushing the 'spacebar' key of a computer keyboard with their right hand, and withhold responding on catch trials. Subjects completed 10 blocks of 160 trials. Each block consisted of 96 valid trials, 16 Cued Within trials in, 16 Cued Between trials, and 32 catch trials.

### 3.2.1.4 Analysis

The median response times (RTs) were analyzed with a 2 (FIGURE-TYPE: Real versus Kanizsa rectangles) × 2 (ORIENTATION: Vertical versus Horizontal rectangles) × 3 (VALIDITY: Valid, Cued Within, or Cued Between) within subjects repeated measures analysis of variance (MANOVA). In order to account for the violation of sphericity assumption in the application of the univariate approach, we used the Huynh-Feldt correction (Huynh and Feldt, 1976) in case of a Huynh-Feldt epsilon ≥0.75, and the Greenhouse-Geisser correction (Greenhouse and Geisser, 1959) in case of an epsilon <.075 (Quintana and Maxwell, 1994).

### 3.2.2 Results

The median RTs are presented in Figure 3.2. Reactions to stimuli presented in Real rectangles were faster than when they were presented in Kanizsa Illusory rectangles (FIGURE-TYPE: F(1,11)=13.2, p<.005). As expected, a main effect of VALIDITY was found (F(2,22)=24.3, p<.001), indicating the fastest reactions on valid trials, and the slowest on Cued Between trials. A planned comparison confirmed that RT was faster in Cued Within trials than in Cued Between trials (F(1,11)=29.8, p<.001). There was no significant interaction between FIGURE-TYPE and VALIDITY (F(2,22)=1.6, ns.), indicating that the pattern of attention effects was similar for both real and illusory figures. VALIDITY interacted with ORIENTATION (F(2,22)=4.2, p<.05). Contrasts revealed that ORIENTATION was only significant in Cued Within trials (F(1,11)=5.5, p<.05), in which RT was slightly faster (6 ms) for horizontal stimuli than for vertical stimuli. In Horizontal objects, responses were given 6 ms earlier than in Vertical objects.
Early ERP components and Object Based Attention

Figure 3.2

Reaction times of Experiment 1 are presented here. RTs to stimuli presented in Real rectangular objects are presented in the left panel, and to stimuli presented in Kanizsa objects in the right panel. Error bars indicate standard error of mean.

3.2.3 Discussion

The results clearly showed both space-based and object-based cuing benefits. These effects were much the same for Real figures and Illusory figures. Moore et al. (1998) obtained similar results with Illusory figures. However, their subjects had to search for a target among nontargets, whereas the subjects in the present experiment simply had to detect targets. Two remarks should be made regarding this difference in task requirements. First, it could be argued that the subjects in Moore, et al's study showed an object cuing search advantage, which does not necessarily implicate that the distribution of visuospatial attention depended on (illusory) objects. McCarley, Kramer, and Peterson (2002) recently suggested that subjects are more inclined to overtly explore within a cued object rather than that visuospatial attention is altered by the object. Subjects were required to look at the target before manually judge its orientation. In invalidly cued trials saccades from the cued location were more likely made within the cued rectangle than between rectangles. Moreover, the time to redirect gaze within a rectangle was shorter than between rectangles, whereas the time between a corrective saccade and the manual response to the target was the same for targets within the cued rectangle and targets in the uncued rectangle. This suggests that the performance benefit at the location within the cued rectangle relative to the location in the uncued rectangle does not so much reflect ‘radiation’ of visuospatial attention within the cued object, but rather a preference to explore locations within a cued object first.
Chapter 3

Second, the RTs in the present experiment with a simple detection task are at least twice as fast as in the search experiment of Moore et al. (1998). In the introduction we argued that the interval between cuing and responding might have an effect on the strength of object-based effects. Despite the fast RTs in the present experiment, we still obtained robust object-based effects, indicating that attention is rapidly allocated to the cued object.

3.3 Experiment 2

3.3.1 Method

3.3.1.1 Participants

Fourteen (4 males, 10 females, age M=21.4) voluntary subjects were paid for their participation. They had normal or corrected-to-normal vision.

3.3.1.2 Procedure and Stimuli

The procedure of Experiment 2 was the same as in Experiment 1 with a few exceptions. Subjects received series of 80 trials per run. In total they received 20 runs. The same stimuli were used in case of Kanizsa object trials as the Kanizsa object trials in Experiment 1. In Experiment 2 Amodal figures were used instead of the Real figures used in Experiment 1. Amodal figures were similar to the Kanizsa figures, with the difference that the 'mouths' of the pacmen were outlined by closed circles (one pixel thick, see Figure 3.1, lower panel). After a variable interval after cue onset (230-320 ms with 10 ms steps) the target appeared in one of the rectangle ends. In this experiment, subjects were seated 1 m from the screen and had their heads in a chin-rest. The subjects had to respond with a release button whenever a target was detected. On catch trials, subjects had to withhold their response. The subjects were informed that the cue location was informative for the target location. After each block the subjects were informed about their performance. Of the 80 trials presented in each block, 32 were Valid trials, 16 were Cued Within trials, 16 were Cued between trials, and 16 were Catch trials. So, on target-present trials the cue predicted the target location with a probability of 50%.

3.3.1.3 Recording

The electroencephalogram (EEG) was measured with an electrocap (Electro-Cap International) using 30 Sn electrodes placed at positions O2, Oz, O1, PO10, PO8, PO7, PO9, P10, P8, P6, P4, Pz, P3, P5, P7, P9, TP8, CP4, CP3, TP7, T8, C4, Cz, C3, T7, F8, F4, Fz, F3, and F7 (Sharbrough, Chartrian, Lesser, Luders, Nuwer, & Picton, 1991) All electrodes were referenced to the right and left mastoids. Horizontal electro-oculogram (hEOG) was measured with Sn electrodes on the outer canthi. Vertical EOG was measured with Sn electrodes, above and below the left eye. The impedance of the electrodes was kept below 5 KΩ. EOG and EEG were amplified with a time constant of

---

Note that the probability of Cued Within and Cued Between trials was higher than in Experiment 1. This was done to increase the signal-to-noise ratio for the ERPs for invalid trials.
10 s and a 200 Hz low-pass filter, sampled at 1000 Hz, digitally lowpass filtered with a cut-off frequency of 35 Hz, and on-line reduced to a sample frequency of 100 Hz.

3.3.1.4 Performance Analysis

The median response times (RTs) were analyzed with a 2 (FIGURE-TYPE: Kanizsa or Amodal rectangles) × 3 (VALIDITY: valid, cued within, or cued between) × 2 (ORIENTATION: horizontal, or vertical) within subjects repeated measures (MANOVA). In order to account for the violation of sphericity assumption in the application of the univariate approach, we used the Huynh-Feldt correction (Huynh and Feldt, 1976) in case of a Huynh-Feldt epsilon ≥0.75, and the Greenhouse-Geisser correction (Greenhouse and Geisser, 1959) in case of an epsilon <.075 (Quintana and Maxwell, 1994).

3.3.1.5 ERP analysis

Only target-present ERPs were calculated from trials in which subject correctly responded within 150-1000 ms from presentation of the target. Since the cue-target interval was rather short (although variable), it could be expected that the target ERPs were overlapped by ERP-activity elicited by the cues. To correct for this, we made ERPs of the catch trials. These were used as an approximation of the cue-related activity and were subtracted from the ERPs in the target-present trials. The catch trial ERPs were averaged by taking as the zero time-point the same time-point at which targets were presented in the target-present trials. The catch trial ERPs were produced by taking the zero time-point with the same jitter relative to cue-onset as the targets in the target-present trials.

In the catch trials (as in the target-present trials), cues were presented at one of four possible display locations. We averaged the catch trial ERPs separately for each of these cue locations, and subtracted them from the target ERPs with the cue at the corresponding location. For further analyses, the waveforms were averaged over both stimulus positions within a visual half-field.

We focused on two aspects of the ERP. The first aspect is how the figural context influences the known spatial cuing effects on the visual components P1 and N1. Secondly, we explored the time-course of attention effects more precisely by testing mean amplitude values in small consecutive time windows. P1 and N1 amplitudes were calculated by averaging all samples between 100 and 140 ms and between 150-200 ms respectively on electrodes P7 and P8. For analysis of the temporal dynamics, the ERP on Cz was chunked from 0 to 360 ms in 18 bands of 20 ms to detect the onset of the different attention effects. Testing many intervals increases Type I errors. One band being significant on the basis of chance is (18 × 0.05=0.60). Therefore, we only report significant F values if there was a significant effect of a factor on at least two adjacent intervals. In this case, the probability of a Type I error in two consecutive significant intervals is reduced to 0.042. For consecutively significant bands the maximal F-value is reported.

Four factors were analyzed in a within subjects repeated measures design (MANOVA), FIGURE-TYPE, ORIENTATION, and VALIDITY. Furthermore, for the
Chapter 3

P1 and N1 analysis an additional factor LATERALITY (electrode ipsilateral versus contralateral to the target visual field) was tested.

3.3.2 Results

3.3.2.1 Performance

The median RTs are presented in Figure 3.3. A main effect of VALIDITY was found (F(2,26)=16.2, p<.001). Planned comparison showed that RTs on validly cued targets was faster than on Cued Within targets (F(1,13)=4.6, p=.05). Also, Cued Between targets were responded to more slowly than to Cued Within targets (F(1,13)=40.1, p<.001). Reactions to stimuli presented within Amodal rectangles did not differ from those presented in Kanizsa rectangles (FIGURE-TYPE F(1,13)=.4, ns.). Importantly, validity effects were found to depend on the type of figure in which the stimuli were presented (FIGURE-TYPE × VALIDITY (F(2,26)=4.9, p<.05). An analysis with Valid versus Cued Within revealed that an interaction existed between VALIDITY and FIGURE-TYPE (F(1,13)=14.6, p<.005). Planned comparisons revealed that responses to validly cued stimuli were faster when they were presented in an Amodal object as compared to Kanizsa objects (F(1,13)=10.9, p<.01).

An unexpected interaction was observed, namely between FIGURE-TYPE and ORIENTATION (F(2,26)=7.6, p<.05). Responses were faster to horizontal Kanizsa rectangles and vertical Amodal rectangles as compared to the other stimulus types.

3.3.2.2 ERPs

P1

Validly cued targets evoked a larger contralateral P1, as can be seen in Figure 3.4. This was statistically expressed in an interaction between VALIDITY and LATERALITY (F(2,26)=6.8, p<.05.). Post-hoc contrasts showed that VALIDITY was significant on the contralateral electrode only (F(2,26)=6.6, p<.05). Importantly, for this contralateral electrode, the P1 amplitudes for Cued Within and Cued Between targets did not differ (F<1), whereas Valid targets evoked larger P1’s than Cued Within targets (F(1,13)=14.0, p<.005), or Cued Between targets (F(1,13)=5.5, p<.05). This indicates that object cuing had no effect on the P1 amplitude.

An interaction was found between VALIDITY, LATERALITY and ORIENTATION (F(2,26)=3.9, p<.05). Figure 3.5 illustrates the origin of this effect. When cue and target were presented within the same hemifield the contralateral P1 was enhanced relative to a target in the uncued hemifield. This was confirmed by separate tests for the contralateral and ipsilateral electrode. Whereas there was a marginally significant ORIENTATION by VALIDITY interaction for the contralateral electrode (F(2,26)=3.3, p=0.53), this interaction was nonsignificant for the ipsilateral electrode (F(2,26)=1.8, ns.).
Figure 3.3

Reaction times of Experiment 2 are presented here. On the left panel, the RTs are presented to stimuli in Kanizsa rectangular objects, and on the right panel to stimuli in Amodal objects. Error bars indicate standard error of mean.

N1

A main effect of VALIDITY was found (F(2,26)=8.6, p<.01). The N1 was larger when the target was validly cued than when it was Cued Within (F(1,13)=7.3, p<.05) or when it was Cued Between (F(1,13)=11.1, p<.05), but the difference between Cued Within and Cued Between trials was not significant (F(1,13)=2.2, p>.05). VALIDITY also interacted with LATERALITY (F(2,26)=16.4, p<.001). As Figure 3.4 shows, this interaction reflects that at the ipsilateral electrode N1 amplitude is enhanced for the Valid trials only, whereas at the contralateral electrode N1 amplitude is enhanced both for Valid trials and for Cued Within trials. Tested separately for the contralateral electrode the Cued Between versus Cued Within difference was significant (F(1,13)=8.9, p=.010).

In the main design, LATERALITY and VALIDITY also interacted with FIGURE-TYPE (F(2,26)=4.8, p<.05). Although this interaction could in principle reflect interesting differences in attentional effects between the two types of figures, the statistics showed that the interaction reflected an unexpected result. It was found that the interaction was mainly caused by a larger N1 for the Cued Between trials in Amodal objects than in Kanizsa objects at the ipsilateral electrode (F(1,13)=9.9, p<.01).

Like in the P1 statistics, an interaction was found between VALIDITY, LATERALITY, and ORIENTATION (F(2,26)=39.4, p<.001). Figure 3.5 (right panel) shows that this interaction reflects that stimuli presented within the uncued hemifield showed an enhanced N1 at the contralateral electrode and a decreased N1 at the ipsilateral electrode.
Figure 3.4

ERPs of the presentation of the targets are presented here. At the top 3 graphs, ERPs are shown of the stimuli presented on Kanizsa objects, in the bottom 3 of the stimuli presented on Amodal objects. Electrode positions are shown at the top of each graph.
Cz

The effects of VALIDITY at Cz in the main design started at 120 ms and continued to 200 ms (7.9<F(2,26)<17.6, p<.005, see Figure 3.4). A large negativity was evoked in the Valid condition as compared to the invalidly cued conditions. Similar early anterior attention effects have been reported by others (e.g., Rugg, Milner, Lines, & Phalp, 1987). Luck and Hillyard (1995) referred to a similar effect in a feature detection experiment as the ‘anterior N1 effect’. Eimer (1996; 1998) observed an early (160-190 ms) attention-related medial centroparietal negativity (‘Nd1’). He found that this effect was specifically related to phasic attention tasks, as the effect was absent in a sustained attention task. Although the functional interpretation of this effect remains somewhat unclear, the result nevertheless demonstrates that the subjects engaged in early selective processing in the present task.

This early effect did not reflect object cuing, however, unlike the contralateral posterior N1. The first object-based attention effects (i.e. Cued Within versus Cued Between) at Cz started at 220 ms and lasted until 280 ms (F(1,13)<6.7, p<.05). In this latency interval, The Cued Within targets evoked a more positive waveform than the Cued Between targets (see Figure 3.4).

VALIDITY interacted with FIGURE-TYPE from 220 to 280 ms (F(2,26)<10.7, p<.001). This reflected that the validly cued targets evoked a more positive ERP in Amodal objects as compared to validly cued targets in Kanizsa objects.

3.3.3 Discussion

As in Experiment 1, in Experiment 2 we found object-based attention effects in performance using illusory Kanizsa objects. This was the case even though the predictability of the cue in Experiment 2 was lower than in Experiment 1 (50% versus 75%). The same effects were found for the Amodal objects, for which the perception of an illusory object is probably weaker than for Kanizsa figures. In both experiments it was also clear that detection of a stimulus benefits the most when the same location is precued. This indicates that spatial and object cuing effects both exist simultaneously and are not mutually exclusive. The important question is how these selection processes are temporally organized in information processing.

The ERP dynamics of Experiment 2 clearly showed earlier effects of spatial cuing than object cuing. On occipital electrodes, stimuli presented at the cued position elicited an enhanced P1 relative to stimuli presented at other positions. For the P1 there was no object-based effect, i.e. stimuli presented in the cued object but at the opposite, uncued position (Cued Within trials), elicited a similar P1 as stimuli presented within the uncued object (Cued Between trials). For the later contralateral N1 component, however, both space-based and object-based cuing effects were observed. The N1 was largest when stimuli were presented at the cued position and smallest when stimuli were presented within the uncued object. Importantly, when stimuli were presented at an uncued position but within the cued object, N1 amplitude was also enhanced relative to stimuli within the uncued object.
Figure 3.5

The objects are presented on the left. Abbreviations: V=Validly Cued, W=Cued Within, and B=Cued Between. Presented on the right are the amplitudes of the P1 and N1 for the different cuing effects. In the top panel the effects are presented when the object was horizontal, in the lower panel when the object was vertical. The cuing effects are presented so that the left and the centre of each graph show the effect when the target is within the cued halffield, in the right of each graph the target was in the uncued halffield.

At Cz effects of attention started later, but showed a similar time-course, namely the space-based effect developed earlier than the object-based effect. So, similar patterns of results were found for the occipital effects (first a space-based effect followed by an object-based effect), the central effects, and performance (largest space-based effect, smaller object-based effect). This might suggest that the central effects and performance effects are the direct consequence of earlier visual (occipital) selection processes.

Spatial attention effects

Our data are compatible with the common view that the modulation of the early visual ERP components by visuospatial attention reflects sensory gain (Mangun, Hillyard, and Luck, 1993; Gomez-Gonzalez, Clark, Fan, Luck, & Hillyard, 1994; Wijers et al., 1997). As in previous studies, spatial cuing modulated both the P1 and the N1, which supports models that propose that spatial attention involves an early selection of visual signals (Posner, 1980). These effects appear to be rather spatially diffuse, however. Stimuli presented at an uncued position, but within the same hemifield as the cued position, also shown enhanced P1 and N1 components.
Early ERP components and Object Based Attention

Object-based attention effects and the N1

We also found that the N1 for cued objects is larger than the N1 for uncued objects. In the following we will discuss this effect by relating it to different interpretations of N1 attention effects, and previously reported object-based attention effects. Mangun, Hillyard, and Luck (1993) suggested that the N1 reflects several different processes. For instance, recently it was proposed that the N1 not only reflects sensory gain, but discriminative processes as well (Vogel and Luck, 2000). Vogel and Luck (2000) showed that the N1 is enhanced in tasks in which the target is relatively hard to discriminate from nontargets. Indeed, in simple detection tasks, such as ours, the N1 is not affected by attention (Mangun and Hillyard, 1991).

Also, it has been suggested that the N1 reflects attentional shifting processes (Luck et al., 1990; Heinze et al., 1990). Luck et al. (1990) and Heinze et al. (1990) found that the usual attentional N1 enhancement found for unilateral stimuli is absent in conditions in which stimuli are presented bilaterally in both visual fields. They argued that with unilateral stimuli attention is involuntarily captured by stimuli at the irrelevant display positions, and has to be shifted back upon presentation of relevant stimuli. With bilateral stimuli it is presumably easier to focus attention constantly on the relevant display position. Indeed, they observed that the N1 effect returned in conditions with mixed bilateral and unilateral stimuli (Luck et al., 1990). The enhanced N1 to attended stimuli was larger the higher the probability of unilateral stimuli. Furthermore, there was a sequence effect on the N1 enhancement, such that the N1 was largest for attended stimuli preceded by unattended stimuli. To summarize, these authors suggested that an increased contralateral negativity overlaps the N1 when an attentional switch is made (see also Yamaguchi, Tsuchiya, and Kobayashi, 1995; Boksem, Lorist, & Meijman, in prep).

Our data, showing a larger N1 to Cued Within than to Cued Between stimuli, might also be interpreted as reflecting a contralateral negativity in the N1 latency range, as the result of an attentional switching mechanism. In the first place, it seems unlikely that the object cuing effect on the N1 reflects modulation in discrimination power. McCarley et al. (2002) recently showed that although more and faster saccades were made within a cued object than to an uncued object, discrimination performance for stimuli presented within the cued object was not better than for stimuli presented on uncued objects (McCarley, Kramer, & Peterson, 2002). Furthermore, our simple detection task does not require much stimulus discrimination in order to perform on the task. Our N1 results are in line with several other ERP findings concerning object cuing, which can also be most readily explained in terms of attentional shifting. Weber, Kramer, and Miller (1997) replicated Duncan’s experiment (Duncan, 1984) in which two superimposed objects were presented and subjects had to report whether two target characteristics were present. As in Duncan’s experiment this was easier when the two target features were on the same object than when they were presented on different (but same location) objects. Importantly, the N1 was larger when the features were on different objects, than when they were on the same object. This may reflect a rapid reallocation of attention onto the other object, once one of the two target features has been selected. Pinilla, Cobo, Torres, & Valdes-Sosa (2001) recently showed that when a rapid attentional switch had to be made from one transparent rotating dot pattern to the
other (on the same location) this lead to an ‘attentional blink’; discriminating a brief change in movement direction of the dots was harder for at least 500 ms. This performance effect was accompanied with an N1 reduction, suggesting that subjects failed to rapidly shift their attention from one dot pattern to the other.

Another notable finding concerning N1 amplitude was that we found the contralateral N1 to be enhanced (and the ipsilateral N1 to be reduced) when a stimulus was presented in the uncued visual half field (Figure 3.5). This was the case both for uncued stimuli within the cued object (Cued Within trials with horizontal objects) and for uncued stimuli presented within the uncued object (Cued Between trials with vertical objects). However, this effect was more pronounced for the Cued Within trials within horizontal objects, yielding an overall Cued Within versus Cued Between N1 enhancement. We speculate that the contralateral N1 is sensitive to shifts of attention in a horizontal direction (more so than to shifts in a vertical direction), and that the overall object-based attention effect reflects a preference to shift attention within a cued object.

Altogether, these data suggest that in early phases of processing stimuli presented at attended locations (and stimuli within the same halffield) gain sensory enhancement by attention. After some time, (150 ms, see Theeuwes, Atchley, & Kramer, 2000) subjects can disengage their attention and rapidly shift their attention, preferably within cued objects (McCarley, Kramer, and Peterson, 2002). We observed object-based cuing effects with both Kanizsa and Amodal figures. This was evident in both performance and in the ERPs. It is surprising that object cuing effects also exist in Amodal objects, because several reports describe a clear difference in the perception of Amodal objects compared to Kanizsa objects (Mattingley, Davis, and Driver, 1997; Corballis et al., 1999). However, others (Ringach and Shapley, 1996, Exp 5; Kellman & Shipley, 1991) argue that despite another perceptual outcome (strong illusory boundaries in Kanizsa objects and no boundaries in Amodal objects) in the formation of objects from Amodal and Kanizsa configurations, the unit formation of, in our case, rectangular shapes, is the same.

Although in general the observed attention effects were similar for Kanizsa and Amodal object, the performance results showed some indication of a difference. There was a significant Validity by Figure-type interaction for RT. The pattern of results suggests that this reflects a smaller object-based attention advantage for the Amodal figures, and a smaller space-based advantage for Kanizsa figures (see Figure 3.3). This would suggest that attention is distributed more evenly over the Kanizsa object than over the amodal object. A statistically significant difference, however, was only found for the valid stimuli. Moreover, since such effects were not observed for early ERP effects, it seems plausible that these RT effects are more likely to reflect response selection or stimulus evaluation processes, rather than the distribution of early space-based or object-based selection.

The main conclusion is that space-based and object-based selection are two processes which are temporally separable. In this experiment, object selection takes place following spatial selection, which is in accordance with early selection models. However, we do not exclude the possibility that object selection can in some situations be prioritized by task demands and/or perceptual circumstances. In our study, the objects served only as landmarks (i.e. the only possible locations for targets to appear were in the presented objects). Other object-based attention effects which have been described concern competition of features which are element of the objects (Kramer and Jacobson,
Early ERP components and Object Based Attention

1991; Duncan, 1984), rather than the contextual effects described here. It seems that the contextual effects of objects reflect a preferential search strategy, rather than attentional modulation by objects.

Furthermore, the perceptual/attentional load was not very high in the present experiment. It is known that when perceptual load is increased, the added stimuli enter competition for spatial attention, so that the chance that irrelevant stimuli or objects are selected increases (Lavie and Tsal, 1994). This would increase the need for early (object-based) selection mechanisms. On the contrary, one could argue that with a relatively low perceptual/attentional load (as in the present experiment) the task can be performed by diffusely distributing attention across larger parts of the visual field. This might more readily allow the target-surrounding object to enter perceptual/attentional processing and lead to larger object-based effects.

To conclude: a question which remains open is under which specific task and perceptual conditions objects alter the spatial distribution of attention. Recently, researchers have started to address these questions more specifically (Shomstein & Yantis, 2002; Lamy & Egeth, 2002). Nevertheless, for the time being, our conclusion is that spatial and object selection are not mutually exclusive, but that spatial selection concerns earlier processing than object selection by default.