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Mental rotation depends on the number of objects rather than on the number of image fragments

Arno Koning *, Rob van Lier

NICI—University of Nijmegen, Room B.01.25, P.O. Box 9104, 6500 HE Nijmegen, The Netherlands

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Abstract

It is often intuitively assumed that disconnected image fragments result in a representation of separate objects. When objects are partly occluded, disconnected image fragments can still result in a representation of a single object, based on visual completion. In a simultaneous matching task, displays showing one object, partly occluded objects, or two objects were compared with each other. When only a translation was required to match pairs of displays, one-object displays were matched faster than both occluded-object and two-object displays, which did not differ significantly from each other. When mental rotation and translation were required, the one-object displays were again matched the fastest. In addition, an advantage for occluded-object displays compared with two-object displays was found. We conclude that when the generation of a mental representation is likely, object-based connectedness determines object matching. Mental rotation then seems to depend on the number of objects rather than on the number of image fragments.

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* Corresponding author. Tel.: +31-24-361-5590.
E-mail address: a.koning@nici.kun.nl (A. Koning).
URL: http://www.nici.kun.nl/~arnok.

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1. Introduction

Image fragments are usually grouped into objects by means of various grouping factors. Here we will focus on connectedness between image fragments, where connections between image fragments enhances grouping. Palmer and Rock (1994) emphasized the importance of connectedness in the grouping process, with a special role for so-called uniform connectedness that deals with connections between image fragments that show uniform visual properties. In general, connectedness between image fragments appears to be a crucial factor in specific tasks (Saiki & Hummel, 1998; Van Lier & Wagemans, 1998). Saiki and Hummel looked at various types of connectedness and part-relation integrations, using a rapid serial visual presentation paradigm. They found that connected target shapes were easier to distinguish among a set of distractors, compared to disconnected target shapes. Similarly Van Lier and Wagemans (1998) found that it is easier to mentally rotate a configuration of connected image fragments than it is to rotate a configuration of disconnected fragments, indicating a higher representational unity of the first configuration.

Connectedness refers not only to connections between image fragments, but connectedness can also be described at a more representational level. For example, two three-dimensional (3-D) objects can be connected to each other or disconnected from each other in 3-D space. A distinction can then be made between image-based (IB) and object-based (OB) connectedness, where IB connectedness refers to connections between objects in the 2-D image, and OB connectedness refers to connections between objects in 3-D space. Recent research has shown that IB connections between objects are less important than OB connections between objects (Koning & Van Lier, 2003; Saiki & Hummel, 1998). Koning and Van Lier examined three different types of displays in one of their experiments, in which IB and OB connectedness between pairs of 3-D objects (a small and a large object) were varied. OB (dis)connectedness was realized by adding a shadow of the small object onto the larger object (see e.g. Kersten, Mamassian, & Knill, 1997; Madison, Thompson, Kersten, Shirley, & Smits, 2001; Meng & Sedgwick, 2001). The first type of display showed the small object resting on the large object (i.e., IB/OB connected objects). The second type of display showed the small object positioned above the large object (i.e., IB/OB disconnected objects). The third type of display showed the small object seemingly floating above the large object as suggested by appropriate shadowing (i.e., IB connected/OB disconnected objects). Koning and Van Lier found that when objects were OB connected, matching was faster as compared with objects that were OB disconnected, regardless of the IB connections between the objects. In a second experiment, this result was also found, but now binocular depth cues were used to differentiate OB connectedness from OB disconnectedness, as well as different objects. Note that, in addition to the conditions tested by Koning and Van Lier, a fourth combination is possible as well. Such an image would show an OB connected object, but with IB disconnectedness between the image fragments. In the present study, we examine such a combination.

It is often intuitively assumed that disconnected image fragments lead to a representation of two separate (OB disconnected) objects. However, it is not uncommon for disconnected image fragments to result in a single-object representation. For example, most of the time, the objects we see are partly occluded by other objects. Somehow, the visual system completes the missing parts, causing spatially separated image fragments to be perceived as belonging to a single object. In Fig. 1a, a single 3-D object (a cone) is shown. In Fig. 1b, the same cone is partly occluded by a black rectangle. Still, the image fragments in Fig. 1b are strongly grouped into a single perceptual unit. That is, the object representation, evoked by the conical image fragments in Fig. 1b, is likely to be the same as that of the cone shown in Fig. 1a. In Fig. 1c, two slightly different conical image fragments are shown. This display is readily perceived as consisting of two OB disconnected cone-like objects. Note, however, that the image fragments in Fig. 1c can also be grouped (for example, based on good continuation of the edges), but this grouping is not as compelling as that of the image fragments in Fig. 1b.

To examine whether there are differences in the grouping of image fragments between these displays, the variation with respect to the disconnectedness between the image fragments needs to be controlled for. Note that, in both Fig. 1b and c the cone-like image fragments are disconnected. Nevertheless, in Fig. 1b the image fragments are indirectly connected to each other due to their connection with the black surface. To control for this, one option is to connect the cone-like objects in Fig. 1c, on the image level, with a black surface as well. A second option is to replace the physical black occluder in Fig. 1b by an illusory occluder. This has been done in the display shown in Fig. 1d. There, four three-quarter disks are used to induce an illusory rectangle, which in turn acts as an illusory occluder. The conical image fragments in Fig. 1d are identical to those presented in Fig. 1b, and the representation is also likely to be that of a single cone as in Fig. 1b. In fact, both options are taken into account in the experiment, to be described further on.

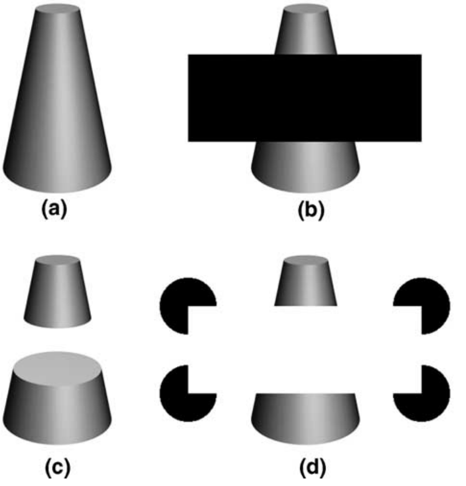

Fig. 1. (a) A 3-D cone, (b) a 3-D cone, partly occluded by a black rectangle, (c) two object-based disconnected cone-like objects, (d) two conical image fragments, juxtaposed with an illusory rectangle.

In the present study, the question is whether differences can be found between displays that show different object representations (i.e., perceived OB connectedness), while controlling for variations in disconnectedness between the image fragments. To investigate this, a matching task similar to Koning and Van Lier (2003) was used. Participants had to match two simultaneously presented displays, for which either a translation of the displays or a translation and a mental rotation of the displays was required. From previous research, it is known that differential effects can be found when mental rotation of objects is involved (e.g., Van Lier & Wagemans, 1998). In the experiment, displays comparable to the ones in Fig. 1 were used. The expectations can be summarized as follows. Pairs of displays showing one object (as in Fig. 1a) were expected to be matched faster compared to pairs of displays that showed two objects (as in Fig. 1c). Next, pairs of displays showing one object were expected to be matched faster than pairs of displays that showed occluded objects, as visual completion might increase reaction times of the latter type of displays. In addition, pairs of displays showing occluded objects (as in Fig. 1b and d) were also expected to be matched faster than pairs of displays showing two objects, based on differences in representational unity (i.e., perceived OB connectedness of the image fragments). Finally, no differences were expected to be found between the variations in disconnectedness between the image fragments (i.e., the difference in disconnectedness between Fig. 1b and d); as Koning and Van Lier (2003) found no effects between IB connectedness and IB disconnectedness of pairs of 3-D objects, it seems plausible that the variations in disconnectedness used here would also have no effect.

2. Experiment

2.1. Participants

Ten participants (aged 18–27) performed the experiment, and were given course credit or were paid for their time. All participants had normal or corrected-to-normal vision.

2.2. Stimuli

Stimulus construction started with four inducers (i.e., three-quarter disks). These were placed such that an illusory rectangle was created. At the center of the illusory rectangle, a 3-D object was placed. The construction of the 3-D objects was carried out using 3-D modeling software (3-DStudioMax, R2, Autodesk, Inc.).

Consider the displays shown in Fig. 2. The 3-D objects in all displays were colored blue to make them clearly distinctive from the three-quarter disks, or the black rectangular surfaces. First, the variable Object-Type had three conditions: one, occluded, and two. Second, the variable Surface-Type had two conditions: illusory and physical. Note that, Surface-Type deals with variations in disconnectedness between image fragments. Third, in order to enlarge the set of objects and to make nonmatch trials possible, concave and convex versions of the standard objects were

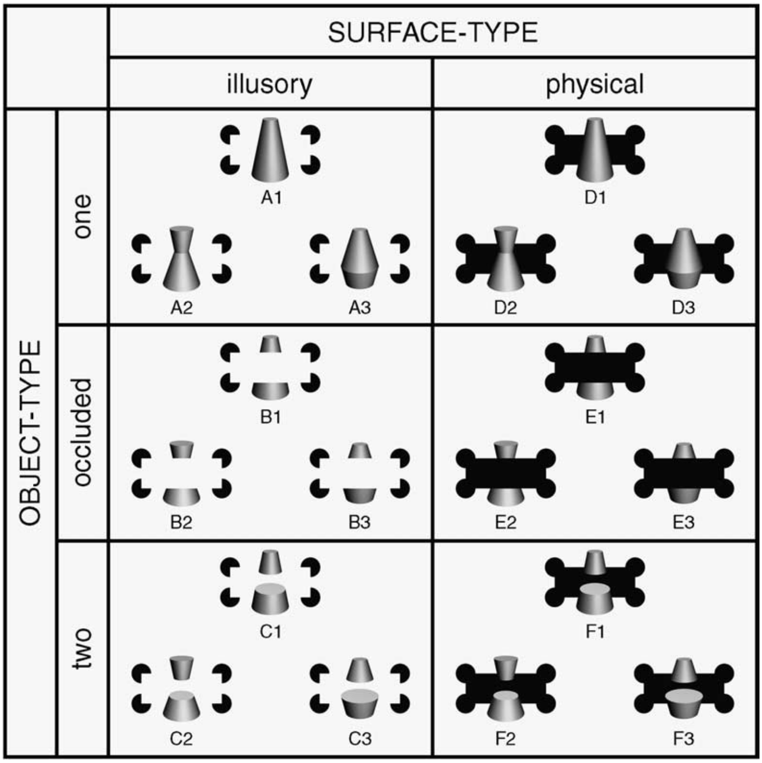

Fig. 2. Examples of the six different variations used in the experiment. All conical image fragments in the displays were colored blue to make them clearly distinctive from the three-quarter disks, and the black rectangular shapes. Each variation is described based on the Object-Type (one, occluded, and two) and Surface-Type (illusory and physical). Additionally, three different Object-Shapes were used: standard shapes (designated 1 in each cell of Fig. 2), concave shapes (designated 2 in each cell of Fig. 2), and convex shapes (designated 3 in each cell of Fig. 2).

constructed by rotating either the top or the bottom part of the objects around 180° in 3-D space. That is, the variable Object-Shape had three conditions: standard, concave, and convex. This resulted in 18 different displays (see displays A1–F3 in Fig. 2).

In display A1, a single object is shown with a standard shape and an illusory background. Displays A2 and A3 show the concave and convex versions of the object, also with an illusory background. The displays A1–A3 in Fig. 2 were used to create five additional variations (i.e., the displays B1 through F3 in Fig. 2). The construction of each subsequent variation will be described below. The first variation, display B1 in Fig. 2, was created by deleting the middle part of the cone in display A1, collinear with the horizontal edges of the three-quarter disks. This resulted in two disconnected image fragments, which were aligned to the top and bottom parts of the illusory rectangle. The concave and convex versions in the displays B2 and B3 were created analogously to the displays A2 and A3, respectively. For the second variation, display C1 in Fig. 2, the middle part of the 3-D object was removed. This resulted in two OB disconnected cone-like objects. The displays C2 and C3 show the concave and convex versions. For the remaining variations, displays D1 through F3, the rectangle defined by the three-quarter disks was colored black such that it appeared either as a physical background (displays D1–D3 and F1–F3) or as a physical occluder (displays E1–E3). Note that the disconnectedness between the image fragments in displays B1–B3 and the image fragments in displays C1–C3 always involved a white intermediate space. Similarly, the image fragments in the displays E1–E3 and F1–F3 were all indirectly connected to each other through the black rectangular shape. Finally, and in addition to all of these variations, three more objects were created (see Fig. 3 for the standard versions of the objects). For each of these objects, the manipulations described above were carried out, thereby creating the variable Object-Set, which comprised four conditions.

A trial consisted of two simultaneously presented displays. The orientation of the displays was varied: the displays could have either the same orientation (i.e., both right side up or both upside down), or the displays could have a different orientation with respect to each other (i.e., left display right side up and right display upside down, and vice versa). Half of the trials were match trials, the other half were nonmatch trials. Match trials consisted of two identical displays, irrespective of their orientation. Nonmatch trials consisted of two displays from the same Object-Set, and with the same Object-Type and Surface-Type, but with a different Object-Shape. A total of 576 trials were used in the experiment: four Object-Sets, three Object-Types (one, occluded, and two), two Surface-Types (illusory and physical), three Object-Shapes (standard, concave, and convex), two same orientations of displays in a trial, two different orientations of displays in a trial, and match/nonmatch trials. A random sample of 35 trials was taken from the corpus of 576 trials to create a practice task.

2.3. Procedure

The experiment was conducted at the University of Nijmegen in a dimly lit room. The trials were presented on a 19″ monitor at a resolution of 1024×768 pixels, controlled by a Windows 98 computer with an Intel Pentium III processor. The participants were seated at one meter from the screen. When two displays were presented on the screen, they covered an area of 21×4 cm^2 (i.e., a visual angle of approximately 12° by 2°). The software used to run the experiment was SuperLab Pro (Cedrus, Inc.). A response box (Cedrus, Inc.) with 1 ms accuracy was used. First, the task

Fig. 3. Examples of the standard versions of the four different objects used in the experiment.

was explained to the participant. After showing examples of a match trial and a non-match trial, a practice task was started.

Each trial started with a fixation cross (500 ms). Next, two displays were presented on the screen simultaneously. The displays remained on the screen until a response was given. It was the participant's task to compare the two displays and decide as quickly as possible whether or not the displays were the same, regardless of the orientation of the displays, by pressing one of two buttons. A label below each button indicated either the 'same' or 'different' response. The participants were instructed to match the blue image fragments. During the practice task (which lasted about 2 min), visual feedback was given on the monitor whether or not the response was correct. In the actual experiment no feedback was given, instead a blank screen appeared (500 ms), after which the next trial was started. After the practice task, the experiment was started which took about 35 min to complete. All 576 trials of the main task were presented randomly to each participant in a single session. In addition, hand dominance and 'same' responses were balanced.

2.4. Results

Analyses were done on the correct match trials (with a 5.3% error rate over all participants for the match trials). There was no speed–accuracy tradeoff. Preliminary analyses revealed no main or interaction effects for the variable Object-Set. Therefore, the data were pooled over this variable. A repeated measures analysis of variance (ANOVA) was performed with a four-factorial design, that is, Object-Type (three levels; one, occluded, and two) $\times$ Surface-Type (two levels; illusory and physical) $\times$ Object-Shape (three levels; standard, concave, convex) $\times$ Rotation (two levels; no rotation required and rotation required), and with reaction times (RTs) as the dependent variable. In Fig. 4, the graph of the mean RT values as a function of the variables Object-Type and Rotation are shown.

Three main effects were significant. First, a main effect was found for Object-Type [$F(2,8) = 18.36$, $p < 0.005$]. The means (M) and standard errors of the mean (SEM) were: one-object condition ($M = 935$ ms, SEM = 51.74), occluded-object condition ($M = 1134$ ms, SEM = 75.29), two-object condition ($M = 1240$ ms, SEM = 92.31). Contrast comparisons showed that the one-object conditions were matched faster than both the occluded-object conditions [$F(1,9) = 35.89$, $p < 0.001$], and the two-object conditions [$F(1,9) = 36.98$, $p < 0.001$]. The occluded-object conditions also differed from the two-object conditions [$F(1,9) = 10.53$, $p < 0.05$]. Second, a main effect was found for the variable Object-Shape [$F(2,8) = 6.24$, $p < 0.05$]. The means and standard errors of the means were: standard ($M = 982$ ms, SEM = 57.14), concave ($M = 1176$ ms, SEM = 88.85), convex ($M = 1151$ ms, SEM = 77.00). Contrast comparisons showed that the standard shapes were matched faster than both the concave shapes [$F(1,9) = 13.90$, $p < 0.01$], and the convex shapes [$F(1,9) = 12.75$, $p < 0.01$]. The concave shapes did not differ significantly from the convex shapes ($p > 0.2$). Third, a main effect for the variable Rotation was found [$F(1,9) = 39.37$, $p < 0.001$]. Trials where mental rotation was not required

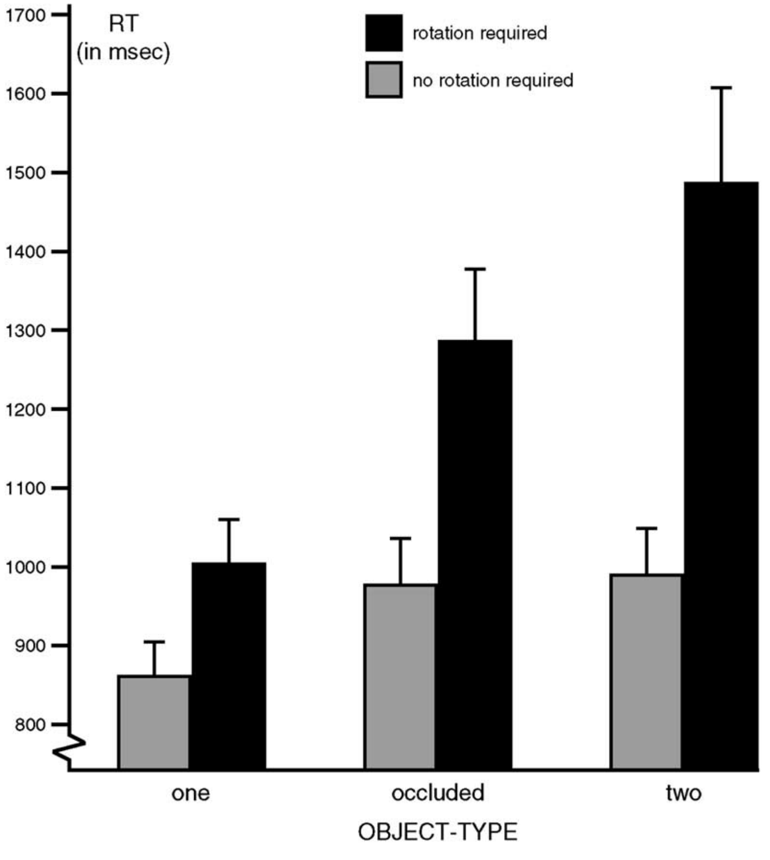

Fig. 4. Bar graph of the mean reaction times (RTs) as a function of Object-Type (one, occluded, and two) and Rotation (no mental rotation required, and mental rotation required). Error bars represent one standard error of the mean.

($M = 905$ ms, SEM = 65.47) were performed faster than trials where mental rotation was required ($M = 1204$ ms, SEM = 99.20). The interaction effect between Object-Type and Rotation was also significant [$F(2,8) = 10.12$, $p < 0.01$] (see Fig. 4). When mental rotation was not required, the one-object condition differed significantly from both the occluded-object condition [$F(1,9) = 25.75$, $p < 0.005$], and the two-object condition [$F(1,9) = 18.52$, $p < 0.005$]. The occluded-object condition did not differ from the two-object condition when mental rotation was not required ($F < 1$). When mental rotation was required, all three conditions differed significantly from each other. The one-object condition differed from both the occluded-object condition [$F(1,9) = 28.04$, $p < 0.01$], and the two-object condition [$F(1,9) = 33.21$, $p < 0.01$]. The occluded-object condition, in turn, differed from the two-object condition [$F(1,9) = 10.78$, $p < 0.01$]. Performance was the fastest in the one-object condition, followed by the occluded-object condition and the two-object condition respectively. Other main and interaction effects were not significant.

3. Discussion

First of all, no main effects or interactions effects were found for the variable Object-Set. Second, the main effect of Surface-Type was not significant, indicating that the illusory and physical surfaces did not result in a difference in matching performance. Thus, the current variations in disconnectedness between image fragments did not influence object matching. This is in line with previous research regarding IB (dis)connectedness between pairs of 3-D objects (Koning & Van Lier, 2003; Saiki & Hummel, 1998). Third, the main effect of the variable Object-Shape was significant. The standard shapes were matched faster than both the concave and the convex shapes, which did not differ significantly from each other. The advantage for the standard shapes as compared with the concave and convex shapes is not surprising as the collinearity of the edges of the objects with standard shapes resulted in lower overall complexity of these objects, compared with the objects that showed concave and convex shapes. Finally, main effects were found for the variables Object-Type and Rotation. Concerning the latter, this main effect is in line with previous research on mental rotation (Shepard & Metzler, 1971). As the interaction effect between Object-Type and Rotation was also significant, the results will be discussed in terms of this interaction effect.

When mental rotation was not required, the one-object displays were matched faster than both the occluded-object displays and the two-object displays, whose means did not differ significantly from each other. It is possible that in this case matching (i.e., a translation of the displays) could have been performed more on an IB level, in contrast with trials where mental rotation was required. Consequently, the same number of image fragments resulted in equal RTs for the occluded-object displays compared with the two-object displays. Alternatively, it is possible that comparisons were performed on an OB level. In this case, the additional matching time of the occluded-object displays, as compared to the one-object displays, might stem from the time needed for completion. However, estimates on the completion time for the present stimuli are rather hazardous as completion is known to depend strongly on specific figural properties (such as complexity; e.g., Bruno, Bertamini, & Domini, 1997; Gerbino & Salmaso, 1987; Van Lier, Van der Helm, & Leeuwenberg, 1995). The additional time needed for the two-object displays, as compared with the one-object displays could be the result of a difference in perceived OB connectedness (Koning & Van Lier, 2003). In comparison, Van Lier and Wagemans (1998) also did not find a significant difference between connected and disconnected 2-D multi-part configurations when only a translation of the displays was required. Note that, the 3-D objects that were used by Koning and Van Lier (2003) did lead to an advantage for OB connected objects compared with OB disconnected objects across different mental operations, possibly due to the more compelling 3-D character of the objects in their study.

When mental rotation was required, the one-object displays were again matched faster than the occluded-object displays and the two-object displays. But now, an advantage was also found for the occluded-object displays compared to the two-object displays. Following Van Lier and Wagemans (1998), it can be said that the grouping of the disconnected image fragments in the occluded-object displays was

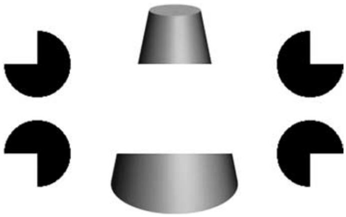

Fig. 5. Example of a stimulus used in the first control experiment. In the control experiment, the displays presented in the left column of Fig. 2 were used, as well as nearly identical versions that only differed with respect to the orientation of the three-quarter disks.

found to be stronger than the grouping of the disconnected image fragments in the two-object displays. This indicates that, in this experiment, the number of interpreted objects (i.e., the perception of OB connectedness) was more of a determining factor than the number of presented image fragments. To obtain further evidence that it is indeed the number of objects, rather than the number of image fragments that influences matching performance, the occluded-object condition should also be compared with a situation in which the *same* image fragments are visible, but the occluding rectangle is not present. That is, due to the occluding rectangle, the perceptual grouping of the image fragments in the occluded-object conditions is very strong and a single-object interpretation is favored. This can be solved by rotating the three-quarter disks 180° (see Fig. 5). Thus, a control experiment [1] was performed for which the stimuli depicted in the left column of Fig. 2 were used, as well as nearly identical stimuli that only differed with respect to the orientation of the three-quarter disks. That is, we have created a new condition in which the three-quarter disks were rotated 180°. Notice that, due to the rotation, the three-quarter disks no longer induce an illusory occluder (see Fig. 5). Nevertheless, to maintain a straightforward comparison with the conditions of Object-Type of the main experiment, the term occluded-object condition is used in the control experiment.

In the control experiment, the gaps of the disks could be pointing to either the inside of the stimulus or the outside of the stimulus. This resulted in an additional variable Disk-Orientation, which had two conditions: gaps inside (as depicted in the stimuli in Fig. 2), and gaps outside (as depicted in the stimulus in Fig. 5). The same matching task was performed ($n = 14$). A repeated measures ANOVA, with Object-Type (three levels: one, occluded, and two), Disk-Orientation (two levels: gaps inside and gaps outside), and Rotation (two levels: rotation required and no rotation required) as the independent variables and RT as the dependent variable, showed three main effects (i.e., Object-Type [$F(2,12) = 19.71$, $p < 0.001$], Disk-Orientation [$F(1,13) = 5,11$, $p < 0.05$], and Rotation [$F(1,13) = 42.99$, $p < 0.001$]). Additionally, an interaction effect between Object-Type and Rotation was found [$F(2,12) = 4,88$, $p < 0.05$].

[1] The authors would like to thank Marco Bertamini for his suggestion to perform this control experiment, in which the three-quarter disks were rotated 180°.

With respect to the control experiment, the results of the main effect of Object-Type and the main effect of Rotation, as well as the interaction effect between these two variables were identical to those of the main experiment. The main effect of Disk-Orientation indicated that matching was significantly faster when gaps of the disks were pointing inside (resulting in the perception of an illusory rectangle) compared to when the gaps of the disks were pointing outside (in which case the illusory rectangle was not visible). Neither the two-way interaction Object-Type × Disk-Orientation, nor the three-way interaction Object-Type × Rotation × Disk-Orientation was significant. Thus, there was no significant difference in matching performance between the conditions of Object-Type when the illusory rectangle was present compared to when the illusory rectangle was absent. Consequently, weakening the perceptual grouping of the image fragments by rotating the three-quarter disks does not significantly alter matching performance. However, when the illusory rectangle was not visible, contrast comparisons showed one exception to the general findings. That is, when the illusory rectangle was not visible and mental rotation was required, the occluded-object displays were not matched differently than the two-object displays (both were matched slower as compared with the one-object displays). This suggests that, when there is no illusory rectangle, there is a tendency for the image fragments to be treated perceptually as two objects rather than as one object. Nevertheless, contrast comparisons also showed that, whether or not the illusory rectangle was present, the two occluded-object displays were not matched differently from each other. Taken together, it is suggested that the stimuli used here show a gradual change from a perception of, most likely, one object (i.e., the occluded-object displays in the main experiment), to more likely two objects (i.e., the occluded-object displays in the control experiment without the illusory rectangle), to two objects (i.e., the two-object displays in both the main and the control experiment). Based on this suggestion it can thus also be said that mental rotation depends on the number of objects (i.e., the perception of OB connectedness) rather than on the number of image fragments.

The results on the conditions where mental rotation was required can be considered as a two-object cost. A two-object cost is generally found in the domain of visual selective attention (see e.g., Duncan, 1984; Gibson, 1994; Hulleman & Boselie, 1997; Mapelli, Cherubini, & Umilta, 2002; Zemel, Behrmann, Mozer, & Bavelier, 2002). A general finding in such studies is that when two object properties have to be searched for and these belong to the same perceived object, such properties are identified faster than when such properties appear to belong to two separate objects. [2] Evidence for an advantage of occluded-object displays compared with two-object displays can also be found in the literature on visual selective attention (Behrmann, Zemel, & Mozer, 1998; Moore, Yantis, & Vaughan, 1998; Pratt & Sekuler, 2001). When object properties appear to belong to the same perceived object, due to visual completion, these properties are identified faster than when they appear

[2] However, note that a two-object cost is not always found using other stimuli and tasks (see e.g., Baylis, 1994; Bertamini, Friedenberg, & Argyle, 2002).

to belong to two separate objects (even when the number of image discontinuities between displays that show occluded objects and displays that show two objects are maintained). The current results are in line with the above studies on visual selective attention, although they are not directly comparable. Based on the findings from such studies, as well as on the present results, it can be said that the representations of objects are important, not necessarily the IB connections in an image. In addition, the present study provides evidence that an advantage of occluded-object displays compared with two-object displays does not depend only on searching for specific object properties, but that it is also apparent when such objects have to be mentally rotated in order for the displays to be matched.

The experiment was set up to investigate differences between displays that show disconnectedness between the image fragments, but with different object representations. To examine whether the same results would be found when 2-D objects were used, a second control experiment was performed. The same displays as in the main experiment were used, but now the conical image fragments comprised homogeneous gray surfaces. Consequently, the information that could be retrieved from the shading of the 3-D objects was removed, but the remaining image fragments could still be distinguished from the inducers and the variations in Surface-Type. In this second control experiment, the same matching task as in the main experiment was used ($n = 13$). Now, a repeated measures ANOVA showed basically the same results as those of the main experiment (i.e., a main effect for Object-Type [$F(2, 11) = 8.30$, $p < 0.01$], a main effect for Shape [$F(2, 11) = 6.31$, $p < 0.05$], a main effect for Rotation [$F(1, 12) = 18.73$, $p < 0.001$], as well as an interaction effect between Object-Type and Rotation [$F(2, 11) = 6.48$, $p < 0.05$]). In addition, contrast comparisons revealed differences that were also comparable to those found in the main experiment. Thus, also for 2-D objects it can be said that when pairs of objects are simultaneously presented and have to be rotated, differences in the grouping of image fragments appear. Van Lier and Wagemans (1998) found a higher representational unity for rotating physically connected multi-part 2-D configurations, compared with rotating physically disconnected multi-part 2-D configurations. The current control experiment provides converging evidence to that conclusion using different stimuli.

In conclusion, we found that differences in the grouping of image fragments are only apparent when mental representations of the objects are likely to be called upon, for example, in the case of mental rotation. Variations in disconnectedness between the image fragments are less important. The visual system apparently uses information regarding object representations, irrespective of disconnections between image fragments. That is, when mental rotation is required to match pairs of displays, the number of represented objects in a display is important rather than the number of presented image fragments.

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