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Role of Symmetry and Simplicity in Shape Disruption Perception Tasks

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Purpose of the present research was further examination of roles of symmetry and complexity in visual perception tasks. We tested hypothesis from perceptual economy theory, and since we used shape disruptions as one of the stimulus characteristics we could also address Luccio's two step theory concerning perception of shape disruptions on good forms.

Four experiments were conducted, visual search and simultaneous and delayed matching. Symmetry and complexity were varied, as well as set size in visual search experiment. Dependent variables were reaction time and error number. In all four experiments, symmetry had dominant effect, while significant effect of complexity was registered only in Experiment 1. However, in first three experiments interaction of symmetry and complexity was also significant.

Analysis of reaction times and performance suggested that our results follow the pattern suggested by perceptual economy, i.e. that symmetry is dominant in easier tasks, while complexity was significant in most difficult task. Our results couldn't completely support Luccio's assumption that shape disruption is better perceived on good forms, although it can't be completely discarded.

Key words*: symmetry, complexity, perceptual economy, visual search, matching task*

Gestalt psychology states that the visual field is organized according to some global structural qualities (Köhler, 1947; Koffka, 1935). These qualities (also called Prägnant qualities – Prägnanzqualität) are present in every perceptual unit, but in different quantities. According to Wetheimer, the more these qualities are present, the more that unit will be integrated, or Prägnant (Koffka, 1935). Although Gestaltists defined Prägnant form (or *good form*) as subjective category, stimulus characteristics determine the level of possible goodness. In other words, the form will be as good as stimulus constraint allow (Koffka, 1935). Some of the stimulus qualities that make Prägnant structure are similarity, simplicity, symmetry, continuity, nearness (Wertheimer, 1923).

Question whether some of the stimulus qualities are dominant over the others is important in cases where two or more of them result in different possible

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perception. However, some of the authors claimed that these qualities could be reduced to two main categories, symmetry and simplicity (Alexander & Carey, 1968; Bear, 1973; Boselie, 1988; Marković, 2002; Marković & Gvozdenović, 2001). Also, it should be noted that some authors claim that simplicity can actually be assigned to the number of axis of symmetry – the more axis of symmetry perceptual unit has, the simpler that unit is (Alexander & Carey, 1968; Donderi, 2006). This point of view makes symmetry and complexity highly correlated. On the other hand, complexity is sometimes identified as number of elements (Marković, 2002; Marković & Gvozdenović, 2001; Donderi, 2006), and in that case it is independent from symmetry. In present research, we considered shapes having two axis of symmetry (horizontal and vertical) as symmetrical, and complexity was defined in terms of number of elements. However, other possible definitions of symmetry and complexity are addressed later in discussion.

Relative importance of stimulus qualities also depends on perceptual economy principles. Perceptual economy represents the tendency of a perceptual system to maintain optimal levels of both – energy and efficacy (Köhler, 1947). Perceptual economy is based on two complementary internal principles – Minimum and Maximum simplicity principle. In the minimum simplicity conditions, which are low energy state conditions (difficult tasks, low vigilance), the perceptual system tends to save energy, and therefore simplicity as organizational quality should be preferred. In situations where energy state is high (interesting or easy tasks, high vigilance) the system is driven by the maximum simplicity principle and symmetry should be a dominant organizational quality. Dominance of symmetry leads to better articulated and more structured perception, which is the objective of maximum simplicity principle. (Koffka, 1935). Therefore, neither of the two principles can be defined as more important in general, only in particular situation.

Perceptual economy suggests that importance of these two qualities, symmetry and complexity, would depend on the situation, especially on task difficulty. Two types of tasks are indicators of perceptual economy tendency toward a balance between energy saving and efficacy. First types of indicators are perceptual load tasks, with main focus on reaction time in visual perception tasks. The other types are those concerning perception quality (Marković, 2007). In several studies the role of simplicity and symmetry (considered as mutually independent features) in visual tasks was examined (Bear, 1973; Kayaert & Wagemans, 2009; Marković, 1999; Marković & Gvozdenović, 2001; Marković & Racković, 2008). Some of the results partially support perceptual economy hypothesis (Bear, 1973; Marković & Gvozdenović, 2001; Marković, 2002), while others suggest that symmetry and simplicity have an additive effect (Kayaert & Wagemans, 2009; Marković, 1999; Marković & Racković, 2008). From the perceptual economy point of view, the additive effect between these two features is not expected, although it can be assumed that tasks in which it appears are somewhere in between very easy and very difficult (Marković, 2007). It should also be noted that the results that confirm perceptual economy hypothesis mostly stem from high energy state experiments, while the additive effect is obtained in experiments with low energy states, that is, from more difficult tasks.

In some of the above-mentioned studies, perception of shape disruption was investigated in goodness of form context. Gestalt theory states that better forms will be more resistant to deformations, being recognizable even after major disintegrations (Koffka, 1935; Köhler, 1947). Some studies support this state, proving that small shape deformations on good forms are not noticed during short presentations (Wertheimer, 1923; Köhler, 1947). On the other hand, other similar studies show completely opposite results – shape deformations are better seen on good shapes (Luccio, 1998; Marković & Racković, 2007). Luccio suggests that different levels of processing may explain these incongruities (Luccio, 1998). Primary processing, activated in perceptual discrimination tasks, is more sensitive to deformations on good forms, while secondary processing (such as categorization) makes deformations of good forms less noticeable. Distinction between primary and secondary processing has first been made by Kanizsa (Kanitzsa, 1979; Kanizsa & Gerbino 1982 according to Marković, 2007; Kanizsa, 1985), but its empirical confirmation from Luccio's experiments is highly connected to our present research.

In present research we continued the line of examination concerning the role of symmetry and complexity in perceptual tasks (visual search, matching tasks). All of our tasks belong to the perceptual load category of tasks, and they are supposed to be difficult, but it is also expected that some differences in difficulty between them will appear. From the Gestalt theory perspective minimum simplicity principle should prevail (Koffka, 1935), However, previously detected additive effect (Kayaert & Wagemans, 2009; Marković, 1999; Marković and Racković, 2008) was obtained on tasks of similar difficulty as ours. As it was noted earlier, this kind of result is difficult to incorporate in perceptual economy theory, but not impossible, perhaps being characteristic for medium difficulty tasks. Moreover, since we used the shape disruption as one of the stimulus characteristics, we were able to consider Luccio's two-step theory (Luccio, 1998), that claims that disruption should be better seen on good forms in this type of tasks, since they are supposed to engage primary processing. Since both, symmetry and simplicity are features that define good form, if we detected additive effect in our experiments, it could arise from task characteristics. Therefore, additive effect in our experiments could be the consequence of both, perceptual economy and Luccio's theory, while dominance of complexity would give credit to perceptual economy point of view. However, if additive effect was registered in some of the experiments, and dominance of one of the features in others, it could be due to differences in difficulty, and it could clarify appearance of additive effect in this type of tasks.

EXPERIMENT 1

Visual search task was used in this experiment. Subjects are searching displays of shapes in order to indicate whether there is a shape with disruption present. Sets are varied in size; effect of set size is expected, as well as difference between target present and absent trials (Treisman & Gelade, 1980). From the perceptual economy point of view complexity should have dominant effect. Predictions from Luccio's theory account for additive effect in all of our experiments.

Method

Participants: Seventeen first year psychology students at University of Belgrade took part in the experiment. Every participant had normal or corrected to normal vision and all of them were naive to the study.

Stimuli: There was one basic shape, which was considered symmetrical (having two symmetry axis – horizontal and vertical) and simple (containing four distinctive elements). Three other shapes were then derived from the basic shape – symmetrical and complex (eight instead of four elements), asymmetrical and simple and asymmetrical and complex. First three stimuli were taken from earlier studies (Marković & Racković, 2007), and fourth (asymmetrical and complex) was created for the purpose of present study. All shapes had white outline on black background.

For the purpose of the Experiment 1, 32 visual displays were created. In each display all shapes were of the same type. Sets were varied by size, containing 3, 6, 9 or 12 shapes. Half of the sets contained a target (Figure 1), one of the shapes in set being disrupted, and half of them were target absent, all shapes in set being whole. Disruption position within the target was varied, but it was not controlled. Shapes were randomly arranged on a black background, position of disrupted shape in set being varied.

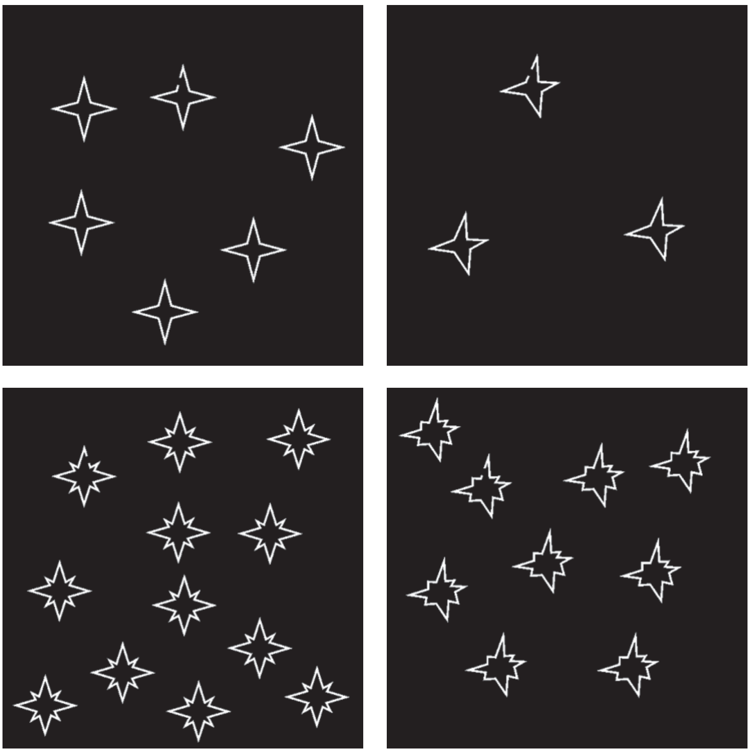

Figure 1. Example of target present displays,
for all four possible shapes and set sizes.

Procedure: Experiment was created in SuperLab 4.0 stimulus presentation programme, equipped with Cedrus RB–300 Response Box device. Subjects were tested individually, in the presence of an experimenter.

Experiment was preceded by 8 practice trials. Experiment consisted of 640 trials, 20 trials per each set. Order of trials was randomized. In each trial, white fixation dot (1000 ms) first appeared in the centre of the black screen, followed by the display and subject was supposed to respond whether there was a disrupted shape present by clicking on an appropriate button on response box. Subjects were instructed to respond as fast as they could while still trying to respond correctly.

Design: Data was analyzed using repeated measures analysis of variance with four factors (target presence, symmetry, complexity and set size). Factor target presence had two levels – presence or absence of stimulus with disruption, symmetry had two levels (symmetrical or asymmetrical shapes), complexity also had two levels (simple or complex shapes), while set size had four levels (3, 6, 9 or 12 shapes in set). Reaction time, defined as an interval between the appearance of a stimuli set and subject's response, was recorded, as well as number of errors.

Results and discussion

Reaction time analysis of variance indicated significant main effects of all four factors – target presence ($F(1,16)=150,7$, $p<.01$), symmetry ($F(1,16)=217,4$, $p<.01$), complexity ($F(1,16)=4,8$, $p=.043$) and set size ($F(3,48)=144.1$, $p<.01$). Standard effects of target presence and set size (Treisman & Gelade, 1980) were obtained – target present sets were searched faster, as well as sets with fewer shapes. More important finding of this experiment is that both, symmetry and complexity affect the search speed – reaction time is shorter for symmetrical and simple shapes. However, results suggest that symmetry is a more important feature than complexity – difference in reaction times between symmetrical and asymmetrical shapes is around 400 ms, while difference between simple and complex is less than 50 ms.

Reaction time analysis also showed some significant interactions. Triple interaction of factors target presence, symmetry and complexity was significant($F(1, 16)=52,6$, $p<.01$), as well as the interaction of target presence and complexity ($F(1,16)=70,9$, $p<.01$), indicating that complex shapes are searched faster in target present sets, but slower in target absent sets. However, triple interaction shows that in target present sets only symmetrical complex shapes are searched faster than symmetrical simple shapes, but trend is reversed for asymmetrical objects. In target absent sets, both, symmetrical and asymmetrical simple shapes are searched faster (Figure 2).

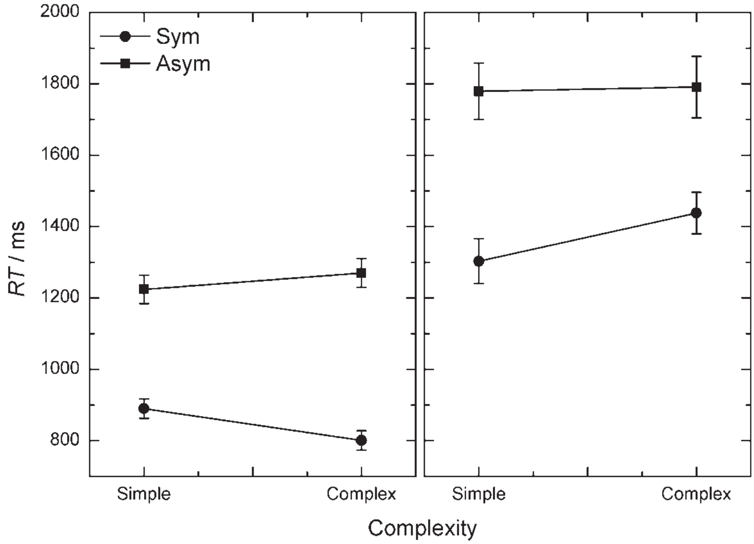

Figure 2. Mean reaction times of visual search
for the target present (left) and target absent (right) sets.

There was another significant triple interaction of target presence, symmetry and set size ($F(3, 48)=4{,}2, p=.011$). Set size interacted also individually with target presence ($F(3, 48)=74{,}9$, $p<.01$) and symmetry ($F(3, 48)=38{,}9$, $p<.01$). Increase in reaction time for larger sets was faster for negative sets, and also for asymmetrical shapes in comparison to symmetrical shapes. Triple interaction shows that increase for positive sets is larger for asymmetrical than symmetrical shapes, while negative symmetrical and asymmetrical sets don't differ much.

Analysis of variance conducted only on target present trials showed somewhat different pattern of results. Main effect of symmetry remained significant ($F(1, 16)=487{,}1$, $p<.01$), as well as main effect of set size ($F(3, 48)=144{,}9$, $p<.01$). Reaction time values for symmetrical shapes were shorter, and they increased with the set size. However, effect of complexity was not significant. It can be assumed that these results indicate dominant role of symmetry in visual search tasks.

The similar interaction as in previous analysis between symmetry and set size was registered ($F(3, 48)=33{,}8$, $p<.01$). However, two new interactions became significant. Interaction of symmetry and complexity ($F(1, 48)=22{,}6$, $p<.01$) showed that symmetrical complex shapes were searched faster than symmetrical simple shapes, while reversed was true for asymmetrical shapes. Triple interaction of symmetry, complexity and set size ($F(3, 48)=3{,}1$, $p=.035$) showed that increase in reaction time with larger sets was faster for symmetrical simple shapes, than for symmetrical complex shapes, but that difference was not registered for asymmetrical shapes.

Performance analysis showed no significant effects when both, target present and target absent sets were analyzed. However, when only positive sets were analyzed, all factors became significant – symmetry ($F(1, 16)=70{,}12$, $p<.01$), complexity ($F(1, 16)=7{,}31$, $p=.016$) and set size ($F(3, 48)=33{,}03$, $p<.01$). There were more mistakes when shapes were asymmetrical, complex, and also when there were more shapes in set. Several interactions also reached significance: symmetry and complexity ($F(1, 16)=30{,}82$, $p<.01$), symmetry and set size ($F(3, 48)=23{,}99$, $p<.01$) and complexity and set size ($F(3, 48)=4{,}68$, $p=.006$. Difference between symmetrical and asymmetrical shapes was greater for complex, than for simple shapes. Also, effect of set size was larger for asymmetrical shapes, and also for complex (comparing to symmetrical and simple shapes).

In addition to the analysis of variance, multiple regression was conducted for target present trials, with mean reaction times as dependent variables, and symmetry, complexity and set size as predictors. Analysis showed that linear combination of the three factors is good in prediction of reaction times: $r^2=.919$, $F(3, 12)=45.386$, $p<.001$. Further analysis confirmed significant effects of symmetry ($\beta=0.778$, $t=9.469$, $p<.001$) and set size ($\beta=0.559$, $t=6.800$, $p<.001$) on dependent variable, while complexity didn't reach significance (Figure 3). Difference between symmetrical and asymmetrical shapes, in favour of symmetrical shapes is once again confirmed, and slope is steeper for asymmetrical than for symmetrical shapes. Linear regression slope analysis suggests that the difference between symmetrical and asymmetrical, and simple and complex shapes is larger for sets that contain more shapes. Analysis of β-coefficients shows that symmetry is the best predictor, contributing more to explaining variance of reaction time than set size.

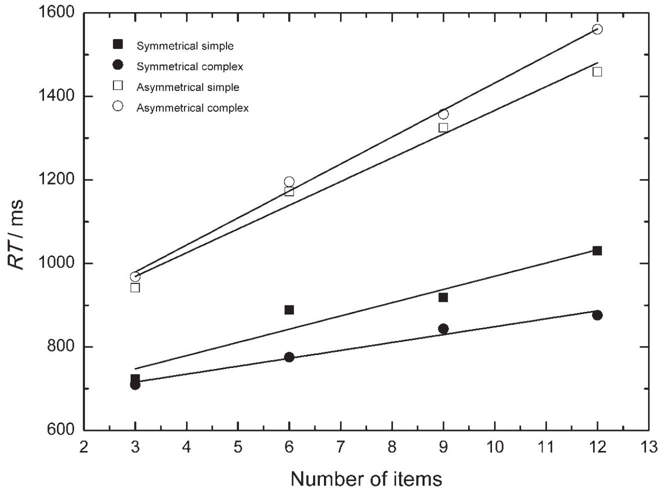

Figure 3. Regression lines of averaged reaction times depending on symmetry, complexity and set size

Some of the results from this experiment fit previously stated expectations, while some of them do not. Expected target presence and set size effects were obtained (Treisman & Gelade, 1980). Additive effect of symmetry and complexity that occurred in reaction time analysis of both, positive and negative sets cannot be explained by classical perceptual economy perspective (Koffka, 1935), but is coherent with some previous studies (Kayaert & Wagemans, 2009; Marković, 1999; Marković & Racković, 2008). It could be supposed that this task was neither very easy nor very difficult, and that significant effects of both, symmetry and complexity emerge from that fact (Marković, 2007). Also, these results could fit with Luccio's theory stating that both symmetry and simplicity enhance the visibility of shape deformation (Luccio, 1998). However, further analysis shows that the effect of symmetry is quite stronger than the effect of complexity, so we could say that symmetry was somewhat superior in this task. Regression analysis on target present sets, as well as triple interaction of set size, symmetry and complexity suggest that difference between symmetrical and asymmetrical, and simple and complex shapes grows with larger set size. This finding can be interpreted as symmetry and complexity getting more important as tasks become more difficult.

Another unexpected result is the interaction of target presence, symmetry and complexity. While in all cases symmetrical shapes were searched faster, as it was expected, complexity did not have such an unambiguous effect. This interaction showed that in target present trials symmetrical shapes were actually searched faster if they were complex, and not simple, while reverse was true for asymmetrical shapes in target present trials and for all target absent trials. This finding does not fit any of proposed theories, as all of them state that simple shapes would be easier to process. Performance analysis conducted on target present trials implied additive effect of symmetry and complexity, but again with unexpected interaction of these two factors.

Main finding of this experiment is the dominant effect of symmetry. This finding is not incoherent with assumptions from Luccio's theory, but the absence of main effect of complexity in reaction time analysis of target present trials is. From perceptual economy point of view this finding would imply that visual search task is quite easy, or at least not very difficult, which was not expected, if we have in mind easy tasks from some other studies (Marković, 2002; Marković & Gvozdenović, 2001). Significant interaction of symmetry and complexity cannot be explained by any of the proposed theories, and it calls for further research.

EXPERIMENT 2

In this experiment, two stimuli were simultaneously matched concerning the disruption. Perceptual economy theory would again suggest dominance of complexity effect in this type of task (Koffka, 1935), and results from similar experiment conducted by Marković and Gvozdenović (2001) in which subjects compared two patterns by orientation support that expectation. However, expectations from Luccio's theory point of view would again suggest significant effects of both, symmetry and complexity (Luccio, 1998).

Method

Participants: Sixteen subjects participated in the experiment, all of them psychology students at University of Belgrade. Each participant had normal or corrected to normal vision and all of them were naive to the study.

Stimuli: Same four shapes as in Experiment 1 were used. Pairs of same shapes were created, one shape set on the left of the screen, and the other on the right. One of the shapes in pair could have been disrupted, or none of them. When only one shape was disrupted, the position of disrupted shape on the screen was balanced.

Procedure: Experiments were created in SuperLab 4.0 stimulus presentation programme, with Cedrus RB–300 Response Box device. Subjects were tested individually, in the presence of an experimenter.

Experiments were preceded by 8 practice trials, and it consisted of 320 trials, whose order was randomized. Each trial consisted of fixation dot (1000 ms) after which pair of stimuli appeared. Subjects were supposed to respond whether two contours were same or different concerning disruption. Subjects responded by pressing one of two buttons on the response box.

Design: Reaction time and number of errors were recorded. Reaction time was defined as an interval between appearance of a pair of stimuli and subject's response.

Data was analyzed using repeated measures analysis of variance with the three factors. Factors were identity (same and different), symmetry (symmetrical and asymmetrical) and complexity (simple and complex).

Results and discussion

Reaction time analysis of variance showed significant effect of factor identity ($F(1, 15)=25{,}32$, $p<.01$). Pairs of same shapes, both of them non-disrupted, had longer reaction times than pairs in which one of the shapes was disrupted.

Significant main effect of symmetry was registered ($F(1, 15)= 44{,}39$, $p<.01$), symmetrical shapes being searched faster than asymmetrical. There was no significant effect of complexity, but the interaction of symmetry and complexity was significant ($F(1, 15)=11{,}62$, $p=.004$). Difference in reaction time among symmetrical and asymmetrical simple shapes was larger than for symmetrical and asymmetrical complex shapes (Figure 4). Unexpected finding is that reaction time for asymmetrical complex shapes is shorter than for asymmetrical simple shapes.

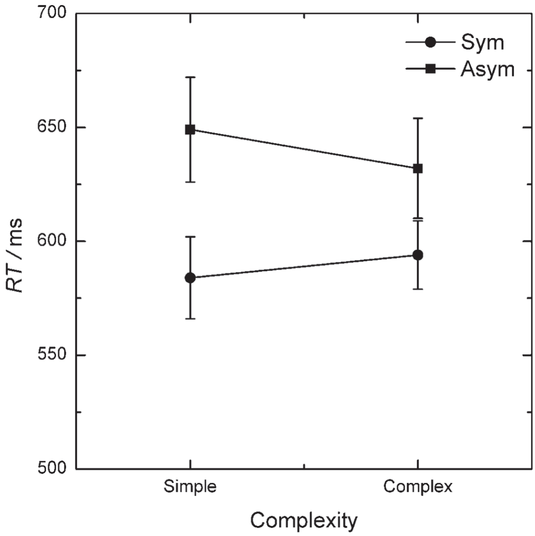

Figure 4. Mean reaction times of simultaneous matching for symmetry and complexity

Another analysis was conducted on pairs of different shapes exclusively. In this analysis, only symmetry was significant ($F(1, 15)=22{,}36$, $p<.01$), symmetrical shapes having shorter reaction times than asymmetrical. Interaction of symmetry and complexity was no longer significant.

Performance analysis showed significant effects of identity ($F(1, 15)=15{,}54$, $p=.001$) and interaction of symmetry and complexity ($F(1, 15)=5{,}44$, $p=.034$). There were less correct responses when shapes in pair were different. Also, responses for symmetrical complex objects contained fewer errors than for symmetrical simple shapes, while there was no difference between asymmetrical simple and complex shapes. Same interaction remained when only different pairs were analyzed ($F(1, 15)=5{,}79$, $p=.029$).

As in Experiment 1, results from this experiment were only partly expected. Significance of factor identity can be explained by self-terminating visual search, and it is comparable to the effect of target presence from Experiment 1. We could assume that subjects, once they find disrupted shape, end search and give a response because they are aware that there is only one disruption on shapes. However, if there is no disrupted shape in a pair, they have to search both shapes entirely, which takes more time.

In this experiment, dominance of symmetry is clearly demonstrated. This finding is somewhat coherent with Luccio's theory, suggesting that primary processing takes part in simultaneous comparison task, disruptions being more noticeable on more regular shapes (Luccio, 1998). However, from this perspective significant effect of complexity was also expected, but it was not registered. Dominance of symmetry, however, is not expected from perceptual economy point of view, because it suggests that this task is easy, which is highly unlikely. This result is also different from one that Marković and Gvozdenović (2001) obtained in their experiment, with procedure similar to ours.

Even more unusual finding is the interaction of symmetry and complexity, registered in both, reaction times and performance analysis.

EXPERIMENT 3

Experiment 3 was very similar to Experiment 2, but instead of two whole shapes, two disrupted shapes appeared. Subject's task was again to compare two shapes concerning disruption, but there was one important difference that could produce important differences between these two experiments. While in Experiment 2 finding disruption on one shape ends the search for disruptions, in Experiment 3 both shapes must always be searched. Expectations for this experiment's results are the same as for Experiment 2. However, we supposed that there is probably some difference in difficulty between Experiments 2 and 3, and both experiments were conducted in order to examine whether there would be some difference in results that could be explained by tasks difficulty.

Method

Participants: Fifteen subjects were engaged in the experiment, all of them psychology students at University of Belgrade. Subjects tested in Experiment 2 were not included in Experiment 3. Each participant had normal or corrected to normal vision and all of them were naive to the study.

Stimuli: Same four shapes as in Experiment 1 were used. One of the shapes in a pair could have been disrupted, or both could be disrupted. If only one shape was disrupted, the position of disrupted shape on the screen was balanced. If both shapes were disrupted, disruption was on the same parts of both shapes.

Procedure: Experiments were created in SuperLab 4.0 stimulus presentation programme, equipped with Cedrus RB–300 Response Box device. Subjects were tested individually, in the presence of an experimenter.

Experiments were preceded by 8 practice trials, and it consisted of 320 trials. Order of the trials was randomized. One of the shapes in a pair could have been disrupted, or both of them. Each trial consisted of fixation dot (1000 ms) after which pair of stimuli appeared. Subjects were supposed to respond whether two contours were same or different concerning disruption. Subjects responded by pressing one of two buttons on the response box.

Design: Reaction time and number of errors were measured. Reaction time was defined as an interval between appearance of pair of stimuli and subject's response.

Data were analyzed using repeated measures analysis of variance with the three factors. Factors were identity (same and different), symmetry (symmetrical and asymmetrical) and complexity (simple and complex).

Results and discussion

Reaction time analysis of variance generated results very similar to those from Experiment 2. Factor identity was significant ($F(1, 14)=19{,}45$, $p=.001$), but this time reaction time was shorter for the same, then for the different pairs.

Symmetry was also significant ($F(1, 14)=36,18$, $p<.01$), as well as interaction of symmetry and complexity ($F(1, 14)=5,30$, $p=.037$). Symmetrical shapes were searched faster, and, same as in Experiment 2, difference between symmetrical and asymmetrical shapes was larger when they were simple, than when they were complex (Figure 5).

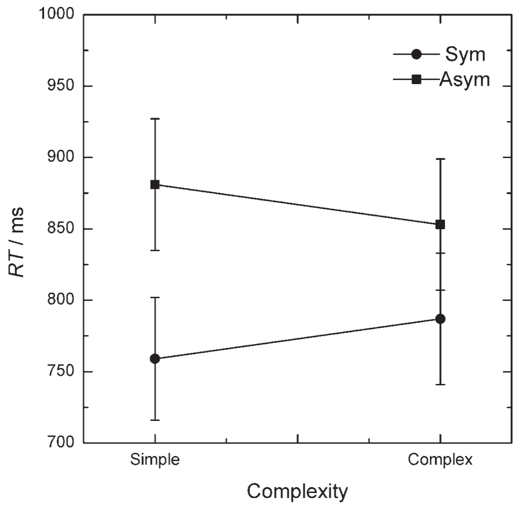

Figure 5. Mean reaction of simultaneous matching times symmetry and complexity.

Results from the analysis of only different pairs were the same as those gained from analysis of all pairs. Symmetry was again significant ($F(1, 14)=47,71$, $p<.01$), as well as interaction of symmetry and complexity ($F(1, 14)=12,19$, $p=.004$), and the pattern of results was same as in previous analysis.

Performance analysis showed only significant effect of factor identity ($F(1, 14)=4,68$, $p=.048$), less mistakes being made on pairs of same shapes. When only different shapes were analyzed, none of the factors and interaction reached significance.

Results from this experiment are very similar to those obtained in Experiment 2, but they also have two important differences. While in Experiment 2 pairs of different shapes were searched faster, here pairs of same shapes (both containing disruptions) had shorter reaction time (same stands for number of errors). We can assume that this result is a consequence of disruptions being at the same places on both shapes, when they were both disrupted. Subjects probably noticed disruption on one shape, and searched for it on the same part of other shape. If they found disruption on second shape, they would terminate search and respond, while if they did not find disruption on particular part of second shape (where on the first shape was disruption) they would probably search entire second shape.

The other difference between Experiments 2 and 3 is that interaction of symmetry and complexity remained when only different pairs were analyzed. As it was stated in the previous experiment, this interaction is not expected and we are not able to offer a good explanation for it. However, a more important finding from this experiment has once more confirmed the dominant role of symmetry in this type of experiments.

EXPERIMENT 4

Experiment 4 was similar to Experiments 2 and 3, but two shapes that were supposed to be matched were exposed one after the other, and between them a mask appeared. Kayaert and Wagemans conducted a similar experiment (only instead of matching shapes concerning disruption they used simple shape matching) and their results showed an additive effect of symmetry and simplicity on reaction times (Kayaert & Wagemans, 2009). However, perceptual economy theory would expect that complexity has a more important effect, since this task should qualify as difficult (Koffka, 1935). Again, Luccio's theory would suggest significant effects of symmetry and complexity (Luccio, 1998).

Method

Participants: Subjects were fifteen psychology students at University of Belgrade. Each participant had normal or corrected to normal vision and all of them were naive to the study.

Stimuli: Same four shapes as in Experiment 1 were used.

Procedure: Experiments were created in SuperLab 4.0 stimulus presentation programme, equipped with Cedrus RB–300 Response Box device. Subjects were tested individually, in the presence of an experimenter.

Experiment was preceded by 8 practice trials. Experiment consisted of 320 trials that appeared in randomized order. Each trial consisted of fixation dot (1000 ms) after which first shape from the pair of stimuli appeared (200 ms), followed by mask (200 ms), and then fixation dot (1000 ms), second shape (200 ms) and another mask (200 ms). Both shapes in one trial were the same. One of the shapes could have been disrupted, or both of them could have been whole. As in previous two experiments, subjects were supposed to respond whether two contours were the same or different concerning disruption. Subjects responded by pressing one of two buttons on the response box.

Design: Reaction time, defined as an interval between disappearance of the second mask and subject's response, as well as number of errors, were measured.

Data was analyzed using analysis of variance for repeated measures with three factors. Factors were identity (same and different), symmetry (symmetrical and asymmetrical) and complexity (simple and complex).

Results and discussion

Analysis of variance of reaction times showed that only factor symmetry had significant effect ($F(1,14) = 5.631$, $p = .033$) (Figure 6). Reaction times were shorter for symmetrical shapes. Other factors and interactions did not have significant effects.

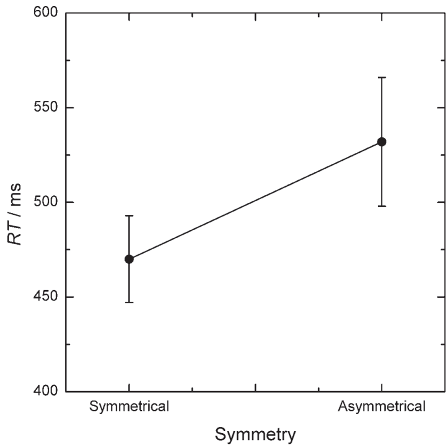

Figure 6. Mean reaction times of delayed matching for symmetrical and asymmetrical shapes.

Analysis of only different shapes confirmed significant effect of symmetry (F(1,14)=5,133, p=.040). Effects of complexity and interaction were not significant.

Performance analysis did not reveal any significant effect.

These results are partly consistent with the results from previous three experiments, showing that symmetry has an important role in the visual search and matching experiments. However, these results do not fit perceptual economy expectations (Koffka, 1935). They are also different from results from Keyeart's and Wagemans's experiment (Kayaert & Wagemans, 2009), because complexity did not reach significance. Since experimental procedure is same in both of the experiments, difference could come from specificity of our task, more precisely, from disruption search. Luccio's theory suggests that disruption should be easier perceived on better forms, which consider both, symmetrical and complex shapes. However, our results do not confirm this hypothesis.

GENERAL DISCUSSION

The present research was conducted in order to continue the investigation of the role of symmetry and simplicity in visual perception tasks. This question was examined in several previous studies, some of the results going in favour of perceptual economy theory (Bear, 1973; Marković & Gvozdenović, 2001; Marković, 2002) and some of them showing an additive effect (Kayaert & Wagemans, 2009; Marković, 1999; Marković & Racković, 2007). Since symmetry was dominant in all our experiments, in order to incorporate this finding in perceptual economy theory, our experiments should belong to the group of easy tasks (Koffka, 1935). However, as it was noted earlier, our tasks were supposed to fall into the difficult tasks group, and comparison with some earlier studies (Kayaert & Wagemans, 2009; Marković & Gvozdenović, 2001) supports that assumption.

Tasks in our experiments, although similar to each other, differ in difficulty, and different ranges of reaction times and number of errors confirm that. It can be supposed that longer reaction times and more errors are characteristic of more difficult tasks. We could conclude from this that Experiment 1 can be thought of as the most difficult of four, while Experiment 4 is the easiest. Experiments 2 and 3 are somewhere in between, with Experiment 3 probably being a bit more difficult.

Possibility that delayed matching is easier than simultaneous matching is introduced in one earlier study (Larsen, McIlhagga & Bundesen, 1999). These authors obtained significant effect of complexity in simultaneous, but not in delayed matching, and, observing these results from perceptual economy point paradigm, they supposed that in the delayed matching paradigm subject compare only subparts of shapes, which makes a task easier. In accordance with this, delayed matching task in our research (Experiment 4) is the one with the shortest reaction times and least errors, but also the one in which only symmetry was significant. Therefore, we cannot dismiss the possibility that this task was actually easy for the participants, although we did not expect that. If this was true, our findings from Experiment 4 would be coherent with perceptual economy assumptions. However, this conclusion cannot be applicable to delayed matching in general, as in Kayert and Wageman's experiment (2009) additive effect of symmetry and complexity was registered.

Experiments 1–3 have more complex pattern of results than Experiment 4. Significant effects of both of the two features were registered only in Experiment 1. As it was stated earlier, while additive effect is not expected from traditional perceptive economy position, possibility that it is characteristic of tasks that are neither easy nor hard is introduced (Marković, 2007). Therefore, the most difficult task in our research would, according to this assumption, pertain between easy and difficult. Regression analysis results show that effects of symmetry and complexity are stronger for larger sets, and since expected set size effect was obtained, we could conclude that these features become more important as task gets more difficult. Another important finding that supports perceptual economy theory is that complexity has significant effect only when target present and absent sets are taken in account, further analysis showing that reaction times are shorter for simple shapes only in target absent sets. Since expected target presence effect was also obtained, target absent sets being searched slower than target present, significant complexity effect is obtained only in more difficult part of the task, as expected from perceptual economy point of view. If we take into account only the main effects, Experiments 2 and 3 show only significant effects of symmetry, not complexity, suggesting that they are easy, which is coherent with reaction times and performance analysis. Simultaneous matching appeared to be a difficult task in some previous studies (Larsen, McIlhagga

& Bundesen, 1999; Marković & Gvozdenović, 2001), but the fact that in our research these tasks appear to be easy could perhaps be due to specificity of our stimuli and experimental design. In presented research, shapes in pair were always the same, and subjects' task was not to compare them in general but only concerning the disruption. If we can treat reaction times and number of errors as task difficulty measures, our results would be quite coherent with perceptual economy hypothesis, although not generating results as we expected. However, interactions of complexity and symmetry observed in Experiments 1–3 are not likely to be explained from this point of view. This kind of interaction has not been registered in previous studies, as simplicity and symmetry always had a facilitating effect, if any. In Experiment 1 the interaction was registered only on positive sets (while complexity stopped being significant), and difference between symmetrical and asymmetrical shapes was larger when they were complex. In Experiments 2 and 3, it was the opposite – difference between symmetrical and asymmetrical shapes was larger for simple shapes. While in all experiments symmetry effect went in the expected direction, symmetrical shapes being searched faster than asymmetrical, complexity showed some unexpected patterns. In Experiment 1, symmetrical complex shapes were searched faster than simple, while similar pattern was registered in Experiments 2 and 3, but for asymmetrical shapes. These results suggest that relations between symmetry and complexity could be complex, and this notion will be further addressed.

As it can be seen, results from our experiments, interactions excluded, can be incorporated in perceptual economy theoretical framework. We also questioned Luccio's two step theory, suggesting that in perception tasks that activate primary processing (i.e. perception without categorization) shape disruptions should be easier perceived on good form shapes (Luccio, 1998). Since both symmetry and complexity affect goodness of form, we should expect both, symmetry and complexity effects. Symmetrical simple shapes would therefore be truly good forms, so shape disruption should be perceived more easily on them. Our results did not confirm this hypothesis, although interactions between two features, as stated earlier, can open questions of relations of symmetry and complexity in defining the good form. Therefore, as we need to keep open question of goodness of form, we cannot disclaim Luccio's theory.

Results from our study can be interpreted as going in favour of perceptual economy theory, but they also open new questions concerning symmetry and complexity effects in perception. As it was mentioned earlier, relationship between symmetry and complexity is not completely clear, and we can't be certain that they are completely independent. Attneave was the first in whose research these two features appeared to be mutually dependant (1957). Another important issue regarding these two features and their relationships is the way they are defined. Most often, symmetry is described as number of axis of symmetry. However, holographic approach treats symmetry as continuum, suggesting a formula for degree of symmetry (van der Helm & Leeuwenberg, 1996). From this point of view, quantification of stimuli symmetry should be included in this type of research. On the other hand, defining complexity is even more difficult, as there are very different views, e.g. complexity as a number of elements, or as a number of axis of symmetry (Donderi, 2006). This ambiguity asks for caution, as incoherent results could appear due to it, and some of mentioned definitions make symmetry and complexity mutually dependant. This happens too in informational approach point of view, which defines good form in terms of information load. Leeuwenberg's coding theory defines structural information load in terms of numbers of elements (primitives) and operations (iterations and symmetry) (Leeuwenberg & van der Helm, 1991). As smaller informational load implies greater simplicity, there is an obvious mutual dependence between complexity and symmetry in this approach. Having this in mind, we should introduce the thought that results obtained in our research can be the consequence of type of stimuli and the way we defined complexity, and this possibility should be further investigated. Another important issue is that, although we chose to interpret our results in terms of perceptual economy, some studies claim that symmetry is one of the stimulus features that are easily, even preattentively, effortlessly perceived (Baylis & Driver, 1995; Julesz, 1981; Olivers & van der Helm, 1998; Pothos & Ward, 2000). This perspective would reject the expectation of complexity dominance in difficult tasks, since symmetry would be easily enough perceived even in low energy states. Therefore, domination of symmetry in our experiments could be an independent from task difficulty and would indicate some more basic phenomenon.

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