Trends and styles in visual masking

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Processing of nonconscious stimuli has a long history as a research topic of experimental vision research. The recent past has seen an increasing number of research articles that address questions of nonconscious vision.

One starting point for this renewed interest has been the provision of visual masking paradigms – the topic of the present edition – as powerful tools for demonstrating the processing of nonconscious visual information (cf. Neumann & Klotz, 1994; Klotz & Neumann, 1999). Neumann and Klotz impeded conscious perception of visual stimuli ('primes') by temporally trailing, spatially adjacent visual masks (meta-contrast masking; cf. Exner, 1868; Stigler, 1910). They further demonstrated that the prime influences speed and accuracy of responses towards the visible mask ("metacontrast dissociation"). Since Neumann and Klotz's original report, numerous studies have replicated the basic finding, including demonstrations of priming in electrophysiological measures of response activation and the shifting of visuospatial attention (see, for instance, Breitmeyer, Ro, & Singhal, 2004; Eimer & Schlaghecken, 1998; Jaśkowski, van der Lubbe, Schlotterbeck, & Verleger, 2002; Leuthold & Kopp, 1998; Schaghecken & Eimer, 2004; Vorberg, Mattler, Heinecke, Schmidt, & Schwarzbach, 2003).

Occasionally, the processing of conscious and nonconscious information was assumed to be accomplished by separate systems, as for example, the dorsal and the ventral stream of the cortical visual system (Milner & Goodale, 1995). Recent results, however, show that there is no single and uniform system for the processing of conscious, or the processing of nonconscious information, even in vision. Instead, it seems that nonconscious stimuli are processed partly like conscious stimuli, especially during early stages of processing, and that the processing diverges only in some respects, at later, reentrant or feedback stages (cf. Aron et al., 2003; Haynes, Driver, & Rees, 2005; Lamme & Roelfsema, 2001; Morris, Öhman, & Dolan, 1999; Ogmen & Breitmeyer, 2006; Pinel, Rivière, Le Bihan, & Dehaene, 2001).

These results suggest a shifting of the research focus towards two general questions: (a) the extent to which processing of conscious and nonconscious information contributes to any specific visual function, and (b) the identification of temporal stages characteristic of the processing of conscious and nonconscious visual information, respectively. These research questions have been addressed in a variety of forms, concerning the temporal dynamics of priming and masking, the comparison of semantic and sensorimotor processing, or the role of intentions for the processing of nonconscious information.

Temporal characteristics of priming

The temporal dynamics of processing visual information may be decomposed into an initial feedforward phase and later feedback or reentry mechanisms (e.g., DiLollo, Enns, & Rensink, 2000). According to the most widely held view, initial feedforward processing of visual information is independent of visibility for about 100-120 ms. During that time it proceeds irrespective of whether the information

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is backward-masked at a later point in time (e.g., Breitmeyer et al. 2004; Lamme & Roelfsema, 2001; Vorberg et al., 2003). Masking, though, plays a role in later, reentrant processing of stimulus information, estimated to have a latency of more than 100–120 ms. Masking thus arises, for instance, when top-down information, which has been activated in higher visual processing areas, is compared with the current, inconsistent visual input (DiLollo et al., 2000), or because connectivity changes between early stages of processing and higher visual processing areas (Haynes et al., 2005).

In line with the proposed temporal sequence of nonconscious feedforward processes preceding conscious reentrant processes, the impact of a masked prime presented less than 100 ms prior to a visible target can reverse if the interval between invisible prime and visible target exceeds 100 ms (Eimer & Schlaghecken, 1998; Vorberg et al., 2003; but see Verleger, Jaśkowski, Aydemir, van der Lubbe, & Groen, 2004). Schlaghecken and Sisman (this volume) present new data backing up their claim that the corresponding effects indeed reflect low-level properties of visual function: The temporal dynamics of masked priming are already present among young school children, a result standing in marked contrast to the evident lack of some executive control functions among the same children.

Temporal characteristics of masking

Another line of research has taken advantage of the temporal characteristics of masking itself. Plotting visibility as a function of the stimulus onset asynchrony (SOA) between masked prime and visible mask, metacontrast masking has been shown to typically follow a u-shaped masking function (Breitmeyer, 1984). Starting from an SOA of zero, visibility of the prime decreases up to an intermediate SOA of about 50-70 ms, and increases again with larger SOAs. Such temporal characteristics have been used to identify physiological markers of visibility (cf. Bridgeman, 1988; Haynes et al., 2005; Schiller & Chorover, 1966).

Van Aalderen-Smeets, Oostenveld, and Schwarzbach (this volume) present an improved methodology for disentangling perceptual and temporal influences in such markers. They use pseudo-mask conditions to control for temporal factors in MEG. Pseudo-masks are presented with the same SOAs after primes as masks. However, pseudo-masks do not diminish prime visibility in such extents as masks do. Therefore, differences between mask and pseudo-mask conditions provide a straightforward measure of visibility. Importantly, the corresponding activity differences are not the same which are observed by using the conventional approach.

Semantic vs. sensorimotor processing

A major debate in recent years concerns the question whether nonconscious information is processed semantically, or whether it is processed in accordance with a more restricted specific target set as part of an action plan (e.g., Kunde, Kiesel, & Hoffmann, 2003; Naccache & Dehaene, 2001). Most of the corresponding studies aimed at either demonstrating that semantic processing of nonconscious information is possible or, conversely at refuting this claim. However, semantic and sensorimotor processing may be less opposed to one another than they are assumed to be. For instance, semantic processing might invariably have a motor component, as proposed, for example, by models of embodied cognition (Barsalou, 1999). Yet, such a general account seems incapable of explaining the dissociations between the two processing domains.

Therefore, another approach has been taken by specifying side conditions which are responsible for whether semantic or sensorimotor processing predominates. Kiesel, Kunde, Pohl, and Hoffmann (this volume) show that sensorimotor processing might be a preferred strategy in situations with a small set of sensorimotor rules and targets which can easily be learned. As a consequence, novel primes not included in the target set (although semantically related to the targets) are not processed. The semantic mode, by contrast, is preferred in situations in which the target set is too large to allow an effective encoding of all relevant stimuli in advance of the experiment. As a consequence, participants choose a semantic processing mode, which also enables nonconscious non-target prime words to be processed.

The role of intentions

Concerning the quest for functional differences between visual processing of conscious and nonconscious information, early dual-process theories identified conscious processes as being intention-dependent and nonconscious processes as being intention-independent (Posner & Snyder, 1975). Recent studies, however, show that appropriate intentions are a necessary precondition for response activation effects of nonconscious primes, much in the same way as it is the case with conscious stimuli (e.g., Ansorge & Neumann, 2005). Such intentions may be implemented in at least two ways, as a preemptive control mechanism or as a trailing control mechanism.

In *preemptive control*, a small set of actions and corresponding stimulus conditions is set up in advance. If such a set of action triggers is available, nonconscious information is able to specify one of the required responses directly, that is, without the necessity for mediating conscious perception of the trigger stimulus. This mode of intention-dependent processing has also been termed direct parameter specification (DPS; Neumann, 1990), or action-triggering (Kunde et al., 2003; Kiesel et al., this volume).

Skalska, Jaśkowski, and van der Lubbe (this volume) demonstrate that preemptive control, or DPS, mediates the allocation of attention towards possible targets. At the same time, however, they also find a contribution by stimulus-driven capture. This finding raises the question how intention-mediated and stimulus-mediated control of attention interact, and how this interaction develops over time. Also, they show that barely visible information may be used in the intention-mediated control of attention (see also Scharlau & Ansorge, 2003). What is more, their data indicate that this control is independent of whether the primes are visible or not.

The contribution of Ansorge and Heumann (this volume) provides a first answer to the question raised by the paper of Skalska et al. They specify conditions under which DPS-like effects are found as opposed to conditions under which stimulus-driven effects are found. In particular, early processing (as reflected in the posterior contralateral negativity) appears to be independent of the current intentions, whereas an index of processing at a later point in time, response time, shows that the nonconscious prime is less effective the more it differs from the expected targets. These findings can be also interpreted within the feedforward/feedback-framework, for example, with the assumption that early phases of attentional capture are driven by salience mechanisms whereas in later phases, intention-dependent mechanisms kick in and may even dominate (e.g., Theeuwes, 2004). In fact, the findings might be an example of a form of intention-mediated control which is temporally *trailing*, as suggested by Schlaghecken and Sisman (this volume). Here, intention-mediated DPS effects are complemented by a low-level inhibitory mechanism. This mechanism is relevant in the feedback phase of visual information processing; it suppresses sensorimotor processing of nonconscious information when this processing is, in the time course of feedforward and feedback mechanisms, no longer supported by sensory evidence (see also Lleras & Enns, 2004; Verleger et al., 2004).

Perceptual consequences of masking

Modern masking research often aims at dissociations, that is, the demonstration that a prime is not consciously perceived, but nevertheless processed in the sensorimotor domain. By contrast, one classical approach to visual masking has been to detail the perceptual traces the masked stimulus leaves on the mask or the conscious percept (e.g., Neumann, 1978; Werner, 1935). Two of the present papers maintain this classical approach. Herzog, Lesemann, and Eurich (this volume) address how the percept of a stimulus is altered by a temporal and spatial interplay of two backward masks or of one forward mask and two backwards masks. The interesting observation is that a second mask trailing the first mask increases the visibility of a masked prime (or test stimulus) under a wide variety of conditions, including gray light masks as second masks. Theoretically, the data suggest that temporal masking characteristics as derived from two-stimulus sequences are not reflecting fixed properties of visual processing. Instead, these short-range or mid-range masking functions are qualified in the context of longer trains of visual events. The findings may thus have important bearings on the study of temporal characteristics of priming functions, too.

Scharlau and Horstmann (this volume) study two illusions which the prime may cause in a trailing stimulus, a temporal pre-dating of the mask and a perception of motion in later stimuli adjacent to the prime. Although both effects have been reported earlier and have been related to the same mechanism, attention-mediated facilitation, their correspondence to one another has so far not been studied. Indeed, they find that their spatial and temporal properties are remarkably similar, indicating a common level of perceptual microgenesis (cf. Ogmen & Breitmeyer, 2006). Thus, the contributions by Herzog et al. and Scharlau and Horstmann relate the feedforward/reentry-framework to a final, important topic, the microgenesis of perception.

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