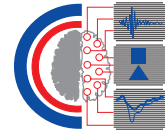


# Kanizsa figures pop out of visual search displays

Christoph S. Herrmann

MPI of Cognitive Neuroscience, PO box 500 355, 04303 Leipzig, Germany  
herrmann@cns.mpg.de



## Introduction

Two of the most important brain processes for correctly perceiving the outside world are binding and attention. Binding is necessary to link together the different features of single objects which are represented in a distributed fashion in the brain. The mechanism of attention serves to focus onto a small subset of the vast amount of incoming information. It is still unclear how exactly these two mechanisms operate and there are two current opinions on the temporal relation of the two processes. One model, which we will call the binding-first model, proposes that binding operates at a very early stage in human information processing and is assumed to be a parallel bottom-up process occurring prior to attention. Evidence from visual search experiments suggests that binding can lead to shifts in selective visuo-spatial attention (Davis, 1994). In these experiments, Kanizsa squares lead to flat slopes of reaction time per item with the conclusion that attention is not needed for illusory contour perception.

On the other hand, it has been argued that Davis and Driver supplied sufficient information in their search displays to support parallel search independently of whether illusory contours were present or not (Gurnsey, 1996). Also, other authors have failed to reproduce the parallel pop-out effect for Kanizsa triangles (Grabowecky, 1989; Grabowecky, 1997). Therefore, there exists the alternative hypothesis, which we will call the attention-first model, stating that attention precedes binding and can even solve the so-called binding problem which occurs when multiple possibilities exist to bind together the individual features of objects, leading to ambiguities, i.e. illusory conjunctions. In this case, focussing attention to a subset of the visual space, the number of objects to be bound together decreases which is assumed to solve the problem. For this to happen, attention has to occur prior to binding.

## Methods

Ten right-handed student subjects were investigated in each experiment. All subjects gave written informed consent and showed no signs of neurological, psychiatric or hearing disorders.

The stimuli were presented for 1000 ms on a computer monitor in black on white background and reaction time was recorded starting at stimulus onset. RTs on trials in which a response error was made, were rejected from the data, as well as trials in which the RT exceeded 2.5 standard deviations of the mean. An ANOVA was computed to assess the effects of the experimental variables target present/absent and set size on the reaction times and error rates.

The 10 subjects of Exp. 1 were aged 20 to 32 (mean age 23.2, 3 male).

Stimulus displays subtended a visual angle of 4.9 degrees for all set sizes. Inducer disks radius subtended 1.2, 0.9 and 0.7 degrees visual angle and were separated by 0.6, 0.45 and 0.35 degrees for set sizes 3x3, 4x4 and 5x5, respectively. Figure 1 (left) shows a target present display of the 5x5 set with a Kanizsa square in the lower right hand corner. The ratio of the radius of the inducer disks and the side-length of the illusory figures was 1/3.

The 10 subjects of Experiment 2 were aged 22 to 33 (mean age 25.8, 6 male).

Stimulus presentation was identical to Experiment 1. Stimulus displays subtended a visual angle of 4 degrees vertical by 6 degrees horizontal visual angle for all set sizes. Inducer disks radius subtended 1.5, 1.3 and 1.1 degrees visual angle for set sizes 15, 21 and 28, respectively. Figure 1 (right) shows a target stimulus of the 21 element set with a Kanizsa triangle in the lower left hand corner.

## Results

The ANOVA of Experiment 1 yielded significant main effects of factors target ( $F(1,9)=23.29, p=0.001$ ) and set size ( $F(1,9)=8.83, p<0.005$ ). The interaction was not significant. The ANOVA for the error rate yielded no significant main effects or interactions.

The ANOVA for Experiment 2 yielded significant main effects of factors target ( $F(1,9)=39.57, p<0.0001$ ) and set size ( $F(1,9)=11.12, p<0.001$ ). The interaction was not significant. The ANOVA of the error rates yielded a significant main effect of factor target ( $F(1,9)=7.61, p<0.05$ ), indicating higher error rates for target present trials than for target absent trials. No other effects or interactions were significant.

Figure 2 shows the RT and error data as well as the corresponding slopes of the reaction times as a function of set size. For Experiment 1, the slopes of 2.4 ms for target present trials and 2.1 for target absent trials were computed for the difference in numbers of inducer disks (25-9). For Experiment 2, the slopes of 2.2 ms for target present trials and 3.2 for target absent trials were also computed for the difference in numbers of inducer disks (28-15).

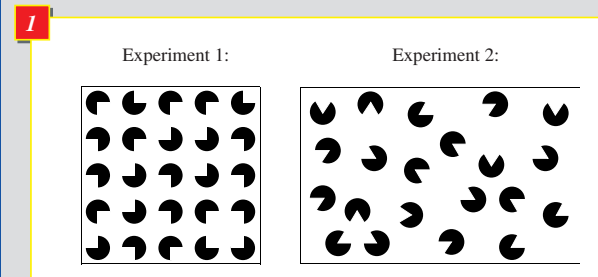


Figure 1: Regular (Exp. 1, left) and irregular (Exp. 2, right) arrangement of inducer disks showing a Kanizsa square and triangle as targets.

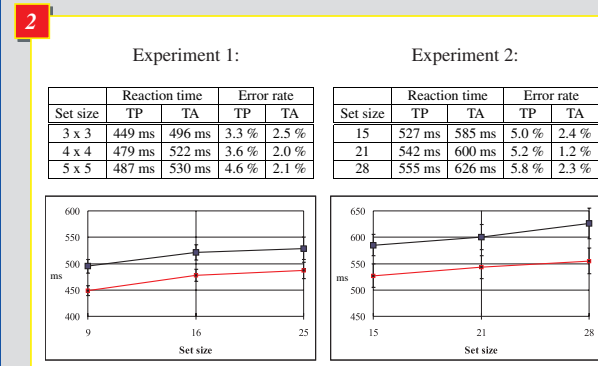


Figure 2: Reaction times, error rates and RT slopes of Experiments 1 and 2 for target present (TP, lower curve) and target absent (TA, upper curve) conditions.

## Discussion

Our experiments both yielded reaction time slopes per item of around 2 to 3 ms. It has been argued that visual search is performed in parallel when these slopes are less than 10 ms (Davis, 1994, cf. Figure 3). Thus, our flat slopes suggest that illusory figures are processed pre-attentively. Another indication that we are dealing with a parallel process is the fact that the typical 2:1 ratio between target absent and target present trials is not present in our reaction times.

Grabowecky et al. (1997) were able to reproduce the findings of Davis and Driver (1994) for parallel detection of Kanizsa squares in a second experiment, after they failed to find this effect for Kanizsa triangles in their initial experiment (Grabowecky, 1989). Nevertheless, they were not able to find parallel detection of Kanizsa triangles in an otherwise unchanged paradigm. This led them to assume that the local stimulus features (triangle versus square) are responsible for this difference. In our Experiment 2, Kanizsa triangles yielded a clear pop-out effect.

Trying to integrate the findings of Davis and Driver as well as Grabowecky et al. with ours, it seems plausible to assume that the global rather than the local stimulus features have strong effect on the degree to which visual search can be performed in parallel. While the local features, Kanizsa triangles and triangular distractors, were very similar to those of Grabowecky et al. (cf. Figure 4), the global ones were very different. It may well be that Kanizsa triangles pop out of visual search displays in our study due to distractors being arranged irregularly, as compared to a regular arrangement in the case of Grabowecky's displays.

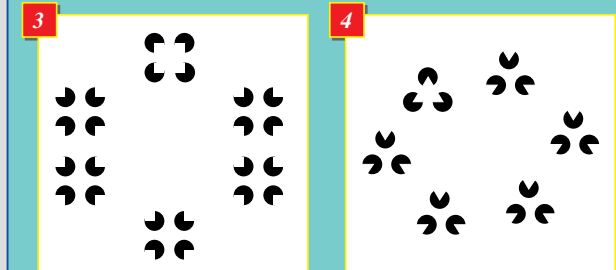


Figure 3: Stimulus arrangements of Davis and Driver (1994).

Figure 4: Stimulus arrangements of Grabowecky et al. (1997).

## References

- Davis G. and Driver J. (1994) Nature 371, 791-793.
- Gurnsey R., Poirier J.A.M. and Gascon E. (1996) Perception 25, 861-874.
- Grabowecky M. and Treisman A. (1989) Investigative Ophthalmology and Visual Science 30, 457.
- Grabowecky M., Yamada S. and Strode C. (1997) Abstracts of the Psychonomic Society 2, 2.