Visual Awareness Is Essential for Grouping Based on Mirror Symmetry

Dina Devyatko [1,*] and **Ruth Kimchi** [1,2,*]

[1]   Institute of Information Processing and Decision Making, University of Haifa, Haifa 3498838, Israel
[2]   Department of Psychology, University of Haifa, Haifa 3498838, Israel
*   Correspondence: tsukit86@gmail.com or ddevyatko@univ.haifa.ac.il (D.D.); rkimchi@univ.haifa.ac.il (R.K.)

check for updates

Abstract: We examined whether symmetry-based grouping can take place in the absence of visual awareness. To this end, we used a priming paradigm, sandwich masking as an invisibility-inducing method, and primes and targets composed of two vertical symmetric or asymmetric lines. The target could be congruent or incongruent with the prime in symmetry. In Experiment 1, participants were presented with masked primes and clearly visible targets. In each trial, the participants performed a two-alternative discrimination task on the target, and then rated the visibility of the prime on a subjective visibility four-point scale (used to assess prime awareness). Subjectively invisible primes failed to produce response priming, suggesting that symmetry processing might depend on visual awareness. However, participants barely saw the prime, and the results for the visible primes were inconclusive, even when we used a conservative criterion for awareness. To rule out the possibility that our prime stimuli could not produce priming per se, we conducted a control visibility experiment (Experiment 2), in which participants were presented with unmasked, clearly visible primes and performed a target task. The results showed that our primes could elicit significant response priming when visible. Taken together, our findings indicate that symmetry-based grouping requires visual awareness.

Keywords: symmetry-based grouping; symmetry; visual awareness; perceptual organization; perceptual grouping; masking; response priming

1. Introduction

Mirror symmetry (henceforth referred to as symmetry) seems to be an omnipresent experience of everyday life. Humans are highly sensitive to symmetry [1,2]. Symmetry, which is detected very quickly even in the presence of noise [3–6], is frequently a salient aspect of form perception, and it plays a role in figural goodness [7,8] and object recognition [9,10].

The Gestalt psychologists considered symmetry as one of the factors of perceptual organization [8,11], for which reviews can be found in [12–16]. A few studies examined the effect of symmetry on perceptual grouping [17–19]. Gillam and McGrath [19] showed that simple lines arranged in vertical symmetry are strongly grouped, and the weaker grouping of lines arranged in horizontal symmetry was improved when the lines were more complex [18]. Feldman [17] reported evidence for the role of symmetry in perceptual grouping, demonstrating that the comparison of features lying on pairs of briefly presented line segments was significantly faster when the segments were symmetric. A number of studies indicate that symmetry operates as a cue for figure–ground segregation [20–23]. For example, Peterson and Gibson [23] found that observers presented with briefly exposed two-region displays reported perceiving the symmetric region as a figure in about three quarters of the trials. Machilsen et al. [22] showed better detection of symmetric shapes than asymmetric ones in arrays of oriented Gabor elements, suggesting that symmetry facilitates figure–ground segregation. Kanizsa and Gerbino [24]

reported that convexity can override symmetry as a figural cue, but Mojica and Peterson [21] showed that, with appropriate control, symmetry can be as effective as convexity. In addition, symmetry plays a role in amodal completion, such that the preference for global completion appears to depend on the degree of object symmetry obtained by that completion [25,26]. It was also suggested that symmetry serves as a cue for the presence of a single object [27,28]. In summation, symmetry is relevant to perceptual organization.

Recent research has examined whether visual awareness is required for perceptual organization to occur. The results indicate that it depends on the specific organization processes, which is quite plausible given that perceptual organization is a multiplicity of processes differing in their time courses, attentional demands, and developmental trajectories [29–36]. The methods used to suppress the stimulus from awareness also play a role, as they may vary in the level at which the suppression takes place [37,38]. Indeed, it was found, for example, that grouping by luminance similarity, proximity, or connectedness could occur when the stimulus was suppressed from awareness by sandwich masking [39,40], but not by continuous flash suppression (CFS) [40]. The organization of line elements into a global shape, based on good continuation, closure, and symmetry, could also be accomplished in the absence of visual awareness when invisibility was induced by metacontrast or sandwich masking [41,42], but not by CFS [42]. On the other hand, the formation of illusory contours appears to depend on visual awareness, regardless of the method used to suppress the Kanizsa-type inducers from awareness [43–47]. The organization of local elements into a global shape in hierarchical stimuli also seems to require visual awareness [48,49].

Can symmetry-based grouping take place in the absence of visual awareness of the stimulus? To the best of our knowledge, there is no empirical study directly addressing this question. Some researchers have taken the fast and seemingly effortless perception of symmetry as suggesting that symmetry processing can occur without visual awareness, confounding attention and awareness, such as in [6] (see [16] for a review). The relationship between attention and consciousness, which has been a matter of lively debate in the last two decades, is beyond the scope of this paper. It suffices to say that although intimately related, there is evidence that attention and awareness are distinct phenomena [50]. Often cited in this context is Driver, Baylis, and Rafal's [20] case study of a patient with left neglect (a failure to deploy attention to the left side of space and objects). When presented with displays of alternating green and red symmetric and asymmetric shapes, which could be perceived, for example, as green symmetric figures on red asymmetric grounds, and requested to report the color of the shapes, the patient, like the controls, tended to report the color of the symmetrical shapes without a bias to reporting the rightmost color. In contrast, when presented with a single shape and requested to make explicit symmetry judgments, the patient's judgments of shapes with vertical symmetry were no different from chance. The authors explained the contrasting results by appealing to different stages of perceptual processing required in the two experimental tasks, which included pre-attentive, figure–ground segregation on the basis of successful performance of the symmetry underlay in the former, whereas successful performance in the latter required directing attention to the left part of the figure, which the patient could not do. Thus, it seems that the patient could use symmetry preattentively for figure–ground segregation, even though he could not explicitly detect it, although the demonstration that information not available to verbal report nevertheless could be represented implicitly may suggest that symmetry processing is possible without visual awareness. The role of attention in the explicit detection of symmetry makes it difficult to disentangle the effects of awareness from the effects of attention.

The current study aimed to directly examine whether or not symmetry-based grouping requires visual awareness. To this end, we used a masked priming paradigm, in which the influence of a masked prime on the processing of a subsequent target was assessed. This paradigm has been widely used to study unconscious processing. A stronger version of this paradigm, which we adopted here, involves the presentation of two types of trials: congruent trials (the prime and target evoke the same response) and incongruent trials (the prime and target evoke different responses).

Faster responses on congruent rather than incongruent trials, namely a response priming effect, indicates unconscious processing [51,52]. In our study, participants were presented with a masked prime, followed immediately with a clearly visible target. Sandwich masking was used to render the prime invisible (i.e., to suppress awareness of the prime form). The primes and targets were two vertically symmetric or asymmetric lines (see Figure 1). The prime and the target could be congruent (both symmetric or both asymmetric) or incongruent (symmetric prime and asymmetric target or vice versa). Participants performed a two-alternative discrimination task on the target, and then rated the visibility of the prime. Unconscious processing of the prime was measured by the difference in response speed between the incongruent and congruent trials (i.e., response priming) and trials with null visibility of the prime. We assessed awareness of the primes in each trial with a subjective visibility four-point scale, akin to the Perceptual Awareness Scale (PAS) [53], which was found to be as sensitive as the measurements relying on objective discrimination [41]. The trial-by-trial measure of awareness allowed us to examine response priming when the prime was consciously perceived and when it was not under the same stimulus conditions. If awareness of the stimulus is not necessary for symmetry-based grouping to take place, we should observe response priming regardless of prime visibility.
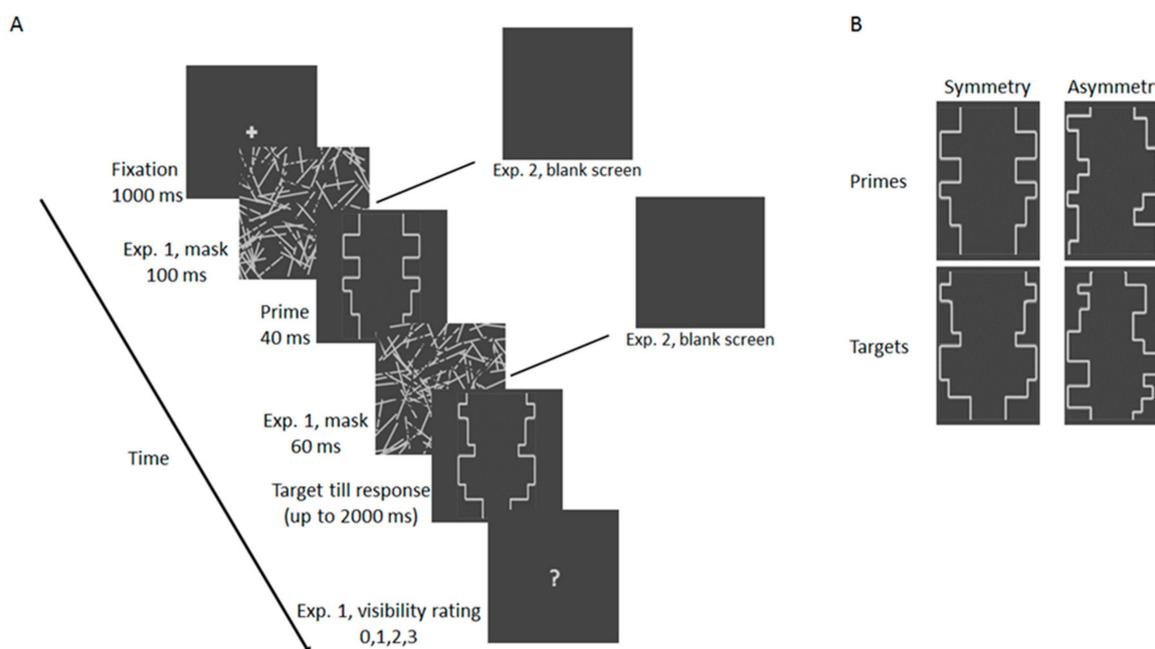

Figure 1. Time course of a trial and stimuli. (**A**) Time course of a trial in Experiments 1 and 2 (see text for details). (**B**) Prime and target stimuli in Experiments 1 and 2.

2. Experiment 1: Symmetry-Based Grouping during Sandwich Masking

2.1. Materials and Methods

2.1.1. Participants

Twenty-five individuals (21 females, 3 left-handed, aged 18–33, mean = 22.4) participated in Experiment 1. The participants were recruited from students at the University of Haifa and were paid in or granted course credit for participating. All participants provided informed consent to a protocol approved by the Ethics Committee of the University of Haifa. All had normal vision and participated in no more than one experiment.

2.1.2. Apparatus

The stimuli and experiments were generated using E-Prime 3.0 software (Psychology Software Tools, Pittsburgh, PA, USA). Participants viewed the stimuli naturally with their heads supported by a chin rest at a distance of 57 cm. All stimuli were presented on an LCD BenQ monitor (24 in, 100 Hz refresh rate, 1920 × 1080 resolution). The stimuli were viewed through a circular aperture (16 cm in diameter) of a matte black cardboard sheet in order to minimize unnecessary lighting from the screen. The testing room was dimly lit. Participants provided responses using a response box (Psychology software tools, model 200A) and a computer keyboard.

2.1.3. Stimuli

The prime and target stimuli are depicted in Figure 1B. The stimuli were inscribed in a rectangle $3.51° \times 7.05°$, the width of line was $0.11°$ (RGB: 210, 210, 210, 63.4 cd/m^2). All stimuli were presented in the center of the screen. The symmetric lines varied randomly between $0.6°$ and $1.755°$ to the left or right of the central vertical meridian of the display, and the asymmetric lines varied randomly between $0.3°$ and $1.935°$. The primes and the targets were vertically symmetric or asymmetric lines (see Figure 1B). The prime and the target could be either congruent (both either symmetric or asymmetric) or incongruent (symmetric prime and asymmetric target and vice versa). Regardless of congruency, the lines of the prime and the target were different in shape so that prime–target congruency was based only on symmetry. In addition, the prime was never presented as the target. All stimuli were presented on a grey background (RGB: 70, 70, 70, 18.2 cd/m^2).

The masks were randomly taken from a pool of 50 images. Each mask ($6.1° \times 6.1°$) contained two hundred randomly placed lines ($1.5°$ in length, 3 pixels in width) in two colors (RGB: 190, 190, 190, 58.9 cd/m^2 and the background color).

2.1.4. Procedure and Design

The sequence of events in the trial is presented in Figure 1A. The experimental trial started with the presentation of the fixation for 1000 ms. Then, a forward mask appeared for 100 ms, followed by a prime that appeared for 40 ms. Immediately following the prime, a backward mask appeared for 60 ms, followed by a clearly visible target. The target appeared until the participant's response or 2000 ms had elapsed. The participants' task was to discriminate between the two targets (symmetric vs. asymmetric) by pressing one of two keys on the response box with their dominant hand as fast as possible while avoiding making mistakes. Following the participant's response, a question mark appeared on the center of the screen, prompting the participant to provide a subjective visibility rating of the prime on a 4-point scale from 0 (I saw nothing) to 3 (I clearly saw an image) by pressing one of the assigned keys on a keyboard (the C, V, B, and N keys, which were covered by labels reading 0, 1, 2, and 3, respectively) using their other hand.

The experiment consisted of a practice block of 12 trials, followed by the main experiment, which consisted of 264 trials, including 24 catch trials in which no prime was presented. During the practice trials, an auditory tone informed participants of incorrect responses or the end of the response time limit. There were two self-administrated breaks in the main experiment.

2.2. Results

Four participants were excluded from the analysis, three because they used visibility rating two or three on more than 50% of the catch (no prime) trials and one because of rating more than 90% of the catch trails with a visibility of one. The remaining twenty-one participants used visibility rating 0 on 73% of the catch trials, visibility rating 1 on 22.02%, visibility rating 2 on 3.17%, and visibility rating 3 on only 1.78% of catch trials. Catch trials were excluded from the following analyses.

On average, participants rated the prime visibility as 0 on 69.52% of the prime present trials, 1 on 25.04% of the trials, 2 on 3.59% of the trials, and 3 on 1.85% of the trials.

Trials with incorrect responses (2.02%) or missed responses (1.55%) were omitted from all reaction time (RT) analyses. Trials with RTs more than 2 SDs from the experimental condition mean for each participant were filtered out (5.39% of correct response trials). Mean RTs and accuracies for congruent and incongruent conditions for each target in each visibility are presented in Table 1. Raw data can be found in the Supplementary Materials. Participants performed the target task with high accuracy (average 96.43%), and there was no indication of a speed–accuracy tradeoff. Therefore, accuracy is not discussed further.

Table 1. Mean and standard error (SE) for reaction times (RTs) (ms) and accuracy (%) in congruent and incongruent conditions for each target as a function of visibility in Experiment 1.

	Asymmetric Target				Symmetric Target			
	Incongruent		Congruent		Incongruent		Congruent	
	RT							
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Visibility rating 0	678.28	25.19	679.29	25.19	662.47	25.15	661.01	25.15
Visibility rating 1	748.76	26.98	741.73	26.88	734.27	27.08	689.74	26.99
Visibility rating 2	740.53	38.03	772.45	39.10	682.28	41.08	832.47	41.20
Visibility rating 3	890.13	49.26	815.67	49.34	667.43	58.23	656.31	52.94
	Accuracy							
	Asymmetric Target				Symmetric Target			
	Incongruent		Congruent		Incongruent		Congruent	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Visibility rating 0	95.68	1.62	97.09	1.62	95.68	1.62	97.04	1.62
Visibility rating 1	96.03	1.75	95.20	1.75	95.73	1.80	97.33	1.75
Visibility rating 2	96.66	2.23	100	2.13	93.87	2.23	94.64	2.05
Visibility rating 3	98.86	3.30	96.76	3.30	80.61	4.25	100	4.25

Not all participants used all possible visibility ratings. Therefore, we used a linear mixed-effects model (LMM) for repeated measures in all analyses involving visibility as a factor. An LMM analysis with visibility (0,1,2,3), congruency (congruent, incongruent), and the target (symmetric, asymmetric) as within-subject factors revealed, in correspondence with previous findings [40,42,54,55], a significant effect on visibility ($F_{(3,34)} = 25.16$, $p < 0.0001$), showing that participants were faster in the absence of awareness. The effect of the target was also significant ($F_{(1,20)} = 17.86$, $p = 0.0004$), indicating that participants responded faster to the symmetric target (698 ms on average) as compared with the asymmetric target (758 ms on average). Visibility interacted with the target ($F_{(3,26)} = 5.25$, $p = 0.0057$) and with congruency ($F_{(3,27)} = 4.56$, $p = 0.0104$). The three-way interaction between visibility, congruency, and the target was not significant ($F_{(3,17)} = 2.14$, $p = 0.1335$).

Since participants rarely reported seeing a prime (visibility rating 2 and 3 = 5.44%), there were not enough trials with visibility ratings of 2 and 3 to allow meaningful analysis at each visibility and evaluate the effect of awareness on symmetry grouping. Consequently, we adopted a more conservative criterion for awareness and combined trials with visibility ratings 1, 2, and 3. The mean RT for congruent and incongruent conditions for symmetric and asymmetric targets as a function of visibility (0, 1+2+3) are presented in Figure 2. A linear mixed-effects model for repeated measures with visibility (0, 1+2+3), the target (symmetric or asymmetric), and congruency (congruent or incongruent) showed significant effects on visibility ($F_{(1,17)} = 73.32$, $p < 0.0001$) and the target ($F_{(1,20)} = 19.59$, $p = 0.0003$). However, there was no significant effect on congruency ($F_{(1,20)} = 1.42$, $p = 0.2474$), nor an interaction between congruency and visibility ($F_{(1,17)} = 1.34$, $p = 0.2625$) or congruency and the target ($F < 1$). The interaction between visibility and the target ($F_{(1,17)} = 3.03$, $p = 0.0996$) and the three-way interaction between the three factors ($F < 1$) were also not significant. These results indicate no response priming when prime visibility was rated as zero. For further testing of the congruency effect in the

absence of visual awareness, we performed a Bayesian paired t-test in favor of the null hypothesis (JASP statistical software www.jasp-stats.org). The comparison of RTs in congruent and incongruent conditions for trials with a visibility rating of 0 revealed that BF01 = 4.294, indicating moderate support for the null hypothesis. Thus, the results suggest that symmetry-based grouping did not take place in the absence of visual awareness.

The results for visibility ratings 1+2+3 were completely inconclusive (BF01 = 0.821 vs. BF10 = 1.218). This outcome can be a consequence of the performance in trials rated with visibility rating 1 (which constitutes the majority of the combined trials). A visibility rating of one may reflect a transitional state between processing without awareness and processing with awareness, with just some glimpses of awareness [56]. The inconclusive results for visibility ratings 1+2+3 raise the possibility that our stimuli could not produce a response priming effect per se, which consequently can affect the interpretation of the absence of response priming when visibility was rated as zero. To rule out this possibility, we ran Experiment 2, which is a visible version of Experiment 1.
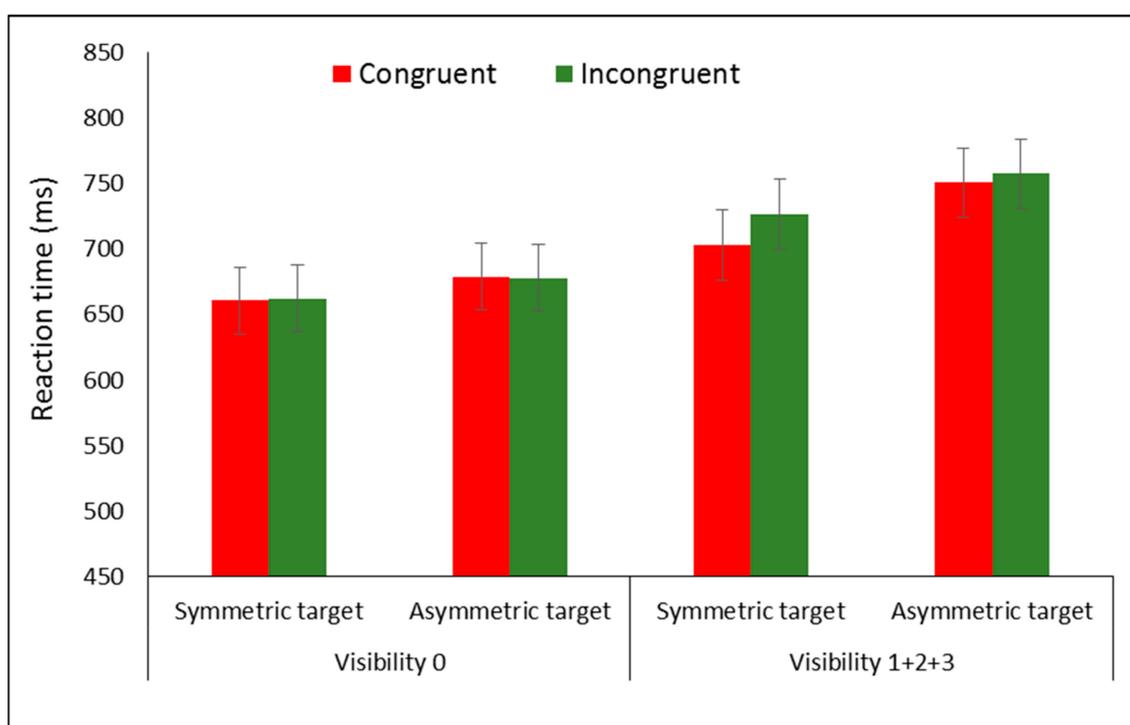

Figure 2. Results of Experiment 1, showing the RTs in congruent and incongruent conditions for symmetric and asymmetric targets as a function of the visibility rating (0 vs. 1+2+3). The error bars represent the SE.

3. Experiment 2: Symmetry-Based Grouping under Full Visibility

3.1. Materials and Methods

Experiment 2 was the same as Experiment 1 with a few exceptions: (1) no masks were presented. Instead, background-colored screens were presented for the same times as in the masking trial (Figure 1A); and (2) there was no visibility rating task, as the primes were clearly visible in the prime-present trials.

Participants

Twelve new individuals (nine females, two left-handed, aged 19–29, mean = 23.2) participated in Experiment 2.

3.2. Results

Participants were highly accurate, with an average accuracy of 98.2%.

Trials with incorrect responses (1.8%) or missed responses (0.19%) were omitted from the following analysis. Additionally, trials with RTs that fell beyond 2 SDs from the mean of the experimental condition for each participant were filtered out (4.74% of correct responses). The mean RTs and accuracies for congruent and incongruent conditions for each target are presented in Table 2.

Table 2. Mean and standard error (SE) for RTs (ms) and accuracy (%) in congruent and incongruent conditions for each target in Experiment 2.

RT							
Asymmetric Target				Symmetric Target			
Incongruent		Congruent		Incongruent		Congruent	
Mean	SE	Mean	SE	Mean	SE	Mean	SE
543.52	23.57	527.33	23.56	536.79	23.56	507.88	23.56
Accuracy							
Asymmetric Target				Symmetric Target			
Incongruent		Congruent		Incongruent		Congruent	
Mean	SE	Mean	SE	Mean	SE	Mean	SE
99.03	1.16	98.61	1.16	99.31	1.16	100.00	1.16

A linear mixed-effects model for repeated measures with the target (symmetric vs. asymmetric) and congruency (congruent vs. incongruent) as within-subject factors was conducted on the RT data. The effects of the target (F(1,11) = 9.42, p = 0.0107) and congruency (F(1,11) = 27.95, p = 0.0003) were significant and did not interact with each other (F(1,11) = 2.23, p = 0.1637). Participants responded faster to the symmetric targets as compared with the asymmetric targets (522.33 ms vs. 535.42 ms). Importantly, participants were faster in the congruent condition than the incongruent condition (540.15 ms vs. 517.60 ms), indicating response priming. This result is in correspondence with a previous study demonstrating that stimuli with a single vertical axis of symmetry can produce a robust response priming effect when visible [6]. Although the target and congruency did not interact, we examined the effect of congruency for each target. The results showed a significant effect from congruency on both the symmetric (F(1,11) = 20.64, p = 0.0008, 28.7 ms) and asymmetric targets (F(1,11) = 8.58, p = 0.0137, 16.3 ms). Thus, when visible, the stimuli used in Experiment 1 produced clear response priming effects.

4. Response Priming for Invisible and Visible Primes: Comparison between Experiments 1 and 2

To examine the processing of symmetry as a function of awareness, which was not possible to do in Experiment 1 (because participants barely saw the prime), we compared response priming between the invisible condition (visibility rating 0) of Experiment 1 and the visible condition in Experiment 2.

A linear mixed-effects model for repeated measures with the targets (asymmetric and symmetric) and congruency (congruent and incongruent) as within-subject factors and the experiments (visible and invisible) as between-subject factors was conducted on the RT data. The analysis revealed significant effects for all three factors: the target (F(1,31) = 16.56, p = 0.0003), congruency (F(1,31) = 9.32, p = 0.0046), and the experiment (F(1,31) = 17.82, p = 0.0002). The target did not interact with congruency (F(1,31) = 0.78, p = 0.3852), nor with the experiment (F < 1), and the three-way interaction between all three factors was also not significant (F < 1). Importantly, however, the interaction between congruency and the experiment was significant (F(1,31) = 7.84, p = 0.0087). Follow-up analyses revealed, as can be seen in Figure 3, a significant effect of congruency (i.e., response priming) for the visible experiment (F(1,31) = 15.77, p = 0.0004), but not for the invisible condition in Experiment 1 (F < 1).
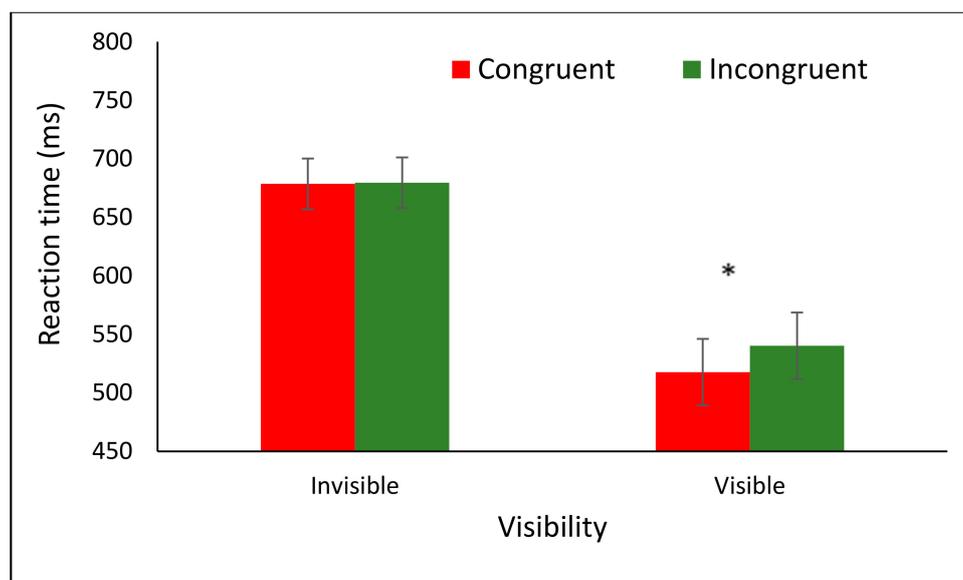
Figure 3. Congruency effects in Experiments 1 and 2, with RTs in congruent and incongruent conditions in the invisible condition of Experiment 1 and the visible condition of Experiment 2. The asterisk represents a significant ($p < 0.05$) difference in RTs between the congruent and incongruent conditions. Error bars represent the SE.

One might consider a comparison between the masked invisible and masked visible conditions, as we intended initially, to be somewhat more favorable than the comparison between masked invisible and unmasked visible conditions because, presumably, it allows for examining response priming when the prime is and is not consciously perceived under identical conditions. However, as we noted earlier, when we employed a mask (Experiment 1), our participants barely saw the prime and, therefore, we ended up doing the latter comparison, which we consider as appropriate. That is, we compared a condition of unawareness (induced by masking) and a condition of clear awareness (due to a lack of masking) in a similar procedure and with identical stimuli. Actually, such a comparison is commonly used in studies that employ an objective measure rather than a subjective visibility rating to assess awareness [49,56]. Thus, the comparison between our two experiments clearly indicates that response priming is obtained only under awareness of the stimuli, suggesting that symmetry-based grouping requires visual awareness of the stimulus.

5. Discussion and Conclusions

In this study, we examined whether symmetry-based grouping can take place in the absence of visual awareness of the stimulus, using a priming paradigm in which the primes—symmetric and asymmetric lines—were rendered invisible by sandwich masking (Experiment 1). The targets, which were also symmetric and asymmetric lines, could be congruent or incongruent with the prime in symmetry. We used response priming as the measure of processing of the prime and a sensitive, subjective visibility rating scale to assess awareness of the prime in each trial. Participants barely saw the prime, and the results for the visible conditions were inconclusive, even when we used a conservative criterion for awareness, so we could not assess response priming under the condition of awareness of the prime. Therefore, we conducted a second experiment, which was identical to Experiment 1 except that the prime was not masked, but completely visible, and no visibility rating was required (Experiment 2), thus allowing us to examine the processing of the prime when participants were aware of it.

The results showed, in both experiments, that responses to the target with symmetric lines were significantly faster than responses to the one with asymmetric lines, in accordance with previous findings indicating faster responses to symmetric than asymmetric shapes [1]. However, the two

experiments yielded disparate results concerning response priming. The unmasked visible prime stimuli elicited significant response priming (Experiment 2), but the same stimuli failed to do so under masking when the prime was reported as invisible (Experiment 1, visibility rating 0). That is, no significant response priming was observed when visibility of the prime was null. These findings suggest that symmetry-based grouping cannot take place in the absence of visual awareness.

Symmetry is considered one of the classical grouping principles, along with proximity, similarity, common fate, good continuation, and closure [8,12,15], yet it appears to diverge from some of these principles. Whereas grouping by symmetry is shown to depend on visual awareness, grouping by other principles seems to be independent of awareness. Thus, grouping by proximity, connectedness, similarity in luminance [39,40], and good continuation [57] was found to take place in the absence of visual awareness. One may argue that the lack of response priming in Experiment 1 was due to a more powerful masking than the masking in these other studies that showed unconscious response priming. This argument, however, is not very plausible, in light of the fact that the luminance of the prime and that of the mask were equated in our previous experiments, whereas in the present experiment, the luminance of the prime was higher than that of the mask, suggesting that the prime–mask similarity in the present experiment was lower. Since the similarity between a stimulus and a mask is known to increase the masking effect [58], it is unlikely that the masking in Experiment 1 was more powerful than the masking in the other studies that demonstrated unconscious grouping.

The divergence in the role of awareness between symmetry and the other grouping factors may be taken by some researchers as support for the view that downplays the role of symmetry in perceptual organization. A number of researchers argue that symmetry is, at best, a weak figural cue [59] and that grouping by other factors precedes and facilitates grouping by symmetry (see [22] for a discussion) [10,60]. It was also found that organization by collinearity alone suffices for automatic capture of attention by a perceptual object, whereas organization by symmetry alone does not, suggesting that symmetry may play a weaker role than collinearity in the formation of objecthood [61].

However, Sweeny, Grabowecky, and Suzuki [62] found that closed curvature aftereffects, in contrast to open curvature aftereffects, occurred only when observers were aware of the adaptor. This finding suggests that closure, like symmetry, may depend on visual awareness.

Symmetry and closure, unlike the other grouping factors (e.g., good continuation and proximity), were considered by Wertheimer [11] as whole properties. Symmetry, much in the same way as closure, operates on a global stimulus level, which may explain the findings that symmetry comes into play in interaction with other grouping factors [22,63]. For example, Machilsen et al. [22] showed that symmetry facilitated figure–ground segregation in arrays of oriented Gabor elements, but the detection of symmetry could only follow the local grouping by collinearity of the Gabor elements, and Hulleman and Humphreys [63] showed that discrimination between symmetric and asymmetric shapes was facilitated by top–bottom polarity. Note that closure also appears to interact with collinearity in the grouping of shapes [64,65].

Most importantly, according to the Gestaltists, symmetry and closure are not grouping factors per se, but rather play a critical role in how the perceptual system arrives at a stable, organized structure. Closure is particularly crucial in determining the shape of an object [8]. Symmetry is particularly crucial in determining figural goodness [7,8,11]. It is possible that these can be achieved only when the stimulus is consciously perceived.

To conclude, we provide here direct evidence that vertical, symmetry-based grouping cannot be accomplished in the absence of visual awareness of the stimulus. This finding may shed further light on the role of symmetry in perceptual organization.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References and Note

1. Baylis, G.C.; Driver, J. Parallel Computation of Symmetry But Not Repetition within Single Visual Shapes. *Vis. Cogn.* **1994**, *1*, 377–400.
2. Bertamini, M.; Makin, A. Brain Activity in Response to Visual Symmetry. *Symmetry* **2014**, *6*, 975–996.
3. Barlow, H.B.; Reeves, B.C. The versatility and absolute efficiency of detecting mirror symmetry in random dot displays. *Vis. Res.* **1979**, *19*, 783–793. [PubMed]
4. Niimi, R.; Watanabe, K.; Yokosawa, K. The role of visible persistence for perception of visual bilateral symmetry. *Jpn. Psychol. Res.* **2005**, *47*, 262–270.
5. Carmody, D.P.; Nodine, C.F.; Locher, P.J. Global detection of symmetry. *Percept. Mot. Skills* **1977**, *45*, 1267–1273.
6. Schmidt, F.; Schmidt, T. Rapid processing of closure and viewpoint-invariant symmetry: Behavioral criteria for feedforward processing. *Psychol. Res.* **2014**, *78*, 37–54.
7. Palmer, S.E. Goodness, Gestalt, groups, and Garner: Local symmetry subgroups as a theory of figural goodness. In *The Perception of Structure: Essays in Honor of Wendell R Garner*; American Psychological Association: Washington, DC, USA, 1991; pp. 23–39.
8. Koffka, K. *Principles of Gestalt Psychology*, 2nd ed.; Harcourt; Brace & Company: New York, NY, USA, 1935.
9. Vetter, T.; Poggio, T. Symmetric 3D Objects are an Easy Case for 2D Object Recognition. *Spat. Vis.* **1994**, *8*, 443–453.
10. Pashler, H. Coordinate Frame for Symmetry Detection and Object Recognition. *J. Exp. Psychol. Hum. Percept. Perform.* **1990**, *16*, 150–163.
11. Wertheimer, M. Untersuchungen zur Lehre von der Gestalt. II. *Psychol. Forsch.* **1923**, *4*, 301–350.
12. Wagemans, J.; Elder, J.H.; Kubovy, M.; Palmer, S.E.; Peterson, M.A.; Singh, M.; von der Heydt, R. A century of Gestalt psychology in visual perception: I. Perceptual grouping and figure-ground organization. *Psychol. Bull.* **2012**, *138*, 1172–1217.
13. Wagemans, J. Detection of Visual Symmetries. *Spat. Vis.* **1995**, *9*, 9–32. [PubMed]
14. Wagemans, J. Characteristics and models of human symmetry detection. *Trends Cogn. Sci.* **1997**, *1*, 346–352. [PubMed]
15. van der Helm, P.A. *Symmetry Perception*; Wagemans, J., Ed.; Oxford University Press: New York, NY, USA, 2014; pp. 1–23.
16. Treder, M.S. Behind the Looking-Glass: A Review on Human Symmetry Perception. *Symmetry* **2010**, *2*, 1510–1543.
17. Feldman, J. Formation of visual "objects" in the early computation of spatial relations. *Percept. Psychophys.* **2007**, *69*, 816–827.
18. Gillam, B. Redundant Symmetry Influences Perceptual Grouping (as Measured by Rotational Linkage). *Symmetry* **2017**, *9*, 67.
19. Gillam, B.; McGrath, D. Orientation relative to the retina determines perceptual organization. *Percept. Psychophys.* **1979**, *26*, 177–181.
20. Driver, J.; Baylis, G.C.; Rafal, R.D. Preserved figure-ground segregation and symmetry perception in visual neglect. *Nature* **1992**, *360*, 73–75.
21. Mojica, A.J.; Peterson, M.A. Display-wide influences on figure-ground perception: The case of symmetry. *Atten. Percept. Psychophys.* **2014**, *76*, 1069–1084.
22. Machilsen, B.; Pauwels, M.; Wagemans, J. The role of vertical mirror symmetry in visualshape detection. *J. Vis.* **2009**, *9*, 11.
23. Peterson, M.A.; Gibson, B.S. Must Figure-Ground Organization Precede Object Recognition? An Assumption in Peril. *Psychol. Sci.* **1994**, *5*, 253–259.

24. Kanizsa, G.; Gerbino, W. Convexity and symmetry in figure-ground organization. In *Vision and Artifact*; Henle, M., Ed.; Springer: New York, NY, USA, 1976.

25. van Lier, R.J.; van der Helm, P.A.; Leeuwenberg, E.L.J. Competing Global and Local Completions in Visual Occlusion. *J. Exp. Psychol. Hum. Percept. Perform.* **1995**, *21*, 571–583. [CrossRef] [PubMed]

26. Sekuler, A.B.; Palmer, S.E.; Flynn, C. Local and Global Processes in Visual Completion. *Psychol. Sci.* **1994**, *5*, 260–267. [CrossRef]

27. Bertamini, M.; Friedenberg, J.D.; Kubovy, M. Detection of symmetry and perceptual organization: The way a lock-and-key process works. *Acta Psychol.* **1997**, *95*, 119–140. [CrossRef]

28. Koning, A.; Wagemans, J. Detection of symmetry and repetition in one and two objects: Structures versus strategies. *Exp. Psychol.* **2009**, *56*, 5–17. [CrossRef]

29. Behrmann, M.; Kimchi, R. What does visual agnosia tell us about perceptual organization and its relationship to object perception? *J. Exp. Psychol. Hum. Percept. Perform.* **2003**, *29*, 19–42. [CrossRef]

30. Kimchi, R.; Behrmann, M.; Olson, C.R. (Eds.) *Perceptual Organization in Vision: Behavioral and Neural Perspective*; Psychology Press: New York, NY, USA, 2003; pp. 117–153.

31. Kimchi, R. The perceptual organization of visual objects: A microgenetic analysis. *Vis. Res.* **2000**, *40*, 1333–1347. [CrossRef]

32. Kimchi, R. Perceptual organization and visual attention. In *Progress in Brain Research*; Elsevier: Amsterdam, The Netherlands, 2009; pp. 15–33.

33. Kimchi, R.; Hadad, B.; Behrmann, M.; Palmer, S.E. Microgenesis and ontogenesis of perceptual organization: Evidence from global and local processing of hierarchical patterns. *Psychol. Sci.* **2005**, *16*, 282–290. [CrossRef]

34. Kurylo, D.D. Time course of perceptual grouping. *Percept. Psychophys.* **1997**, *59*, 142–147. [CrossRef]

35. Rashal, E.; Yeshurun, Y.; Kimchi, R. Attentional requirements in perceptual grouping depend on the processes involved in the organization. *Atten. Percept. Psychophys.* **2017**, *79*, 2073–2087. [CrossRef]

36. Quinn, P.C.; Bhatt, R.S. Are some gestalt principles deployed more readily than others during early development? The case of lightness versus form similarity. *J. Exp. Psychol. Hum. Percept. Perform.* **2006**, *32*, 1221–1230. [CrossRef]

37. Moors, P.; Hesselmann, G.; Wagemans, J.; van Ee, R. Continuous flash suppression: Stimulus fractionation rather than integration. *Trends Cogn. Sci.* **2017**, *21*, 719–721. [CrossRef] [PubMed]

38. Breitmeyer, B.G. Psychophysical "blinding" methods reveal a functional hierarchy of unconscious visual processing. *Conscious Cogn.* **2015**, *35*, 234–250. [CrossRef] [PubMed]

39. Montoro, P.R.; Luna, D.; Ortells, J.J. Subliminal Gestalt grouping: Evidence of perceptual grouping by proximity and similarity in absence of conscious perception. *Conscious Cogn.* **2014**, *25*, 1–8. [CrossRef]

40. Kimchi, R.; Devyatko, D.; Sabary, S. Can perceptual grouping unfold in the absence of awareness? Comparing grouping during continuous flash suppression and sandwich masking. *Conscious Cogn.* **2018**, *60*, 37–51. [CrossRef] [PubMed]

41. Breitmeyer, B.; Ogmen, H.; Ramon, J.; Chen, J. Unconscious and conscious priming by forms and their parts. *Vis. Cogn.* **2005**, *12*, 720–736. [CrossRef]

42. Devyatko, D.; Sabary, S.; Kimchi, R. Perceptual organization of line configurations: Is visual awareness necessary? *Conscious Cogn.* **2019**, *70*, 101–115. [CrossRef]

43. Banica, T.; Schwarzkopf, D.S. Induction of Kanizsa Contours Requires Awareness of the Inducing Context. *PLoS ONE* **2016**, *11*, e0161177. [CrossRef]

44. Devyatko, D.; Pastukhov, A. Extrinsic grouping factors in motion-induced blindness. *PLoS ONE* **2018**, *13*, e0192133. [CrossRef]

45. Harris, J.J.; Schwarzkopf, D.S.; Song, C.; Bahrami, B.; Rees, G. Contextual Illusions Reveal the Limit of Unconscious Visual Processing. *Psychol. Sci.* **2011**, *22*, 399–405. [CrossRef]

46. Moors, P.; Wagemans, J.; van Ee, R.; de-Wit, L. No evidence for surface organization in Kanizsa configurations during continuous flash suppression. *Atten. Percept. Psychophys.* **2016**, *78*, 902–914. [CrossRef]

47. Sobel, K.V.; Blake, R. Subjective contours and binocular rivalry suppression. *Vis. Res.* **2003**, *43*, 1533–1540. [CrossRef]

48. Sabary, S.; Devyatko, D.; Kimchi, R. The role of visual awareness in processing of global structure: Evidence from the perceptual organization of hierarchical patterns. *Cognition* **2020**, *205*, 104442. [CrossRef] [PubMed]

49. Schwarzkopf, D.S.; Rees, G. Interpreting local visual features as a global shape requires awareness. *Proc. R. Soc. B Biol. Sci.* **2011**, *278*, 2207–2215. [CrossRef] [PubMed]

50. Koch, C.; Tsuchiya, N. Attention and consciousness: Two distinct brain processes. *Trends Cogn. Sci.* **2007**, *11*, 16–22. [CrossRef] [PubMed]

51. Kouider, S.; Dehaene, S. Levels of processing during non-conscious perception: A critical review of visual masking. *Philos. Trans. R. Soc. B Biol. Sci. R. Soc.* **2007**, *362*, 857–875. [CrossRef]

52. Van den Bussche, E.; Van den Noortgate, W.; Reynvoet, B. Mechanisms of Masked Priming: A Meta-Analysis. *Psychol. Bull.* **2009**, *135*, 452–477. [CrossRef]

53. Ramsøy, T.Z.; Overgaard, M. Introspection and subliminal perception. *Phenomenol. Cogn. Sci.* **2004**, *3*, 1–23. [CrossRef]

54. Avneon, M.; Lamy, D. Reexamining unconscious response priming: A liminal-prime paradigm. *Conscious Cogn.* **2018**, *59*, 87–103. [CrossRef]

55. Peremen, Z.; Lamy, D. Comparing unconscious processing during continuous flash suppression and meta-contrast masking just under the limen of consciousness. *Front. Psychol.* **2014**, *5*, 969. [CrossRef]

56. Overgaard, M.; Rote, J.; Mouridsen, K.; Ramsøy, T.Z. Is conscious perception gradual or dichotomous? A comparison of report methodologies during a visual task. *Conscious Cogn.* **2006**, *15*, 700–708. [CrossRef]

57. Devyatko, D.; Kimchi, R. Grouping by good continuation is independent of visual awareness. In preparation

58. Breitmeyer, B.; Ogmen, H. *Visual Masking: Time Slices Through Conscious and Unconscious Vision*; Oxford University Press: New York, NY, USA, 2010; pp. 1–384.

59. Devinck, F.; Spillmann, L. Multiple cues add up in defining a figure on a ground. *Vis. Res.* **2013**, *77*, 51–58. [CrossRef] [PubMed]

60. Labonté, F.; Shapira, Y.; Cohen, P.; Faubert, J. A Model for Global Symmetry Detection in Dense Images. *Spat. Vis.* **1995**, *9*, 33–55. [PubMed]

61. Kimchi, R.; Yeshurun, Y.; Spehar, B.; Pirkner, Y. Perceptual organization, visual attention, and objecthood. *Vis. Res.* **2016**, *126*, 34–51. [CrossRef] [PubMed]

62. Sweeny, T.D.; Grabowecky, M.; Suzuki, S. Awareness becomes necessary between adaptive pattern coding of open and closed curvatures. *Psychol. Sci.* **2011**, *22*, 943–950. [CrossRef]

63. Hulleman, J.; Humphreys, G.W. Is there an assignment of top and bottom during symmetry perception? *Perception* **2004**, *33*, 615–620. [CrossRef]

64. Elder, J.; Zucker, S. The effect of contour closure on the rapid discrimination of two-dimensional shapes. *Vis. Res.* **1993**, *33*, 981–991. [CrossRef]

65. Hadad, B.-S.; Kimchi, R. Time course of grouping of shape by perceptual closure: Effects of spatial proximity and collinearity. *Percept. Psychophys.* **2008**, *70*, 818–827. [CrossRef]