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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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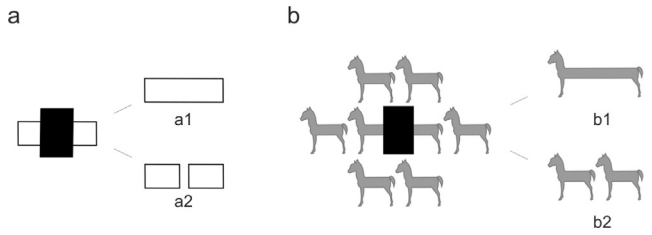

Fig. 1. A partly occluded rectangle with two possible interpretations (a), and a partly occluded horse with its two possible interpretations (*b*). The first interpretations (a1 and b1) are preferred in both cases.

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

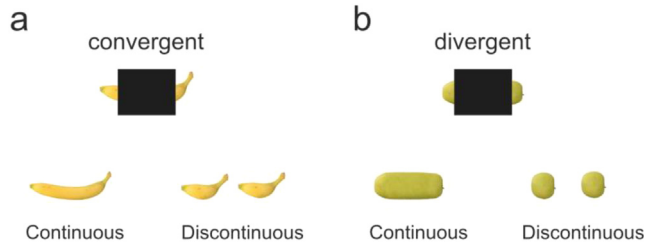

Fig. 2. a) A convergent occlusion pattern, for which good continuation and knowledge result in an identical completion. b) A divergent occlusion pattern, for which good continuation and knowledge diverge, resulting in different completions.

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