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ORIGINAL ARTICLE

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# Effects of asynchrony on symmetry perception

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**Abstract** The effect of temporal image segmentation on symmetry perception was investigated by means of stimuli composed of one part surrounding another. The two parts could be presented synchronously or with a temporal offset (20–100 ms), and each part could be either symmetrical or random. The task was to discriminate completely symmetrical (S) stimuli (in Experiment 1) or completely random (R) stimuli (in Experiment 2) from partially symmetrical (PS) stimuli in which one part was symmetrical and the other random. The R stimuli showed an asynchrony effect but the S stimuli did not. Furthermore, in both experiments, the PS stimuli showed an asynchrony effect when the symmetrical part was presented last but not when the symmetrical part was presented first (independent of whether it was the surrounded part or the surrounding part). Both results suggest that symmetry is strong enough to override this kind of temporal image segmentation.

## Introduction

Mirror symmetry (henceforth, symmetry) is a physical property that humans readily perceive. Almost every living organism and many human–made artifacts possess some form of symmetry. It is therefore not surprising that humans are especially good at detecting this object characteristic, as already noted by Mach more than a century ago (Mach, 1886). When parts of the visual array exhibit symmetry, it can indicate the presence of living organisms such as predators, preys, and conspecifics. Furthermore, just as other animal species, humans judge symmetrical patterns (Enquist & Arak, 1994) and symmetrical potential mates (Grammer & Thornhill, 1994) as more attractive than asymmetrical ones.

Research on human symmetry perception has been quite extensive (for overviews, see Tyler, 1996; van der Helm & Leeuwenberg, 1996; Wagemans, 1995). This research showed, among many other things, that a distinctive characteristic of symmetry is that it is a "one object" cue. In other words, symmetry tends to bind stimulus elements into one object. This means that symmetry, when perceived, is usually interpreted as coming from a single object. It would be rather coincidental for a symmetry to originate from more than one object: Either the symmetry axes of two symmetrical objects would have to be in line, or the symmetry originates from two objects that happen to be each other's mirror image.

For instance, Baylis and Driver (1994, 2001) demonstrated that when symmetrical contours are presented as part of a single shape, symmetry detection was hardly affected by the complexity of the pattern. However, when figure/ground segmentation assigned the contours to separate objects, subjects showed decreased performance in detecting symmetry with increasing complexity of the contours. Bertamini, Friedenberg, and Kubovy (1997) and Friedenberg and Bertamini (2000) obtained similar results comparing symmetry and repetition in contour patterns that defined multiple objects or single objects. They found a "one object" preference for symmetry and a "multiple object" preference for repetition.

Furthermore, Parovel and Vezzani (2002) showed that ambiguous chromatically homogeneous surfaces are more likely to be perceived as a single object when they are symmetrical. Their stimuli could either be interpreted as a single shape or as one shape occluding another. When, for example, two squares had their symmetry axes in line, participants generally interpreted these patterns as single shapes, whereas when the squares did not form a single symmetry, the multiple shape interpretation prevailed. Global symmetry thus

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biases the percept of ambiguous figures to global percepts.

In previous research, we investigated the effect of heterogeneous coarseness content on the perception of symmetrical patterns (Csathó, van der Vloed, & van der Helm, 2003). A performance decrement in symmetry detection was found when fine-scale information was presented centrally and coarse-scale information peripherally, relative to patterns that were of a homogeneous coarseness level. These results could be explained by a segregation of the symmetry information due to differences in spatial frequency content (see also van der Helm & Leeuwenberg, 1999, 2004). In other words, the differences in coarseness could cue the observer that the symmetry information originates from different depth planes, which rivals with the "one object" preference of symmetry. This rivalry may have caused the performance decrement in symmetry detection.

In Csathó et al.'s (2003) study, the segregation of symmetry information due to differences in spatial frequency content might have been helped, however, by a temporal asynchrony in the lateral geniculate nucleus (LGN). That is, coarse-scale information is believed to be processed by the relatively fast magnocellular pathway, and fine-scale information by the relatively slow parvocellular pathway (see, e.g., Palmer, 1999). We therefore decided to investigate the effects of temporal asynchrony in symmetry stimuli. Just as Csathó et al. did, we introduced a center-surround difference but, this time, a temporal difference instead of a scale difference. Hence, whereas Csathó et al.'s scale difference induced a temporal asynchrony in the LGN, we now introduced a temporal asynchrony in our stimuli without a scale difference. This may provide evidence as to whether the performance decrement in symmetry detection, as found by Csathó et al., was due to the scale difference alone or also due to a temporal asynchrony in the LGN.

A few studies provide evidence that temporal asynchrony in stimuli may induce image segregation. For example, Ramachandran and Rogers-Ramachandran (1991) and Rogers-Ramachandran and Ramachandran (1998) used alternating patterns consisting of adjacent fields of black and white dots that reversed polarity in time. They found that when these patterns alternated at high temporal frequencies, participants were not able to discriminate the temporal phase of these patterns but saw "phantom contours" separating the image parts. Furthermore, Lee and Blake (1999) demonstrated that in an array of randomly oriented moving gabor patches, synchronized reversal of movement direction can easily define a figure, even when the movement directions did not correlate between patches in the figure region. Lee and Blake concluded that this figural binding is caused by visual registration of correlated changes in motion, but see also Farid and Andelson (2001) who argued that it can just as well be caused by a temporal band-pass filter.

Leonards, Singer, and Fahle (1996) investigated the interaction between temporal and spatial cues on the segregation of stimuli using a texture segmentation paradigm. Using a flickering paradigm they found that, when temporal offset exceeds 10 ms, temporal cues alone sufficed to instigate figure–ground segregation. However, temporal cues could be overruled by textural segmentation based on orientation of pattern elements if temporal offset did not exceed 100 ms.

In sum, in the current study, we focus on the interaction between symmetry and temporally induced center–surround segregation. In two experiments, we investigated the effect of a temporal offset of the two stimulus parts on the discriminability of completely symmetrical stimuli (Experiment 1) or completely random stimuli (Experiment 2) from partially symmetrical stimuli in which one part was symmetrical and the other random. We hypothesized that, within the range of 20–100 ms asynchrony, symmetry is persistent enough to overcome the temporally induced center–surround segregation. Hence, for the completely symmetrical stimuli, we did not expect an effect of asynchrony. This then would imply that the earlier discussed weakening effect on symmetry detection with scale differences (Csathó et al., 2003) has to be explained in spatial rather than temporal terms.

At least as interesting, however, is that our persistence hypothesis predicts an order effect for the partially symmetrical stimuli. That is, persistence is directed forward rather than backward, so that we expected an effect of asynchrony when the symmetrical part was presented last but not when the symmetrical part was presented first. This order effect will be the main topic in the general discussion in which it will be evaluated not only in terms of persistence but also in terms of masking.

## Experiment 1

### Method

#### *Participants*

Twenty-seven participants (12 males and 15 females) performed the experiment. They were aged between 17 and 42 years and had normal or corrected-to-normal visual acuity. All participants were undergraduate or postgraduate students at the University of Nijmegen and were paid or received course credits.

#### *Stimulus materials*

The stimuli used in this experiment were black and white Gaussian blob patterns of 250×220 pixels. The luminance of the black patches was 1.4 cd/m$^2$ and the luminance of the white patches was 86 cd/m$^2$ . Each stimulus subtended 3.7°×3.2° of the visual field. The patterns were created as follows: An image was filled with random Gaussian noise and blurred with a Gaussian filter with a 6-pixel radius. Afterwards, the pattern was thresholded to obtain black and white images. At the center of the pattern, an area was introduced with a vertically elliptical shape (which agrees with the shape of the so-called integration region in vertical symmetry; Dakin & Herbert, 1998) and with a size of 70×110 pixels (1.0°×1.6° visual angle).

Three symmetry conditions were constructed, namely, Perfect, R-center/S-surround, and S-center/R-surround. In the Perfect condition, the pattern showed (vertical) symmetry in the center area as well as in the surrounding area. In the R-center/S-surround condition, the center area was random while the surrounding area showed symmetry. In the S-center/R-surround condition, the center area showed symmetry while the surrounding area was random (see Fig. 1).

During the presentation of a stimulus, the center area and the surrounding area were each presented for 200 ms, either synchronously (i.e., with an SOA of 0 ms) or asynchronously with an SOA of 20, 40, 60, 80, or 100 ms (see Fig. 1). Hence, in the asynchronous conditions, the whole pattern was visible for 200 ms minus the SOA. Furthermore, in the asynchronous conditions, the two areas were presented in two different orders. In the first order condition, called ‘‘center first’’, the center area was presented first. In the second order condition, called ‘‘surround first’’, the surrounding area was presented first. Thus, for example, with an asynchrony of 60 ms in the center first condition, a complete stimulus would be: first, for 60 ms, only the center area is visible; then, for 140 ms, the whole pattern is visible; and, finally, for again 60 ms, only the surrounding area is visible.

Twelve different stimuli were produced in the Perfect condition. The two imperfect conditions (the R-center/S-surround condition and the S-center/R-surround condition) each consisted of six different stimuli. The total experiment consisted of 288 trials: [Stimulus Type: 12 Perfect + 6 R-center/Surround + 6 S-center/R-surround]×Asynchrony 6×Order 2.

### *Apparatus*

A standard PC and monitor using a 800×600 pixel resolution were used to present the stimuli. The stimuli were displayed on a gray background with 70 cd/m$^2$ luminance. Participants viewed the screen from a distance of 114 cm and a button-box was used to record their responses.

### *Procedure*

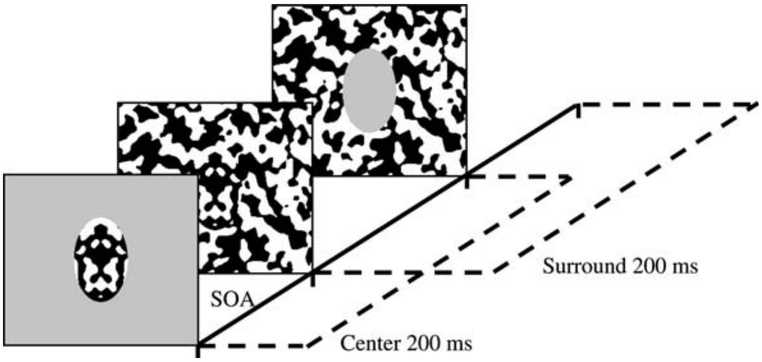
Participants were instructed to discriminate perfectly symmetrical stimuli from stimuli that were only partly symmetrical by pressing the appropriate button on the button box. Examples were given of each of the three pattern conditions. It was emphasized that fixation should be maintained throughout each trial and responses should be made as quickly and accurately as possible.

Before the experiment, participants performed 48 practicing trials including feedback about the correctness of their response. During the actual experiment, no feedback was given. The 288 stimuli of the actual experiment were presented in a randomized order, with a break after each 72 trials. For each trial, before the test stimulus appeared, a fixation cross (500 ms) was presented centered on the screen, followed by a blank screen (500 ms), after which the stimulus sequence (as discussed in the stimulus section) was presented. Reaction times (RTs) and error rates were recorded. RTs were measured from the onset of the whole pattern.

## Results

Repeated measures ANOVAs were performed on both error rates (see Fig. 2) and RTs. First, the main effects of symmetry (Perfect, R-center/S-surround, and S-center/R-surround) were investigated. Subsequently, within each symmetry condition separately, analyses were run for effects of asynchrony and order. These subsequent

**Fig. 1** This figure depicts the time course of a trial in the S-center/R-surround condition. The central area is symmetrical and the surrounding area is random. After a fixation cross and a blank screen, both lasting 500 ms, the central area is presented for 200 ms; after an SOA of 0–100 ms, the surrounding area is added and is also presented for 200 ms. Thus, the whole pattern is visible for 200 ms minus the SOA



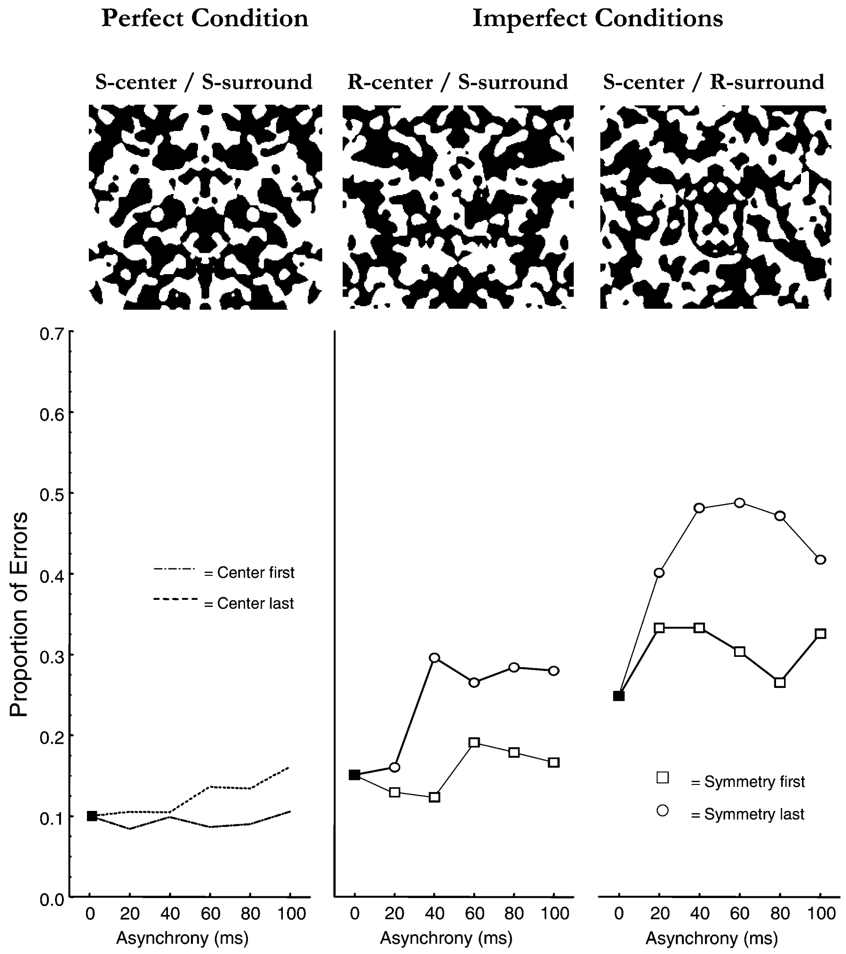


**Fig. 2** Mean error rates in Experiment 1, plotted for the Perfect condition in which the whole pattern is symmetrical, the R-center/S-surround condition in which the central elliptical area is random and the surrounding area is symmetrical, and the S-center/R-surround condition in which the central elliptical area is symmetrical and the surrounding area is random. The *filled square* represents the synchronous condition

analyses were divided into two parts. First, the asynchronous conditions (i.e., with an SOA of more than 0 ms) were analyzed, and, second, the pooled data of these asynchronous conditions were compared with the synchronous conditions (i.e., with an SOA of 0 ms). Except for a main effect of symmetry condition, RTs revealed no significant effects in any of the analyses.

### Symmetry conditions

The main effect of symmetry was significant for both error rates, $F(2, 25) = 25.056$, $p < 0.001$, and RTs, $F(2, 25) = 6.992$, $p < 0.005$. Further investigation of these main effects revealed that participants made more errors in the S-center/R-surround condition (36.0%) than in the other two conditions $F(1, 26) = 17.241$, $p < 0.001$, whereas the error rates of the Perfect condition (10.9%) and the R-center/S-surround condition (19.8%) did not differ significantly. For RTs the pattern was different. Participants were faster in the R-center/S-surround condition (720 ms) than in the other two conditions $F(1, 26) = 12.766$, $p < 0.005$. There were no significant RT differences between the Perfect (786 ms) and S-center/R-surround (815 ms) conditions.

### Asynchronous conditions

In the Perfect condition, there was no significant effect of order, and in all three symmetry conditions, there were no significant effects of the amount of asynchrony. In the R-center/S-surround condition, the main effect of order was significant, $F(1, 26) = 17.449$, $p < 0.001$. Here, participants made more errors when the symmetrical surround as presented last (25.7%) than when it was presented first (15.8%). In the S-center/R-surround condition the main effect of order was also significant, $F(1,26) = 22.049$, $p < 0.001$. This time, participants made more errors when the symmetrical center was presented last (45.2%) than when it was presented first (31.2%). None of the three symmetry conditions showed significant interactions between order and amount of asynchrony.

### Asynchronous versus synchronous conditions

Next, we analyzed contrasts between synchronous and asynchronous conditions. Because we found no trends for the amount of asynchrony in the previous analyses, the asynchronous conditions were pooled and compared with the synchronous conditions. For the Perfect condition, there were no differences between the synchronous and asynchronous conditions for either of the order variants. In the imperfect conditions, however, we did find differences. In the R-center/S-surround condition, participants made significantly more errors in the asynchronous conditions (25.7%) than in the synchronous condition (15.1%) $F(1, 26) = 9.541$, $p < 0.01$ when the symmetrical surround was presented last, but not when it was presented first. Similarly, in the S-center/R-surround condition, participants showed significantly more errors in the asynchronous conditions (45.2%) than in the synchronous condition (24.9%), $F(1, 26) = 27.620$, $p < 0.001$ when the symmetrical center was presented last, but not when it was presented first.

### Discussion

The S-center/R-surround showed an overall higher error rate than the other two conditions did. In this condition symmetrical information was presented in the center area and the random information was presented in the surrounding area. Participants seemed to be misled by the central symmetry and frequently judged the pattern to be completely symmetrical. This is in line with research by Barlow and Reeves (1979) and by Dakin and Herbert (1998), which showed that the symmetrical information around the axis near the point of fixation dominates the symmetry percept.

There were no effects of asynchrony in the Perfect symmetry condition. That is, symmetry appears robust to temporally induced image segregation. Likewise, both imperfect conditions did not show an effect of asynchrony when the symmetrical part of the stimulus was presented first. When the symmetrical part was presented last, however, the imperfect conditions did show a substantial increase in error rate. To investigate whether this differential effect is indeed to be attributed to symmetry, we performed a second experiment in which participants had to discriminate random patterns from the same imperfect symmetries as used in Experiment 1.

## Experiment 2

### Method

The method employed in this experiment was identical to the method employed in Experiment 1 with the following exceptions. This experiment had 25 participants (6 males and 19 females) aged between 18 and 39 years.

Instead of a Perfect symmetry condition we now introduced a Random condition, in which both the center area and the surrounding area were random. The imperfect conditions were identical to those in Experiment 1. The procedure was also identical except that now the participants were instructed to discriminate random stimuli from partly symmetrical stimuli.

### Results

Repeated measures ANOVAs were performed on both error rates (see Fig. 3) and RTs. Like in Experiment 1, the main effects of symmetry condition were investigated first and after that, within each condition separately, analyses were run for effects of asynchrony and order, which, again, were divided into an analysis of the asynchronous conditions and an analysis in which the asynchronous conditions were compared with the synchronous conditions.

### Symmetry conditions

The main effect of symmetry was significant for both error rates, $F(2, 23) = 30.123$, $p < 0.001$, and RTs, $F(2, 23) = 17.547$, $p < 0.001$. Further investigation of these main effects revealed that participants made more errors in the R-center/S-surround condition than in the other two conditions $F(1, 24) = 57.036$, $p < 0.001$, whereas the error rates of the Random condition and the S-center/R-surround condition did not differ significantly. For RTs the pattern was different. Participants were faster in the S-center/R-surround condition (719 ms) than in the other two conditions $F(1, 24) = 36.107$, $p < 0.005$, and there were no significant differences between RTs in the Random (840 ms) and R-center/S-surround (828 ms) conditions.

### Asynchronous conditions

In the Random condition there were no significant effects for error rates nor for RTs. In the R-center/S-surround condition, the main effect of order was significant for error rates, $F(1, 24) = 45.259$, $p < 0.001$. Participants made fewer errors when the symmetrical surround was presented last (39.0%) than when it was presented first (58.2%). For RTs there was no significant main effect of order, but there was a main effect of amount of asynchrony $F(4, 21) = 2.989$, $p < 0.05$. Further investigation of this effect showed that participants showed a marginally significant linear trend, $F(1, 24) = 3.217$, $p = 0.086$, toward becoming faster with increasing asynchrony. In the S-center/R-surround condition, the main effect of order was significant for both error rates, $F(1, 24) = 9.857$, $p < 0.005$ and RTs, $F(1, 24) = 8.902$, $p < 0.01$. Participants made fewer errors (10.3%) and responded slower (718 ms) when the symmetrical center was presented last than when it was presented first (16.1% and 687 ms, respectively). Furthermore, there was a main effect of amount of asynchrony for RTs, $F(1, 24) = 4.536$, $p < 0.01$. A trend analysis revealed a significant linear trend $F(1, 24) = 20.538$, $p < 0.001$, with participants becoming faster with increasing asynchrony. None of the three symmetry conditions showed significant interactions between order and amount of asynchrony.

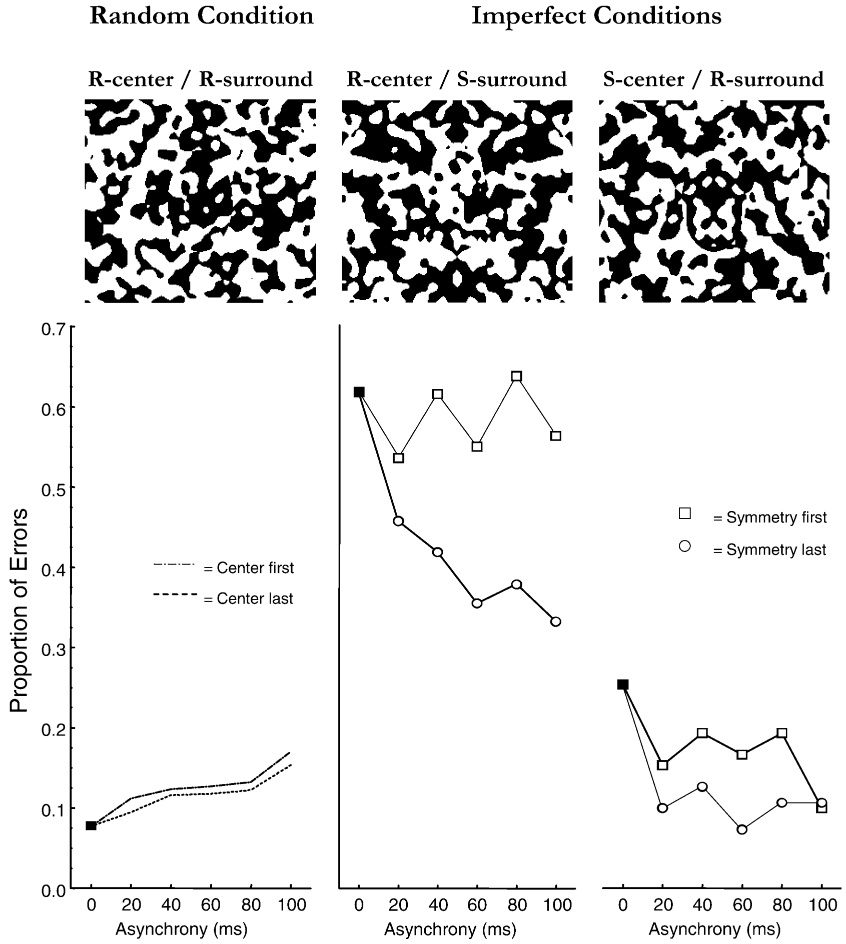


**Fig. 3** Mean error rates in Experiment 2, plotted for the Random condition in which the whole pattern is random, the R-center/S-surround condition in which the central elliptical area is random and the surrounding area is symmetrical, and the S-center/R-surround condition in which the central elliptical area is symmetrical and the surrounding area is random. The *filled square* represents the synchronous condition

## Asynchronous vs synchronous conditions

Next, we analyzed contrasts between synchronous and asynchronous conditions. As in the analysis for the data of Experiment 1, the asynchronous conditions were pooled and compared with the synchronous conditions. When the order conditions differed significantly in the previous analyses, the order conditions were analyzed separately, otherwise their data were pooled.

For the Random condition, there was a significant difference between the asynchronous conditions and the synchronous condition for error rates $F(1, 24) = 6.168$, $p < 0.05$. Participants made more errors in the asynchronous conditions (12.7%) than in the synchronous condition (7.7%). For RTs there were no significant differences.

In the R-center/S-surround condition the participants made significantly fewer errors in the asynchronous conditions (39.0%) than in the synchronous condition (62.0%) when the symmetrical surround was presented last $F(1, 24) = 38.130$, $p < 0.001$, but not when it was presented first. For RTs participants were faster in both order conditions (816 ms) when compared to the synchronous condition (888 ms) $F(1, 24) = 16.913$, $p < 0.001$.

In the S-center/R-surround condition, participants made significantly fewer errors in the asynchronous conditions than in the synchronous condition (25.4%), both when the symmetrical center was presented first (16.1%) $F(1, 24) = 6.387$, $p < 0.05$, and when it was presented last (10.3%) $F(1, 24) = 19.086$, $p < 0.001$. For RTs the difference of the pooled asynchrony conditions (797 ms) and the synchronous condition (703 ms) was also significant $F(1, 24) = 48.274$, $p < 0.001$.

## Discussion

The R-center/S-surround condition showed a higher error rate than the other two conditions did. In this condition random information was presented in the center area and symmetrical information was presented in the surrounding area. Participants were required to detect whether or not the pattern showed symmetrical deviations from randomness and, like in Experiment 1, performance drops when the distinctive image property was presented off center.

In the imperfect conditions participants showed a decrease in error rates when the symmetrical part was presented last. This effect cannot be explained by a salience effect of the most recently viewed stimulus part, because subjects did not show an increase in error rates when the random part was presented last (in the S-center/R-surround condition there was even a modest decrease of errors when the random part was presented last).

## General discussion

In the current study, we investigated whether symmetry is strong enough to override temporal image segregation. Thereby, this study expands on, in particular, the studies by Parovel and Vezzani (2002) and Leonards et al. (1996). First, Parovel and Vezzani (2002) found that two partly-overlapping shapes tend to be perceived as one shape if the combination of the two shapes forms a symmetry, which demonstrates the binding force of symmetry. Second, for a figure–ground segregation task, Leonards et al. (1996) found that temporal segregation cues may become stronger with increasing asynchrony, but can also be overridden by textural segregation cues. For our current discrimination task, we found an effect of increasing asynchrony for the random stimuli, but not for the perfectly symmetrical stimuli. Hence, it appears that symmetry too can override temporal segregation. This suggests that the weakening effect of spatial scale differences on symmetry detection, as found by Csathó et al. (2003), must be explained in spatial rather than temporal terms. That is, it hardly seems to be attributable to a temporal difference between the output of the relatively fast magnocellular channel and the output of the relatively slow parvocellular channel.

Just as the perfectly symmetrical stimuli, the partly symmetrical stimuli do not show an effect of the amount of asynchrony. They do, however, show a robust effect of the order in which the symmetrical part and the random part are presented (this order effect is independent of whether the symmetry information is presented centrally or peripherally). When the symmetrical part is presented last, performance differs significantly from performance in the synchronous condition. That is, it yields worse discrimination from completely symmetrical stimuli and better discrimination from completely random stimuli. Both changes in performance are consistent with a high salience of the symmetry part once the random part has disappeared, but this high salience cannot be merely a recency effect. After all, the reversed order does not show a reversed pattern of performance. In fact, for the reversed order, performance is virtually identical to performance in the synchronous condition.

In the remainder of this discussion, we therefore elaborate further on the question of whether or not the order effect is to be attributed to a property specific to symmetry. To this end, we first examine whether the findings in the imperfect conditions can be framed in terms of forward and backward masking, without invoking properties specific to symmetry.

In metacontrast masking, a briefly presented stimulus is masked when it is followed by a flanking stimulus (Breitmeyer, 1984). This is a form of backward masking in which the stimulus and the mask do not show spatial overlap. In our experiments, the main candidates for metacontrast masking would be the conditions in which the surround is presented last. The conditions in which a random center is followed by a symmetrical surround show error rates that are consistent with what would be predicted from metacontrast masking. That is, compared to the synchronous condition, performance dropped when such stimuli had to be discriminated from perfect symmetries, and performance increased when they had to be discriminated from random images. This indicates that the symmetry signal becomes relatively stronger, which would be consistent with the symmetrical surround functioning as a metacontrast mask of the random center. However, in the conditions in which a symmetrical center is followed by a random surround there were no differences with the synchronous conditions, whereas one would expect the random signal to become relatively stronger if metacontrast masking was to take place. Furthermore, in the conditions in which a symmetrical center is preceded by a random surround, the differences with the synchronous condition even go against with what would be predicted from metacontrast masking.

One might also consider the possibility of paracontrast masking, which is the forward masking counterpart of metacontrast masking. If paracontrast masking would at hand then it would also have to occur, for instance, in the conditions in which a symmetrical center is preceded by a random surround. That is, then, the random surround would have to forward mask a symmetrical center. However, from this we would expect a decrease in the number of symmetry responses compared with the synchronous conditions whereas we find an increase.

Hence, at best, one could say that symmetry masks backward but not forward. This already indicates, however, that the order effect is probably due to something specific to symmetry. Therefore, next, we specify and compare two possible explanations of the order effect in terms of properties specific to symmetry.

First, it is plausible that the visual system contains a dedicated mechanism for the detection of symmetry information, but not for the detection of random information. That is, to classify a pattern as random, observers have to rely on a *reductio ad absurdum* strategy to establish the absence of regularity. Conversely, even in random patterns, the symmetry detection mechanism might detect spurious symmetry information. In our experiments, a spurious symmetry signal from the random part would be incorporated into the genuine symmetry signal from the symmetrical part, thus establishing the total symmetry signal. The order effect might then arise as follows.

Once the random part has disappeared in the symmetry last conditions, the symmetry detection mechanism would have to rely on iconic memory to assess the spurious symmetry at the locations where the random information had been. It might well be that memory processes amplify the spurious symmetry signal, thus leading to an overestimation of the total symmetry. After all, Tversky and Schiano (1989) found a bias to remember images as being more symmetrical than they really were. In the symmetry first conditions, such an overestimation is not likely to occur because the total symmetry signal is established while the random part is present.

The second explanation of the order effect relies on temporal persistence, as follows. First, when a symmetrical part is added to an earlier presented random part, the initial zero symmetry signal increases to the symmetry signal of a partly symmetrical stimuli, and increases further once the random part has disappeared. As a consequence, compared to the synchronous condition, the final symmetry signal is closer to the high symmetry signal of a completely symmetrical stimulus (hence, worse discrimination), and farther off the zero symmetry signal of a completely random stimulus (hence, better discrimination). Second, when a random part is added to an earlier presented symmetrical part, the initially high symmetry signal decreases to the symmetry signal of a partly symmetrical stimuli, but then persists even once the symmetrical part has disappeared. As a consequence, the final symmetry signal is more or less identical to the symmetry signal in the synchronous condition. Thus, because symmetrical information persists longer in visual memory than random information does, there are no differences between the synchronous conditions and the random last conditions, whereas there are differences between the synchronous conditions and the symmetry last conditions.

Comparing the two explanations, we observe the following. On the one hand, in the symmetry last conditions, the memory explanation would predict a stronger spurious symmetry signal from the random parts than the persistence explanation would. On the basis of the present data alone, it is hard to decide which prediction is correct, and future research may clarify this issue further. On the other hand, both explanations refer to forms of binding. According to the memory explanation, amplified spurious symmetry in the random first conditions binds with later added genuine symmetry. According to the persistence explanation, genuine symmetry in the symmetry first conditions binds with later added random information.

The just-mentioned forms of binding are more general than the form of binding that makes symmetry a one-object cue. The current forms of binding do not so much imply that symmetry is interpreted as coming from one object but, rather, that symmetry codetermines what perceptual wholes are. That is, the current experiments show that symmetry is strong enough to overcome temporally induced image segregation.

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