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Temporal properties of amodal completion: Influences of knowledge

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ABSTRACT

We studied the influence of knowledge in the interpretation of partly occluded objects. In the past decades, amodal completion has often been studied by using abstract, meaningless outlines of rather stylistic, geometric shapes. It has been recognized that smooth continuation of partly occluded contours behind an occluding surface is a strong completion tendency. In the current study we contrast this structurally driven completion tendency with knowledge driven tendencies. We used a set of partly occluded well-known objects for which structure-based completions and knowledge-based completions resulted in either the same or different interpretations. We adopted the behavioural primed matching paradigm to measure differential priming effects due to these completion tendencies. Our results implied differential temporal properties for structure-based and knowledge-based effects during perception of partly occluded objects. Interestingly, knowledge has an influence as early as 150 ms after the onset of the prime.

1. Introduction

Objects are often partly occluded by other objects. Our brain, however, appears to fill in the occluded parts, resulting in a complete object, a phenomenon that has been referred to as amodal completion (Michotte, Thinès, & Crabbé, 1964). An example of amodal completion is shown in Fig. 1a. This occlusion pattern could be interpreted in different ways. One possible interpretation would be of a black occluder and a single rectangle (a1) formed by continuing the horizontal lines. Another interpretation could include two small rectangles, both partly occluded by the black occluder (a2). Considering all possible interpretations, a1 seems most plausible, as it seems highly unlikely that two separate objects would just happen to line up behind an occluder such that their edges would appear perfectly collinear (see e.g., Michotte et al., 1964). In the same way, the partly occluded horses (see Fig. 1b), adapted from illustrations by Kanizsa (1970), tend to be interpreted as a single elongated horse (b1) even though it conflicts with our knowledge. The pattern appears ambiguous as we know that usually horses are not elongated and are more likely to have a shape as pictured in b2. This simple and elegant example hides a wealth of interesting issues. For example, one may question whether knowledge is always overruled by perceptual tendencies, or whether knowledge takes an effect at a later stage and then competes with the perceptual output. Recently, it has been shown that the perception of partly occluded objects can be modulated by our knowledge of well-known objects (Hazenberg & van Lier, 2016; Vrins, de Wit, & van Lier, 2009). Here we aim to study the differential roles structure (i.e., stimulus properties) and knowledge play during the formation of representations of the partly occluded objects, measured at different moments in time.

Previous research on amodal completion provides various structure-driven explanations based on specific structural properties of the partly occluded shapes. For example, according to Kellman and Shipley (1991), completion depends on relatability; two edges are considered relatable if they can be connected by a smooth, monotonic curve. This idea is consistent with the Gestalt principle of good continuation (see also Wouterlood & Boselie, 1992, for another application of the good continuation principle in amodal completion). In Fig. 1, both interpretations a1 and b1 can be seen as a result of the good continuation principle. Other approaches advocate the role of figural simplicity and take more global figural properties into account such as symmetry (Buffart, Leeuwenberg, & Restle, 1981), arguing that the simplest possible interpretation is perceptually preferred (as derived from the global minimum principle, Hochberg & McAlister, 1953). This idea was later extended by van Lier, van der Helm, and Leeuwenberg (1994) who also indicated that visual processing of the occlusion patterns evoke multiple completions, rather than a single completion, accounting for both local and global figural properties.

In recent years, various studies support the notion that interpretations of partly occluded objects do not merely depend on structure, but can also be influenced by higher-level processing, including visual short-term memory (Lee & Vecera, 2005), temporal context (Plomp & van Leeuwen, 2006), and an explicit learning task (Hazenberg, Jongsma, Koning, & van Lier, 2014). Recently, Carrigan, Palmer, and Kellman (2016) showed that global completions are much less precise

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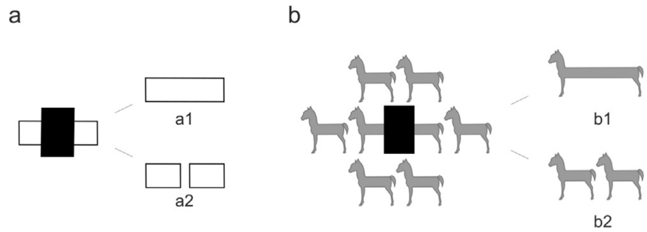

Fig. 1. A partly occluded rectangle with two possible interpretations (a), and a partly occluded horse with its two possible interpretations (*b*). The first interpretations (a1 and b1) are preferred in both cases.

than local completions, and argued that such completions are therefore based on recognition from partial information of the occluded figures. Other studies also probed the sensitivity to higher-level influences by using well-known objects as stimuli. For example, Vrins et al. (2009) found that knowledge of material properties (i.e., the relative hardness) affected amodal completion. Recently, Hazenberg and van Lier (2016) chose two types of occlusion patterns as stimuli for which the completions varied with respect to the compatibility with structure and knowledge. We will discuss this in more detail as the present study extends on their findings.

The stimuli in Hazenberg and van Lier (2016) were designed such that a completion could be structurally plausible, i.e., by a simple continuation of the contours, or it could comply with our knowledge of the specific shapes. These two tendencies could result in the same shape interpretation or in different interpretations. For example, for the partly occluded banana in Fig. 2a, the interpretation based on a continuation of contours converges with knowledge (as a banana is a well-known object). For the partly occluded apples in Fig. 2b however, the continuation interpretation results in an anomalous elongated apple (note that this completion is conceptually rather similar to Kanizsa's partly occluded horse, as in Fig. 1b). We will hereafter use the term convergent occlusion patterns to refer to stimuli for which knowledge and good continuation lead to the same interpretation. We will use the term divergent occlusion patterns to refer to stimuli for which knowledge and good continuation lead to different interpretations. In the study of Hazenberg and van Lier (2016), these kinds of partly occluded objects and completions were presented in a sequential fashion while event-related potentials (ERPs) were measured during the presentation of the completions (i.e., after removing the black occluder). The authors found a late component (P3) in which knowledge had an influence (violations of knowledge caused the largest P3) and an early component (P1) without knowledge influence (violation of continuation caused the largest P1). With that, the ERP results suggest that, at a certain point in the microgenesis of occlusion interpretations, the influence of knowledge is apparent.

In the study of Hazenberg and van Lier (2016), the ERPs were recorded after the occluder was removed. In the present study, we explore what is actually happening during the completion process itself by means of a behavioral paradigm. In particular, we aim to investigate the

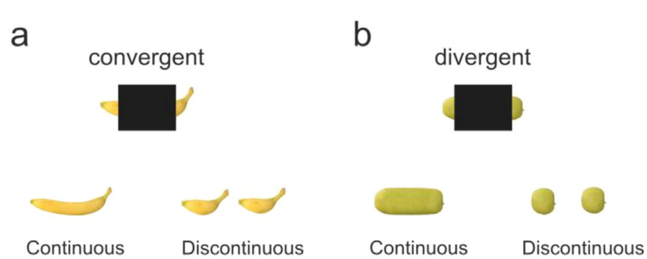

Fig. 2. a) A convergent occlusion pattern, for which good continuation and knowledge result in an identical completion. b) A divergent occlusion pattern, for which good continuation and knowledge diverge, resulting in different completions.

time course of the influence of knowledge by using the primed matching paradigm that was introduced to the field of amodal completion by Sekuler and Palmer (1992). In the primed matching paradigm, primes are briefly presented and then followed by a matching task. The shapes in the matching task might have been completely visible in the primes or they might have been partly occluded. This provides the possibility to check whether a partly occluded shape has the same influence on the matching task as fully visible shapes. If so, this suggests that the partly occluded shape was amodally completed, having representational similarity with the fully visible shape. As Sekuler and Palmer (1992) noted, by comparing differential priming effects with specific prime durations, the paradigm enables us to have 'snapshots in time' with regard to amodal completion (for various applications and conclusions drawn from the paradigm see, for example, Bruno, Bertamini, & Domini, 1997; de Wit & van Lier, 2002; Sekuler, 1994; Sekuler, Palmer, & Flynn, 1994; van Lier, Leeuwenberg, & van der Helm, 1995; Vrins et al., 2009).

Note that the rationale of the primed matching paradigm resides in the perceived similarity between the prime and the shapes presented in the test pair. This similarity may be based on figural properties of the occluded prime that suggests a good continuation-driven completion, but it may also be based on the subjective, knowledge-driven interpretation of the occluded prime. In other words, it is an open issue whether this similarity is the outcome of a purely perceptual completion process or is the result of cognitive inference. The advantage of the primed matching method is that it allows us to implicitly test the representational similarity between the prime and test pairs at different moments in time. In fact, our study focus on determining whether—and if so, when— knowledge influences occur.

2. Experiment 1

The aim of this experiment was to disentangle differential effects of structure and knowledge during the completion process by choosing a short (150 ms) and long (500 ms) prime duration. Based on previous findings in Hazenberg and van Lier (2016), we expected a separation between structure effects and knowledge effects in the respective time windows.

2.1. Methods

2.1.1. Participants

Thirty-five students (aged 18–35 years; 13 males) from the Radboud University were paid 10 Euros or received course credit to participate in the experiment. Participants all gave written informed consent and had no current or past neurological or psychiatric illness. This study was approved by the local ethics committee, in accordance with the declaration of Helsinki.

2.1.2. Stimuli

We adopted stimuli based on ten species of well-known fruits and vegetables, the same as Hazenberg and van Lier (2016), see Fig. 3. The stimuli comprise two sets of images of fruits and vegetables, the convergent set and the divergent set. In the convergent set good continuation and knowledge reveal the same interpretation, while in the divergent set they reveal different interpretations. As shown in Fig. 4, for both the convergent and the divergent set there were three different primes, the occlusion prime and two foreground primes. The Occlusion prime (to be referred to as Oc-prime) always comprised an object of which the middle part was occluded by a black rectangle. In the foreground primes the objects were positioned in front of the black rectangle. The depicted objects complied with one of two possible occlusion interpretations, i.e., either the continuous or the discontinuous completion. Therefore, there were two different types of foreground primes, the Foreground-Continuous prime (to be referred to as FC-prime), and the Foreground Discontinuous prime (to be referred to as

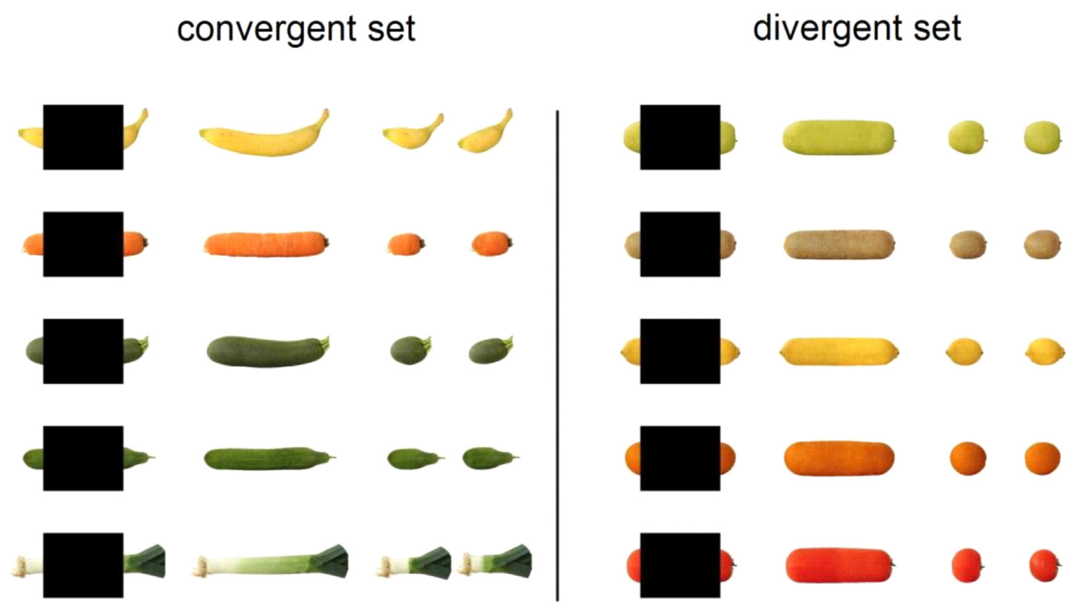

Fig. 3. All occlusion stimuli and completions in the convergent set (*left*) and the divergent set (*right*) used in the experiment, derived from Hazenberg and van Lier (2016, copied with permission).

FD-prime). The latter primes were used to test for basic priming effects.

Test pairs were presented by placing two shapes left and right of the center fixation, with the black occluder placed at the bottom center of the display so as to reduce possible disruption of the priming effect due to an apparent motion effect, as reported in Sekuler and Palmer (1992) (i.e., from the black occluder in the prime to one of the test shapes). For each prime, there were always two trials in which it was followed by a match pair, comprising two shapes of either the continuous or the discontinuous completion, i.e., the Continuous test pair and the Discontinuous test pair (to be referred to as C-pair and D-pair, respectively). In addition, for each prime there were also two trials in which the prime was followed by a non-match pair. In a match pair (the C-pair, or the D-pair), both shapes were exactly the same (and of the same fruit/vegetable as that was shown in the prime), whereas in a non-match pair the shapes were different either in species (different fruits/vegetables), but using the same completion type (e.g. "long banana" and "long apple"), or in completion type but from the same species ("long banana" and "small bananas"). Following previous investigations using the primed matching paradigm (e.g., de Wit, & van Lier, 2002; Sekuler, 1994; Sekuler & Palmer 1992; Sekuler et al., 1994), only results on match pairs can be related to interpretations of the prime stimuli. We therefore focus on the match trials in our experiments. Note that the test pairs always comprise two shapes, irrespective of the type of completion. Together, there are three crucial independent variables in our experimental design: 2 stimulus sets (convergent, divergent), 3 prime types (Oc-prime, FC-prime, FD-prime), and 2 test pair types (C-pair, D-pair).

2.1.3. Procedure

Participants were seated in front of the monitor (75-Hz refresh rate). The experiment was run using Presentation (Version18.1, Neurobehavioral Systems, Inc.). Before the experiment, participants gave written informed consent, and they indicated that they understood the instructions for the task.

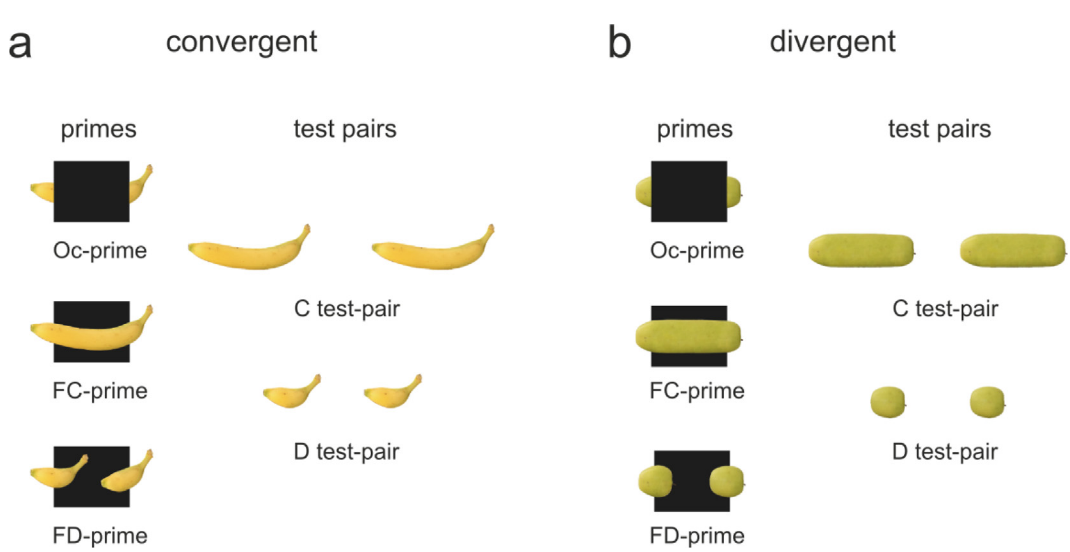

Fig. 4. An example of three primes with their match pairs in the convergent set (a), and in the divergent set (b). In both a and b, the left column consists of three types of primes: Occlusion prime (Oc-prime), Foreground Continuous prime (FC-prime), Foreground Discontinuous prime (FD-prime), and the right column consists of two types of test pairs: test pairs with shapes of Continuous completion (C-pair) and with shapes of Discontinuous completion (D-pair).

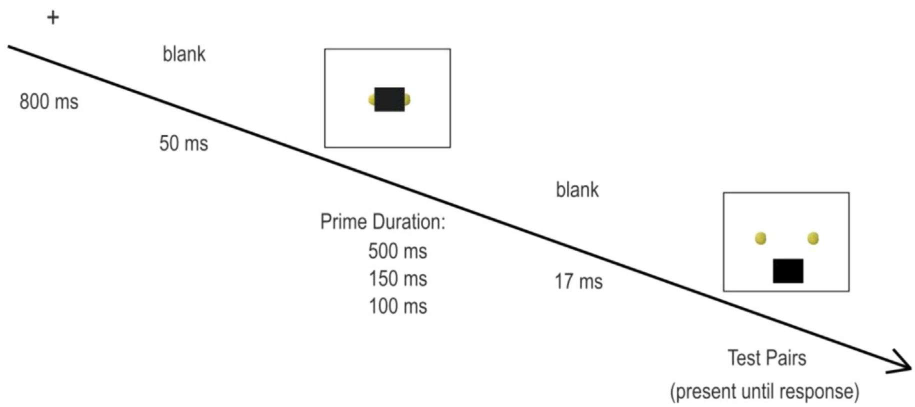

Fig. 5. An example trial of the primed matching paradigm with prime (e.g., the occluded apple) in three experiments (prime duration: 150 ms and 500 ms in Experiment 1, 500 ms in Experiment 2, and 100 ms in Experiment 3). In the no-prime trials the prime was replaced by a black dot presented in the center of the screen. Note that the illustrations are not exactly proportional to what was presented on the screen.

Each trial started with a fixation cross that was presented for 800 ms on the screen. After that, a blank screen was present for 50 ms, after which a prime (or a black dot in the no-prime condition) remained on screen with a duration of 150 ms or 500 ms. After an inter-stimulus interval of 17 ms, the test pair appeared and remained on the screen until the participants responded (see Fig. 5). After the response, the next trial started. The occlusion prime subtended approximately 9 degrees. The shapes in the test pairs were positioned left and right of the center of the screen. Participants were instructed to rest their right and left index fingers on two buttons of the button box. The task was to indicate if the two shapes in the test pair match (Yes/No) by pressing a button as quickly as possible. The response keys were counterbalanced between participants.

The experiment consisted of two parts, with prime duration of 150 ms in the first part and 500 ms in the second part. For each part, there were 3 blocks and 960 trials in total. Trials were pseudo-randomized within each block. Participants were instructed to have a rest both half-way and at the end of each block, and to continue with the test when they were ready by pressing any button. Before the experiment, participants completed a practice block of 12 trials with prime duration of 150 ms to get familiar with the procedure.

2.2. Results

We calculated the priming effect (*PE*) by subtracting RTs in each prime condition from the corresponding no-prime condition for any test pair (see Eq. (1)):

$$PE\,(\text{Prime}) = \text{RT}(\text{No-prime} \mid \text{test pair}) - \text{RT}(\text{Prime} \mid \text{test pair}) \quad (1)$$

In this way, the more positive the value (*PE*) is, the shorter the response time a given test pair requires after seeing a particular prime. Before collapsing trials across participants, we did an outlier detection as we observed a few exceptionally long response times (e.g. 5180 ms, 8235 ms), which would obscure the data. Apparently, participants seem to have become distracted from the task during some trials. The outlier trials were identified by 2.5 median absolute deviations from the overall median within each participant (see Leys, Ley, Klein, Bernard, & Licata, 2013, for details of outlier identification). In the first part of the test with 150 ms prime duration, the average percentage of correct response trials across participants was 96% (SD = 2.7%), of which about 7% (SD = 2.3%) of trials were excluded. In the second part of the test with 500 ms prime duration, the average percentage of correct response trials across participants was 95% (SD = 4.0%), of which about 8% (SD = 2.2%) of trials were excluded. To check the influence of the outlier exclusion as advocated in Leys et al. (2013) we also ran the analyses on the raw data of the three experiments reported here. Doing this does not alter our main results and conclusions. We come back to the raw data analyses in the general discussion.

In Fig. 6, the priming effects are presented for each prime duration (150 ms, 500 ms) and stimulus set (convergent, divergent) as a function of test pairs (C-pair, D-pair) and prime types (Oc-prime, FC-prime, FD-prime) in four different graphs (Fig. 6a-d: 150-prime duration/convergent; 150-prime duration/divergent; 500-prime duration/convergent; 500-prime duration/divergent). The priming effects were calculated according to Eq. (1) using RTs in the no-prime conditions as a baseline. The RTs in the no-prime conditions are as follows. For the 150 ms prime duration, in the convergent set, the RTs to C-pair and D-pair are 511.491 ± 67.81 ms and 520.169 ± 69.94 ms, respectively. In the divergent set, the RTs to C-pair and D-pair are 509.818 ± 69.95 ms and 511.943 ± 64.09 ms, respectively. For the 500 ms prime duration, in the convergent set, the RTs to C-pair and D-pair are 497.286 ± 61.28 ms and 506.833 ± 61.22 ms, respectively. In the divergent set, the RTs to C-pair and D-pair are 496.577 ± 66.18 ms and 496.160 ± 64.71 ms, respectively.

For each of the mentioned subsets, we first performed a repeated-measures analysis of variance (ANOVA) on the factors of Primes (3: Oc-prime, FC-prime, FD-prime) × Test pairs (2: C-pair, D-pair), resulting in the following significant results: *i)* 150-prime duration/convergent (Fig. 6a): main effect of Primes [F (2, 68) = 13.453, p < .001, η_p^2 = 0.284], interaction between Primes × Test pairs [F (2, 68) = 38.715, p < .001, η_p^2 = 0.532]. *ii)* 150-prime duration/divergent (Fig. 6b): main effect of both Primes [F (2, 68) = 12.920, p < .001, η_p^2 = 0.275], and Test pairs [F (1, 34) = 16.803, p < .001, η_p^2 = 0.331], interaction between Primes × Test pairs [F (2, 68) = 46.244, p < .001, η_p^2 = 0.576]. *iii)* 500-prime duration/convergent (Fig. 6c): main effect of Primes [F (2, 68) = 5.941, p = .004, η_p^2 = 0.149], interaction between Primes × Test pairs [F (2, 68) = 52.840, p < .001, η_p^2 = 0.608]. *iv)* 500-prime duration/divergent (Fig. 6d): main effect of Primes [F (2, 68) = 8.524, p < .001, η_p^2 = 0.200], main effect of Test pairs [F (1, 34) = 8.280, p = .007, η_p^2 = 0.196], interaction between Primes × Test pairs [F (2, 68) = 25.043, p < .001, η_p^2 = 0.424]. In the following, we have a closer look at the pairwise interactions for each subset as they actually reveal the representational similarities between the occlusion prime and foreground primes.

2.2.1. 150 ms prime duration

2.2.1.1. Convergent set. To examine the effect of different primes on the response times to different test pairs in more detail, three follow-up 2 by 2 ANOVAs were performed. First, comparing the effect of the two foreground primes (FC-prime vs FD-prime) revealed an interaction [F (1, 34) = 50.072, p < .001, η_p^2 = 0.596], showing that the primes had a differential effect on the test pairs. As expected, the FC-primes resulted in faster response times to C-pairs compared to D-pairs, t (34) = 4.514, p < .001, whereas FD-prime resulted in faster response times to D-pairs compared to C-pairs, t(34) = 4.540, p < .001. Secondly, the Oc-prime had a different effect on the test pairs compared with the FD-prime [F (1, 34) = 47.453, p < .001, η_p^2 = 0.583]. Specifically, the Oc-prime facilitated C-pairs relative to D-pairs, t(34) = 2.115, p = .042. This contrasts with the FD-prime

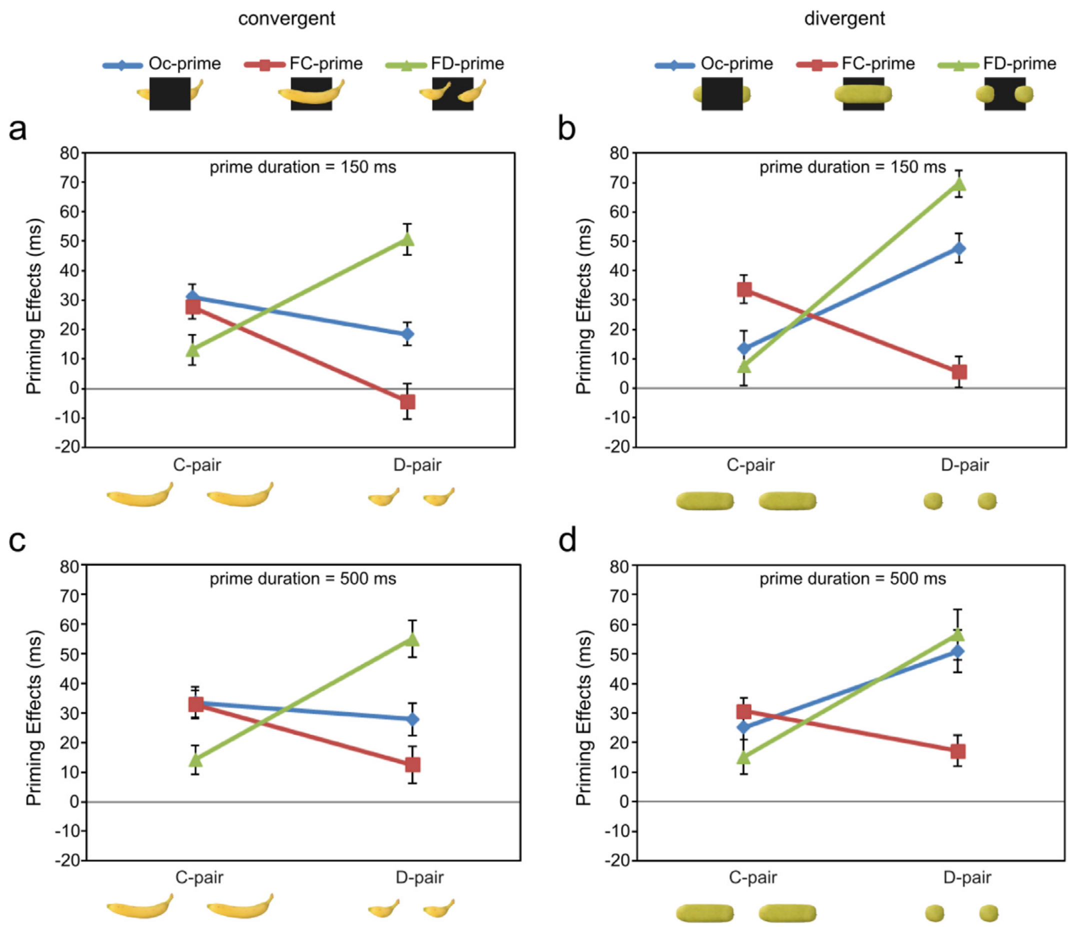

Fig. 6. Priming effects for the convergent set (*left column*: a and c) and the divergent set (*right column*: b and d) with two different prime durations (*top row*: 150 ms; *bottom row*: 500 ms) in Experiment 1. Error bars represent one standard error of the mean.

which, as mentioned, shows the opposite effect. Thirdly, the effect of the Oc-prime also differed from the effect of the FC-prime [F (1, 34) = 7.574, p = .009, η_p^2 = 0.182]. It appears that, although both primes facilitate C-pairs relative to D-pairs, this effect is larger for the FC-prime.

2.2.1.2. Divergent set. For the divergent set again three follow-up 2 by 2 ANOVAs were performed. Comparing the effects of the two foreground primes again revealed an interaction [F (1, 34) = 68.779, p < .001, η_p^2 = 0.669]. For both the FC-prime [t(34) = 3.857, p < .001] and the FD-prime [t(34) = = 7.496, p < .001] the priming effects were in the expected directions as well (see Fig. 6b). Again, the Oc-prime interacted with both the FC-prime [F (1, 34) = 40.696, p < .001, η_p^2 = 0.545], and the FD-prime [F (1, 34) = 12.280, p = .001, η_p^2 = 0.265]. In contrast to the convergent set, the Oc-prime revealed a higher priming effect for the D-pair relative to the C-pair, t(34) = 4.311, p < .001.

2.2.2. 500 ms prime duration

2.2.2.1. Convergent set. The effect of the two foreground primes again revealed an interaction [F (1, 34) = 138.008, p < .001, η_p^2 = 0.802]. The priming effects for the FC-prime and the FD-prime were in the expected direction, t(34) = 3.333, p = .002; t(34) = 6.204, p < .001; respectively (see Fig. 6c). The Oc-prime interacted with both the FC-prime [F (1, 34) = 5.019, p = .032, η_p^2 = 0.129], and the FD-prime [F (1, 34) = 47.791, p < .001, η_p^2 = 0.584]. The Oc-prime did not reveal any differential priming effect on the two test pairs, t(34) = 0.977, p = .335.

2.2.2.2. Divergent set. The effect of the two foreground primes again revealed an interaction [F (1, 34) = 32.918, p < .001, η_p^2 = 0.492]. Again, the priming effects for the FC-prime and the FD-prime were in the expected direction, t(34) = 2.640, p = .012; t(34) = 4.139, p < .001; respectively (see Fig. 6d). The Oc-prime interacted with both the FC-prime [F (1, 34) = 28.984, p < .001, η_p^2 = 0.460], and the FD-prime [F (1, 34) = 5.209, p = .029, η_p^2 = 0.133]. Similar to the 150-prime duration, the Oc-prime revealed a higher priming effect for the D-pairs relative to C-pairs, t(34) = 3.515, p = .001.

2.3. Discussion

The results in Experiment 1 showed differential priming effects. Firstly, for both prime durations (150 ms, 500 ms) and for both sets (convergent, divergent) the foreground primes showed a facilitation for test pairs that contain exactly the same shapes as seen in the foreground primes. In particular, the FC-primes have a stronger facilitating effect on the C-pair, whereas the FD-primes have a facilitating effect on the D-pair. This basic priming effect shows the validity of this paradigm in our study. In other words, the paradigm does what it should do: primes facilitate test pairs that contain exactly the same shapes. With regard to the occlusion primes, the tendencies are opposed for the convergent and divergent set. For the convergent set, the priming effect is highest for the continuous completion (150 ms prime), which also complies with the well-known completion (e.g., a normally shaped banana), whereas for the divergent set, the priming effect is highest for the discontinuous completion (both 150 ms prime duration and 500 ms prime duration), again complying with the well-known completion (e.g., two normally shaped apples). This pattern of results might be

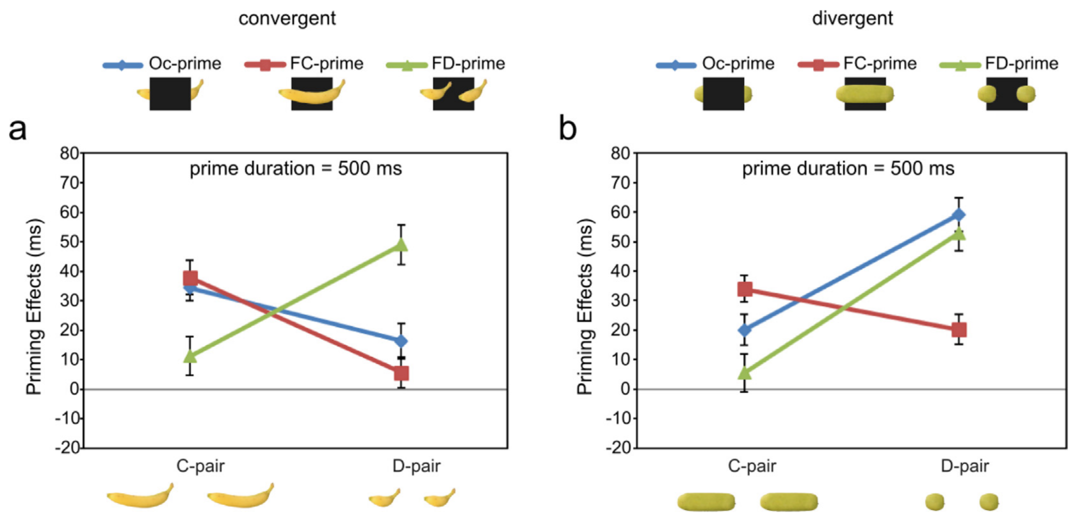

Fig. 7. Priming effects for the convergent set (a) and the divergent set (b) in Experiment 2. Error bars represent one standard error of the mean.

caused by differential knowledge-based influences during the completions of the partly occluded objects in the primes.

However, before claiming that this result supports the role of knowledge at early stages, there is a difference between primes and test pairs in the convergent and the divergent set that we have to deal with. Given the nature of the primed matching paradigm, there are always two shapes in a test pair that have to be matched. Consequently, it may be that primes with two shapes (e.g., FD-primes) have an advantage over primes with just one shape (e.g., FC-primes). The data of the foreground primes appear to confirm this. That is, for both the convergent and the divergent set, the priming effects that FD-primes have on D-pairs appear larger than the priming effects that FC-primes have on C-pairs (see Fig. 6). This shows that the priming effect is not only driven by the representational similarity between the partly occluded shape in the prime and the shapes in the test pair, but perhaps also by the number of presented shapes in the prime and the test pair. Because Oc-primes also consist of two shapes (although separated by a black rectangle), similar effects may be expected. For the divergent set, we indeed find that Oc-primes have a larger priming effect on D-pairs compared to C- pairs. Thus, this effect can be explained by both knowledge-based processing and by the number of presented parts. However, if the latter would be the only factor driving the observed effects, one would expect a similar pattern in the convergent set. This is not the case, as for the convergent set Oc-primes induce a lower priming effect for D-pairs compared to C- pairs. These opposite tendencies reveal that an explanatory account that is solely based on the number of presented parts or on completion by continuation cannot hold. Instead, knowledge of common shapes of fruits and vegetables must have played a role in the priming effects. That is, the differential priming effects indicate that knowledge has an influence after 150 ms priming of the occluded objects. Note, however, that in the current set-up the occlusion prime did not result in the same priming effects as the foreground primes, for both the 150 ms prime and the 500 ms prime.

The results for the 500 ms prime are rather similar to the results of the 150 ms prime. Noticeably, the effect for the convergent set seems somewhat weaker. However, we need to be cautious here as the 500 ms prime blocks were all presented after the 150 ms prime blocks. That is, compared to the 150 ms prime duration, the 500 ms prime duration results might have been biased by the more frequent exposure to the stimuli. Therefore, to exclude such a bias, we repeated testing with only the 500-prime duration using the same number of trials and blocks.

3. Experiment 2

The aim of this experiment was to exclude the possibility of an effect of exposure frequency for the 500 ms prime duration in the second part of Experiment 1.

3.1. Methods

3.1.1. Participants

Another twenty participants (aged 22–35 years; 3 males), students at the Radboud University, were paid 7.5 Euros to participate in the experiment. All participants gave written informed consent, and had no current or past neurological or psychiatric illness. This study was approved by the internal ethics committee, in accordance with the declaration of Helsinki.

3.1.2. Stimuli

The stimuli used in Experiment 2 are the same as Experiment 1 (see Fig. 4).

3.1.3. Procedure

The experimental procedure was exactly the same as the second part of Experiment 1. The practice block was almost the same as Experiment 1, except that the prime duration was 500 ms.

3.2. Results

According to the same criteria as Experiment 1, the average percentage of correct response trials across participants was 98% (SD = 1.2%), of which about 7% (SD = 2.7%) of trials were excluded.

In Fig. 7 the priming effects for each prime are presented for each stimulus set as a function of test pairs in two different graphs. RTs in the no-prime conditions are as follows. In the convergent set, the RTs to the C-pairs and the D-pairs are 483.020 ± 68.70 ms and 492.603 ± 71.03 ms, respectively. In the divergent set, the RTs to the C-pairs and the D-pairs are 478.147 ± 70.80 ms and 482.325 ± 62.85 ms, respectively. For each of these subsets we again first performed an ANOVA on the factors of Primes (3: Oc-prime, FC-prime, FD-prime) × Test pairs (2: C-pair and D-pair), with the following significant results: *i)* convergent (Fig. 7a): interaction between Primes × Test pairs [F (2, 38) = 27.353, p < .001, $\eta_p{}^2 = 0.590$]. *ii)* divergent (Fig. 7b): main effect of both Primes [F (2, 38) = 4.626, p = .016, $\eta_p{}^2 = 0.196$], and Test pairs [F (1, 19) = 13.462, p = .002, $\eta_p{}^2 = 0.415$], interaction between Primes × Test pairs [F (2, 38) = 30.381, p < .001, $\eta_p{}^2 = 0.615$]. In the following, we have a closer look at the same pairwise interactions for each subset as the Experiment 1.

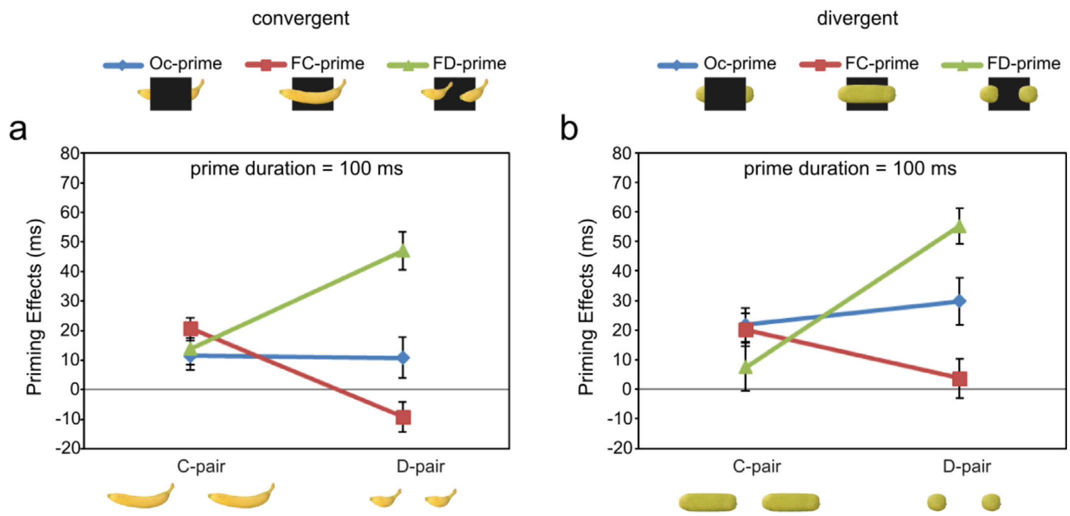

Fig. 8. Priming effects for the convergent set (a) and the divergent set (b) in Experiment 3. Error bars represent one standard error of the mean.

3.2.1. *Convergent set*

The effect of the two foreground primes revealed an interaction [$F(1, 19) = 36.091, p < .001, \eta_p^2 = 0.655$]. Again the priming effects for the FC-prime and the FD-prime were in the expected direction, $t(19) = 4.370$, $p < .001$; $t(19) = 4.079$, $p = .001$; respectively (see Fig. 7a). The Oc-prime interacted with the FD-prime [$F(1, 19) = 49.920, p < .001, \eta_p^2 = 0.724$], but not with the FC-prime [$F(1, 19) = 1.920$, $p = .182$, $\eta_p^2 = 0.092$]. Specifically, the Oc-prime facilitated C-pairs relative to D-pairs, $t(19) = 2.432$, $p = .025$.

3.2.2. *Divergent set*

The effect of the two foreground primes revealed an interaction [$F(1, 19) = 34.472$, $p < .001$, $\eta_p^2 = 0.645$]. Again, the priming effects for the FC-prime and the FD-prime were in the expected direction, $t(19) = 2.287$, $p = .034$; $t(19) = 4.460$, $p < .001$; respectively (see Fig. 7b). The Oc-prime interacted with the FC-prime [$F(1, 19) = 50.222, p < .001, \eta_p^2 = 0.726$], but not with the FD-prime [$F(1, 19) = 1.327, p = .264, \eta_p^2 = 0.065$]. Again, the Oc-prime facilitated D-pairs relative to C-pairs, $t(19) = 5.290$, $p < .001$.

3.3. *Discussion*

For the convergent set, the conjunction of a FC-prime × FD-prime interaction, an Oc-prime × FD-prime interaction and no Oc-prime × FC-prime interaction strongly supports 'long banana-like' representations for occlusion patterns. In a similar way, for the divergent set, the conjunction of a FC-prime × FD-prime interaction, an Oc-prime × FC-prime interaction and no Oc-prime × FD-prime interaction strongly supports 'two apples-like' representations for occlusion patterns. That is, after 500 ms, the occlusion prime interacts in a similar way as the prime comprising the well-known shapes and differs from the prime comprising the anomalous shapes. The post hoc tests also revealed that priming effects of the occlusion prime on the test pairs with the well-known shapes is higher than that of the anomalous shapes. Thus, the current results reveal a dominant role of knowledge in the completion process of partly occluded objects about 500 ms after prime onset. Detailed implications will be discussed in general discussion.

The results of Experiment 2 show that knowledge has a clear influence after a prime with a 500 ms duration. The results of Experiment 1 showed that knowledge influence was already apparent after 150 ms prime duration. To push this lower limit a little further we conducted another experiment, now having a prime duration of 100 ms.

4. Experiment 3

4.1. *Methods*

4.1.1. *Participants*

Another twenty-five students (aged 18–29 years; 11 males) from the Radboud University participated in the experiment. One participant was excluded from the analysis because of the low number of correct response trials, which exceeded three standard deviations of the mean value across participants. Inspecting the responses, it appeared that this participant was not matching the test shapes (but possibly attempted to match the test shapes with the prime). All participants gave written informed consent, and were paid a small amount or received course credit. All participants had no current or past neurological or psychiatric illness. This study was approved by the internal ethics committee, in accordance with the declaration of Helsinki.

4.1.2. *Stimuli*

The stimuli used in Experiment 3 are the same as in Experiments 1 and 2 (see Fig. 4).

4.1.3. *Procedure*

The procedure was exactly the same as Experiments 2, except that the prime duration was 100 ms.

4.2. *Results*

The average percentage of correct response trials across participants was 96% (SD = 2.3%). Using the same criteria as in Experiments 1 and 2, about 6% (SD = 2.5%) of the correct response trials were excluded.

In Fig. 8, the priming effects are again presented for the convergent and divergent stimulus sets (Fig. 8a-b: convergent and divergent). RTs in the no-prime conditions are as follows. In the convergent set, the RTs to the C-pairs and the D-pairs are 530.890 ± 220.86 ms and 535.235 ± 207.45 ms, respectively. In the divergent set, the RTs to the C-pairs and the D-pairs are 526.184 ± 213.84 ms and 523.996 ± 206.99 ms, respectively. For each of these sets, we again first performed an ANOVA on the factors of Primes (3: Oc-prime, FC-prime, FD-prime) × Test pairs (2: C-pair and D-pair), with the following significant results: *i)* convergent (Fig. 8a): main effect of Primes [$F(2, 46) = 13.290$, $p < .001$, $\eta_p^2 = 0.366$], interaction between Primes × Test pairs [$F(2, 46) = 39.059$, $p < .001$, $\eta_p^2 = 0.629$]. *ii)* divergent (Fig. 8b): main effect of Primes [$F(2, 46) = 9.158, p < .001$, $\eta_p^2 = 0.285$], interaction between Primes × Test pairs [$F(2, 46) = 21.005$, $p < .001$, $\eta_p^2 = 0.477$]. In the following, we have a closer look at the same pairwise interactions for each subset as in Experiments 1 and 2.

4.2.1. Convergent set

The effect of the two foreground primes again revealed an interaction [F (1, 23) = 68.468, $p < .001$, $\eta_p{}^2 = 0.749$]. The priming effects for the FC-prime and FD-prime were in the expected direction, t (23) = 4.946, $p < .001$; t(23) = 5.146, $p < .001$; respectively (see Fig. 8a). The Oc-prime interacted with both the FC-prime [F (1, 23) = 21.343, $p < .001$, $\eta_p{}^2 = 0.481$], and the FD-prime [F (1, 23) = 20.862, $p < .001$, $\eta_p{}^2 = 0.476$]. The Oc-prime did not reveal any differential priming effect on the two test pairs, t(23) = 0.124, $p = .902$.

4.2.2. Divergent set

The effect of the two foreground primes again revealed an interaction [F (1, 23) = 51.324, $p < .001$, $\eta_p{}^2 = 0.691$]. The priming effects for the FC-prime and FD-prime were in the expected direction, t (23) = 2.535, $p = .019$; t(23) = 5.535, $p < .001$; respectively (see Fig. 8b). The Oc-prime interacted with both the FC-prime [F (1, 23) = 6.761, $p = .016$, $\eta_p{}^2 = 0.227$], and the FD-prime [F (1, 23) = 12.016, $p = .002$, $\eta_p{}^2 = 0.343$]. Similar to the convergent set, the Oc-prime did not reveal any differential priming effect on the two test pairs, t(23) = 0.726, $p = .475$.

4.3. Discussion

Consistent with both Experiments 1 and 2, foreground primes showed strong facilitations for match pairs containing the same objects as foreground primes in both sets. No such facilitation effects were found for Oc-primes. It seems that 100 ms is not enough for the completion process to arrive at a preferred interpretation yet. At least, no clear evidence for structure effects or knowledge effects during amodal completion can be detected in our design.

5. General discussion

By probing three different prime durations, we aimed to study temporal properties in the completion of well-known objects. Our results showed differential effects for the three prime durations on the two types of completion (continuous versus discontinuous) with increasing prime durations. For the 100 ms prime duration, we found no clear evidence to draw any conclusions with regard to the effects of knowledge versus structure. For the longer priming durations, a differential pattern emerged, revealing knowledge-based influences at these durations. An important indication for the validity of the paradigm is the observation that the two foreground primes (FC-prime and FD-prime) and the two types of completion in the test pairs (C-pair, D-pair) always interacted with each other. This confirms that the priming effects relate to shape similarity, with the highest priming effects occurring when the shapes in the foreground prime and the test pairs are the same. Having established this basic interaction, the priming effects of the occlusion pattern are of interest. The F-values and effect sizes for the interactions between the occlusion primes and foreground primes are presented once more in Table 1 for three prime durations (100 ms, 150 ms, and 500 ms). As previously mentioned, we also ran analyses on the raw data and found almost the same result, besides one interaction which appeared to be not significant ($p = .074$), indicated in Table 1. Note that for the 500 ms prime duration, we used the results of Experiment 2 as effects due to frequent exposure may have influenced the 500 ms condition in Experiment 1.

What can clearly be seen from this table is the difference between the tendencies for the convergent set and the divergent set with increasing prime durations. Specifically, for the convergent set, the interaction between Oc-prime and FC-prime observed at 100 ms becomes less strong at 150 ms and eventually disappears at 500 ms (see also the decreasing effect size; note further that when using the raw data the non-significance already appears at 150 ms prime duration). In addition, the interaction between Oc-prime and FD-prime becomes stronger with longer prime durations (see increasing effect size). This shows that at 500 ms prime duration the partly hidden shape functions as if it were a continuous shape (e.g., a normally shaped banana). For the divergent set, this pattern is reversed. Here, the interaction between Oc-prime and FC-prime becomes stronger with longer prime durations, while the interaction between Oc-prime and FD-prime disappears at 500 ms. For this pattern, the partly occluded shape eventually becomes functionally equivalent to the discontinuous shapes (e.g., two normally shaped apples). Combined, these results indicate a gradual tendency towards knowledge-based completions.

To further compare the results of the experiments we have done an additional analysis, combining data from three prime durations (100 ms, 150 ms, and 500 ms). First, we determined a measure of deviation (δPE) for each of the two different foreground primes (continuous versus discontinuous). To do this we calculated the absolute difference between the priming effects of the partly occluded shape (i.e., the baseline prime) with each of the two foreground primes (see Eqs. (2a) and (2b)).

$$\begin{aligned}\delta PE(\text{Oc-prime, FC-prime}) = \text{ABS}\{&[PE(\text{Oc-prime} \mid \text{D-pair}) \\ &-PE(\text{FC-prime} \mid \text{D-pair})] \\ &-[PE(\text{Oc-prime} \mid \text{C-pair}) \\ &-PE(\text{FC-prime} \mid \text{C-pair})]\}\end{aligned} \tag{2a}$$

$$\begin{aligned}\delta PE(\text{Oc-prime, FD-prime}) = \text{ABS}\{&[PE(\text{Oc-prime} \mid \text{D-pair}) \\ &-PE(\text{FD-prime} \mid \text{D-pair})] \\ &-[PE(\text{Oc-prime} \mid \text{C-pair}) \\ &-PE(\text{FD-prime} \mid \text{C-pair})]\}\end{aligned} \tag{2b}$$

The smaller value of δPE in the above equations, the more similar the effects of the occlusion prime and that particular foreground prime are, and the more likely the partly occluded object in the occlusion prime is interpreted as the completely visible object in the foreground prime. Therefore, for example small values for (2a) suggest that Oc-primes are interpreted as continuous completions, whereas small values for (2b) suggest discontinuous completions. In Fig. 9, we have plotted the difference between both δPE values (to be referred to as ΔPE) in a single graph for the two stimulus sets with ΔPE = (2b) – (2a).

Fig. 9 visualises different completion tendencies for the convergent set and the divergent set, similar to our observations in Table 1. What can be seen in the graph is that for the longer prime durations (150 ms and 500 ms) the tendencies diverge. We conducted t-tests on the influence of the stimulus sets (convergent vs. divergent) on ΔPE values for the three prime durations. This revealed a significant effect of stimulus set for the longer prime durations (150 ms and 500 ms), t(34) = 3.692, $p = .001$; t(19) = 3.318, $p = .004$; respectively. No such effect of stimulus set was found with 100 ms prime duration, t(23) = -0.385, $p = .704$.

All in all, we found that knowledge takes an effect as early as 150 ms after prime onset. This complies with an earlier finding that knowledge of material hardness could affect the amodal completion of a notched circular slice after 150 ms (Vrins et al., 2009). These findings apparently extend the range of amodal completion phenomena. As mentioned, there are various models on amodal completion. Some of these models stress some kind of local continuation under specific occlusion conditions (Fantoni & Gerbino, 2003; Kellman & Shipley, 1991; Singh & Hoffman, 2001; Wouterlood & Boselie, 1992), while others advocate the influence of global regularities (Buffart et al., 1981; Sekuler, 1994; van Lier et al., 1994), fuzzy regularities (van Lier, 1999) or influences of 3D information (Ekroll, Sayim, & Wagemans, 2013; Tse 1999; Tse 2017; van Lier & Wagemans 1999). More recently, effects of previous exposure and of learning on amodal completion have been shown

Table 1
F-values of the Interactions Between the Occlusion Primes and the Foreground Primes.

Prime Duration	Convergent				Divergent			
	Oc-prime × FC-prime		Oc-prime × FD-prime		Oc-prime × FC-prime		Oc-prime × FD-prime	
	F	η_p^2	*F*	η_p^2	*F*	η_p^2	*F*	η_p^2
100 ms	21.343**	0.481	20.862**	0.476	6.761*	0.227	12.016*	0.343
150 ms	7.574* #	0.182	47.453**	0.583	40.696**	0.545	12.280*	0.265
500 ms	1.920ns	0.092	49.920**	0.724	50.222**	0.726	1.327ns	0.065

Note. *indicates significant interactions at the .05 level; **indicates significant interactions at the .001 level; nsindicates no significant difference. #indicates deviation from the raw data analyses, in which this specific interaction is not significant.

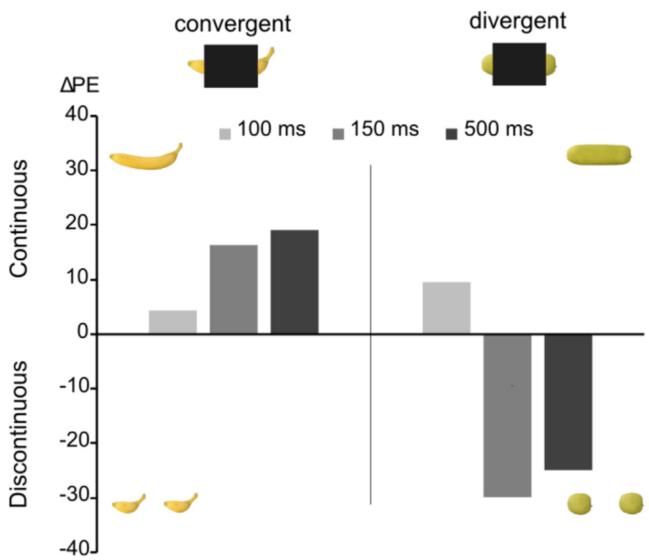

Fig. 9. Differential preferences for continuous versus discontinuous completions for each occlusion pattern (*left*: convergent set, *right*: divergent set) with three prime durations (100 ms, 150 ms, and 500 ms).

(Hazenberg et al. 2014; Plomp & van Leeuwen, 2006). The current findings further extend the findings of Hazenberg and van Lier (2016), showing that knowledge can influence the appearance of amodally completed objects. These results seem to fit with other findings that visual perception does not solely rely on visual mechanisms, but rather is modulated by previous experiences (Albright, 2012; Hurlbert & Ling, 2005; Mast, Berthoz, & Kosslyn, 2001; Trujillo, Allen, Schnyer, & Peterson, 2010). Note however, that our results do not exclude an initial perceptual process. The current results, for example, would also comply with a two-stage process in which an initial perceptual stage is later modulated or even overruled by knowledge.

In the past decades, there has been some debate whether various amodal completion phenomena are truly perceptual or whether they are cognitive (Carrigan et al., 2016; Kellman, 2001; van Lier & Gerbino, 2015). In our view, the distinction between perceptual and cognitive stages in case of amodal completion is still vague, certainly so at the brain level. Simple continuations of contours are triggered relatively early and may appear more perceptual (even young babies are sensitive to local good continuation; de Wit, Vrins, Dejonckheere, & van Lier, 2008; Johnson, 2004). Other completion tendencies, including knowledge-based characteristics, may involve larger networks at later processing stages. Obviously, drawing a line between perception and cognition should be done with great care (see also Firestone & Scholl, 2016). In our view, the current results support the idea that all kinds of stimulus aspects may trigger the amodal content in which continuation, symmetry, or knowledge, gathered from all 'corners of the brain' play a role and compete with each other. Perhaps this flexibility is the system's best way to deal with the unseen.

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Reference

Albright, T. D. (2012). On the perception of probable things: neural substrates of associative memory, imagery, and perception. *Neuron, 74*(2), 227–245. http://dx.doi.org/10.1016/j.neuron.2012.04.001.

Bruno, N., Bertamini, M., & Domini, F. (1997). Amodal completion of partly occluded surfaces: is there a mosaic stage? *Journal of Experimental Psychology: Human Perception and Performance, 23*(5), 1412–1426. http://dx.doi.org/10.1037/0096-1523.23.5.1412.

Buffart, H., Leeuwenberg, E., & Restle, F. (1981). Coding theory of visual pattern completion. *Journal of Experimental Psychology: Human Perception and Performance, 7*(2), 241–274. http://dx.doi.org/10.1037/0096-1523.7.2.241.

Carrigan, S. B., Palmer, E. M., & Kellman, P. J. (2016). Differentiating global and local contour completion using a dot localization paradigm. *Journal of Experimental Psychology: Human Perception and Performance, 42*(12), 1928–1946. http://dx.doi.org/10.1037/xhp0000233.

de Wit, T. C. J., & van Lier, R. (2002). Global visual completion of quasi-regular shapes. *Perception, 31*(8), 969–984. http://dx.doi.org/10.1068/p3374.

de Wit, T. C. J., Vrins, S., Dejonckheere, P. J. N., & van Lier, R. (2008). form perception of partly occluded shapes in 4-month-old infants. *Infancy, 13*(6), 660–674. http://dx.doi.org/10.1080/15250000802458864.

Ekroll, V., Sayim, B., & Wagemans, J. (2013). Against better knowledge: The magical force of amodal volume completion. *i-Perception, 4*(8), 511–515. http://dx.doi.org/10.1068/i0622sas.

Fantoni, C., & Gerbino, W. (2003). Contour interpolation by vector-field combination. *Journal of Vision, 3*(4) 4–4. https://doi.org/10.1167/3.4.4.

Firestone, C., & Scholl, B. J. (2016). Cognition does not affect perception: Evaluating the evidence for "top-down" effects. *Behavioral and Brain Sciences, 39*, 1–77. http://dx.doi.org/10.1017/S0140525X15000965.

Hazenberg, S. J., Jongsma, M. L. A., Koning, A., & van Lier, R. (2014). Differential familiarity effects in amodal completion: support from behavioral and electrophysiological measurements. *Journal of Experimental Psychology: Human Perception and Performance, 40*(2), 669–684. http://dx.doi.org/10.1037/a0034689.

Hazenberg, S. J., & van Lier, R. (2016). Disentangling effects of structure and knowledge in perceiving partly occluded shapes: An ERP study. *Vision Research, 126*, 109–119. http://dx.doi.org/10.1016/j.visres.2015.10.004.

Hochberg, J., & McAlister, E. (1953). A quantitative approach to figural 'goodness'. *Journal of Experimental Psychology, 46*(5), 361. http://dx.doi.org/10.1037/h0055809.

Hurlbert, A. C., & Ling, Y. (2005). If it's a banana, it must be yellow: The role of memory colors in color constancy. *Journal of Vision, 5*(8) 787–787. https://doi.org/10.1167/5.8.787.

Johnson, S. (2004). Development of perceptual completion in infancy. *Psychological Science, 15*(11), 769–775. http://dx.doi.org/10.1111/j.0956-7976.2004.00754.x.

Kanizsa, G. (1970). Amodale ergänzung und, erwartungsfehler" des gestaltpsychologen. *Psychologische Forschung, 33*(4), 325–344. http://dx.doi.org/10.1007/BF00424558.

Kellman, P. J. (2001). Separating processes in object perception. *Journal of Experimental Child Psychology, 78*(1), 84–97. http://dx.doi.org/10.1006/jecp.2000.2604.

Kellman, P. J., & Shipley, T. F. (1991). A theory of visual interpolation in object perception. *Cognitive Psychology, 23*(2), 141–221. http://dx.doi.org/10.1016/0010-0285(91)90009-D.

Lee, H., & Vecera, S. P. (2005). Visual cognition influences early vision: the role of visual short-term memory in amodal completion. *Psychological Science, 16*(10), 763–768. http://dx.doi.org/10.1111/j.1467-9280.2005.01611.x.

Leys, C., Ley, C., Klein, O., Bernard, P., & Licata, L. (2013). Detecting outliers: Do not use standard deviation around the mean, use absolute deviation around the median. *Journal of Experimental Social Psychology, 49*(4), 764–766. http://dx.doi.org/10.

1016/j.jesp.2013.03.013.
Mast, F., Berthoz, A., & Kosslyn, S. (2001). Mental imagery of visual motion modifies the perception of roll-vection stimulation. *Perception, 30*(8), 945–957. http://dx.doi.org/10.1068/p3088.
Michotte, A., Thinès, G., & Crabbé, G. (1964). *Les compléments amodaux des structures perceptives.* Louvain, Belgium: Publications Universitaires ((Reprinted as Michotte's experimental phenomenology of perception, G. Thinés, A. Costall, & G. Butterworth, Ed., 1991, Hillsdale, NJ: Lawrence Erlbaum) (1964)).
Plomp, G., & van Leeuwen, C. (2006). Asymmetric priming effects in visual processing of occlusion patterns. *Perception & Psychophysics, 68*(6), 946–958. http://dx.doi.org/10.3758/BF03193357.
Sekuler, A. B. (1994). Local and global minima in visual completion: effects of symmetry and orientation. *Perception, 23*(5), 529–545. http://dx.doi.org/10.1068/p230529.
Sekuler, A. B., & Palmer, S. E. (1992). Perception of partly occluded objects: A microgenetic analysis. *Journal of Experimental Psychology: General, 121*(1), 95–111. http://dx.doi.org/10.1016/0010-0285(83)90017-8.
Sekuler, A. B., Palmer, S. E., & Flynn, C. (1994). Local and global processes in visual completion. *Psychological Science, 5*(5), 260–267. http://dx.doi.org/10.1111/j.1467-9280.1994.tb00623.x.
Singh, M., & Hoffman, D. (2001). Part-based representations of visual shape and implications for visual cognition. In T. Shipley, & P. Kellman (Vol. Eds.), *From fragments to objects: Segmentation and grouping in vision: . Vol. 130. Advances in psychology* (pp. 401–459). New York: Elsevier. http://dx.doi.org/10.1016/S0166-4115(01)80033-9.
Trujillo, L. T., Allen, J. J. B., Schnyer, D. M., & Peterson, M. A. (2010). Neurophysiological evidence for the influence of past experience on figure – ground perception. *Journal of Vision, 10*(2), 5. http://dx.doi.org/10.1167/10.2.5.
Tse, P. U. (1999). Volume completion. *Cognitive Psychology, 39*(1), 37–68. http://dx.doi.org/10.1006/cogp.1999.0715.
Tse, P. U. (2017). Dynamic volume completion and deformation. *i-Perception, 8*(6) 2041669517740368. https://doi.org/10.1177/2041669517740368.
van Lier, R. (1999). Investigating global effects in visual occlusion: from a partly occluded square to the back of a tree-trunk. *Acta Psychologica, 102*(2–3), 203–220. http://dx.doi.org/10.1016/S0001-6918(98)00055-9.
van Lier, R., & Gerbino, W. (2015). Perceptual completions. In J. Wagemans (Ed.). *Oxford handbook of perceptual organization* (pp. 294–320). Oxford, U.K.: Oxford University Press.
van Lier, R., Leeuwenberg, E. L. J., & van der Helm, P. A. (1995). Multiple completions primed by occlusion patterns. *Perception, 24*(7), 727–740. http://dx.doi.org/10.1068/p240727.
van Lier, R., van der Helm, P. A., & Leeuwenberg, E. L. J. (1994). Integrating global and local aspects of visual occlusion. *Perception, 23*(8), 883–903. http://dx.doi.org/10.1068/p230883.
van Lier, R., & Wagemans, J. (1999). From images to objects: Global and local completions of self-occluded parts. *Journal of Experimental Psychology: Human Perception and Performance, 25*(6), 1721–1741. http://dx.doi.org/10.1037/0096-1523.25.6.1721.
Vrins, S., de Wit, T. C. J., & van Lier, R. (2009). Bricks, butter, and slices of cucumber: Investigating semantic influences in amodal completion. *Perception, 38*(1), 17–29. http://dx.doi.org/10.1068/p6018.
Wouterlood, D., & Boselie, F. (1992). A good-continuation model of some occlusion phenomena. *Psychological Research Psychologische Forschung, 54*(4), 267–277. http://dx.doi.org/10.1007/BF01358264.