

When masks reveal more than they hide: A review of Bachmann and Francis'
Visual Masking: Studying Perception, Attention, and Consciousness.

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Running head: A review of *Visual Masking*

Imagine a young woman at a masquerade ball holding a glittering and feathered mask over her face. Now think of *The Joker*, with his face concealed under a thick blanket of clownish make-up. What do these two instances have in common? They share the use of a *mask* to hide, obscure, or in some way transform the identity of the masked face. *Visual masking* is a laboratory tool developed by experimental psychologists, and now widely used across fields such as vision science, cognitive psychology, and cognitive neuroscience. Just like masks in everyday life, masks in the lab can be used to conceal or change the identity of the masked object, called the target. In other words, the presentation of one stimulus (the mask) close in space and/time to another stimulus (the target) affects the perception of the target. Talis Bachmann and Gregory Francis' book *Visual Masking: Studying Perception, Attention, and Consciousness* (2014) is about the rich and diverse history and current usage of this technique and tool in science. It has been said that, "A mask tells us more than a face" (A Study in Green, by Oscar Wilde). This sentiment is also true for visual masking: its utility is not limited to concealment. In fact, masking effects and patterns can actually reveal much about the temporal dynamics of conscious perception.

Why visual masking? The majority of research on form perception has focussed on how we perceive or recognise static features, objects and scenes. But visual perception is inherently dynamic: the brain is continuously confronted with changing visual input, and it can transform this information to form the coherent and stable visual scene filled with objects that we consciously perceive. Visual masking allows us insight into this process. This process of object formation in the face of dynamic and ambiguous input is especially critical under particularly demanding conditions that push the capacity limits of visual processing. For example, when walking down a crowded street, there are a large number of people, who are moving, and can

disappear temporarily behind other objects. From this, the brain needs to infer what stimulation belongs to a continuing object over time (e.g., the same person, despite changes in their appearance due to viewpoint variation and location), versus what belongs to distinct objects (e.g., two different people who might occupy the same location between successive glances). The brain therefore regularly has to draw an inference of whether visual input from a given location belongs to a continuous object identity through time or two (or more) separate objects. Visual masking, in particular backward masking and more modern forms such as object-substitution masking, allows us to probe these fascinating temporal dynamics.

Bachmann and Francis' book provides an excellent overview of the many decades of visual masking research. Visual masking as a field is smattered with at times divisive theoretical controversies, and to their credit, the authors deal with the literature even-handedly and without favor to a particular framework or theory. The ideal audience for this book would be someone seeking a comprehensive and unbiased introduction to and overview of the vast visual masking literature, such as a graduate student. In their judicious coverage of the field, among the major strengths of the book are that Bachmann and Francis highlight some of the pitfalls that have befallen the field, such as uncritical over-reliance and on particular interpretations for observed effects, and how individual differences substantively affect theoretical development in the field. The authors also identify the particular utility of visual masking in tackling some of the thornier research questions surrounding visual perception, cognition, and awareness, such as the quest for the neural correlates of consciousness. I will explain these in more detail below, after summarising the main topics that the book incorporates.

Visual Masking covers topics such as individual differences in masking effects, sensitivity, bias and criterion contents in masking, masking and attention, masking and consciousness, dependence of masking on the characteristics of target and mask stimuli and effects on mask perception, microgenesis and masking, new forms of masking, masking by transcranial magnetic stimulation (TMS), modelling and masking, applied aspects of psychobiology, and the psychophysics of masking. Relatively little time is devoted to theories of visual masking, although some are touched upon, as the authors point out that this is not their focus and a topic too large and cumbersome for the scope of the book. This book would be less suitable, therefore, to the more seasoned researcher, seeking, for example, in-depth critical analysis of findings or theoretical frameworks.

The first few chapters introduce the reader to the basic historical forms of masking, such as masking by light versus masking by pattern. The authors also differentiate forward masking, in which the mask precedes the target, from backward masking, in which the mask follows the target – the form of masking which has been far more extensively studied and theorised about. In Chapter 3, Bachmann and Francis reveal the ‘skeleton in the closet’ for many masking researchers: that there are individual differences in visual masking functions. While most researchers would readily accept (and observe) the presence of quantitative differences in performance across individuals, here the authors discuss the presence of meaningful *qualitative differences*. This, of course, throws a spanner in the works for simple and elegant theories of visual masking, since this means that without incorporating individual differences in the theory (and many do not), there are obvious limitations in the explanatory power of the theory (for a welcome exception, see for example (Massaro & Loftus, 1996)). That is, there are going to be systematic divergences between the

pattern predicted by the one-size-fits-all theory and that produced by at least some observers. It is worth noting, of course, this is not a limitation specific to visual masking, but an issue that plagues much of visual and cognitive theorising: the widespread assumption that meaningful individual differences are non-existent, or trivial variance to be averaged over. It is a credit to Bachmann and Francis that they tackle this critical issue so early in the book.

Furthermore, in Chapter 5, the authors examine some of the effects that occur prior to the presentation of the target and mask in backward masking and metacontrast masking paradigms that can affect target perception. That is, it is interesting that identical presentation parameters in a masking paradigm, when presented to the same person at different times, can yield different perceptual outcomes. For instance, a target letter presented for 20ms and then masked by the presentation of a spatially-overlapping pattern mask can be perceived by the participant on one trial, and then fail to be perceived on another trial. How so? For many years, such variability was not explicitly addressed, and perhaps assumed to reflect meaningless error variance. However, a recent body of work has examined how the participants' state of mind, as measured by neural indices such as the presence of alpha waves in the electroencephalogram (EEG), can reliably predict whether the target is perceived on a given trial or not. Moreover, there is evidence that this 'readiness' to perceive that target can actually be experimentally manipulated, for example, via entrainment to rhythmic pulsing of stimuli generating an expectation of when the target should appear (e.g., Mathewson, Fabiani, Gratton, Beck, & Lleras, 2010). Such issues are of course, not unique to visual masking, but the visual masking literature is a useful microcosm to consider these issues and how they have been explicitly addressed, and the authors give a nice summary of this research in this section.

Next Bachmann and Francis review the ‘new kid on the block’: object substitution masking (OSM), in which masking is produced by the delayed disappearance of a four-dot stimulus that appears simultaneously with, and does not spatially overlay the target. OSM was first documented and named in 1997 (Enns & Di Lollo, 1997), and more fully mapped out in 2000 (Di Lollo, Enns, & Rensink, 2000), which is a relatively recent addition to the long and rich history of visual masking spanning much of the 20th Century (Breitmeyer & Ögmen, 2006). When OSM was first introduced, its novelty and uniqueness among forms of visual masking was emphasised by its discoverers according to two main criteria: (1) the role of attention, and (2) the role of re-entrant neural processing in OSM. With respect to (1), it has long been touted as a hallmark of OSM that masking magnitude interacts with attentional demands, such that the greater the number of distractor objects that are presented simultaneously with the target, the larger the masking effect, and critically, that the distribution of attention was critical in order for masking to be observed. In other words, a target presented without distractors, would not produce OSM. Historically, it was taken for granted that other forms of masking, such as backward pattern masking and metacontrast masking, which were thought to operate at earlier perceptual levels, were immune to the vagaries of visual attention. This reflected the historical consensus in the field: that visual attention affected only relatively ‘late-stage’ processing, and not basic visual processing. This, of course, is not the case and it is now appreciated that visual attentional effects operate even at very early levels of visual processing (e.g., Williams, Visser, Cunnington, & Mattingley, 2008), and it has been shown that other forms of masking are also modulated by visual attention (e.g., Boyer & Ro, 2007; Tata, 2002). Moreover, even the purported ‘hallmark’ of OSM: the interaction between trailing mask duration and set-size (number of items – a proxy

for attentional demands) has come into question (Argyropoulos, Gellatly, Pilling, & Carter, 2013), and is only observed under particular conditions (Camp, Pilling, Argyropoulos, & Gellatly, 2015), and there is clear evidence that OSM occurs even for individually-presented targets (Filmer, Mattingley, & Dux, 2015). Chapter 6 provides a good overview of how the role of attention has been conceptualised in OSM.

In relation to (2), Vince Di Lollo and colleagues offered an explanation for OSM in terms of the neural dynamics of re-entrant processing. Specifically, Di Lollo (Di Lollo, 2010; Di Lollo et al., 2000) conceptualised OSM as reflecting a mismatch between descending signals from frontal regions representing the target, and the feedforward information in more posterior regions (e.g., V1) pertaining to the trailing mask, which is resolved in favor of the stronger feedforward input. Di Lollo et al. (2000) also developed a computational model (CMOS) designed to articulate the precise machinations of these re-entrant processes, and the role of attention, in OSM. In this chapter, Bachmann and Francis insightfully point out that at times Di Lollo's explanation for OSM has been somewhat uncritically accepted as the inconvertible mechanism underlying OSM. Di Lollo's enthusiastic embrace of re-entrant-processing reflects the zeitgeist at the time for throwing off the shackles of the historically narrow and rigidly 'feedforward' view of visual processing conforming to single hierarchy of visual processing, and appreciating the role of re-entrant or feedback processes in vision, particularly in rendering object representations accessible to visual awareness (e.g., Lamme & Roelfsema, 2000). However, despite some general evidence suggesting that re-entrant activation of V1 (Kotsoni, Csibra, Mareschal, & Johnson, 2007), and that frontal and V1 regions are broadly implicated in masking (Weidner, Shah, & Fink, 2006), there is a dearth of evidence to support Di

Lollo's precise model. In fact, even CMOS has come under scrutiny for not truly engaging re-entrant processes as its core (Pöder, 2012). It should of course be noted that Francis was among the main critics of Di Lollo's model at the time (Francis & Hermens, 2002), and that Bachmann is a proponent of another model of visual masking, *perceptual retouch* (Bachmann, 1984, 1994, 2005). But this potentially vested interest does not distort their coverage of these issues. Instead, Bachmann and Francis' critical analysis is sharp and on-point, and they do not advocate for their own models at this juncture, but instead merely rightly point out the limitations in what has become the dominant explanation of OSM. I think that this is very important to do, because a new reader of the field could well be forgiven for concluding that the empirical evidence for Di Lollo's model was stronger, given the way it is taken as a true starting point for a study (e.g., Bouvier & Treisman, 2010).

Furthermore, another issue that has been debated in OSM is the level of processing of the masked target. Some studies claim that OSM curtails all but basic featural processing (Chen & Treisman, 2009), whereas we have found evidence for much advanced processing, through to the level of abstract meaning (Goodhew, Visser, Lipp, & Dux, 2011). Bachmann and Francis avoid taking a side of this debate, and instead just note the use of OSM to study implicit visual and cognitive processing.

Chapter 7 of the book tackles the use of masking (backward masking, in particular) in the search for the neural correlates of consciousness. This section identifies masking as a useful tool in this quest, because it allows for consciousness to be decoupled from changes in stimulus presentation. As noted earlier, even with identical presentation parameters, participants can sometimes perceive the target and sometimes fail to perceive it. The fact that this occurs despite identical physical

stimulation, clarifies the interpretation of any neural correlates that differ between these two instances: they must reflect the machinations of visual awareness, and do not reflect any confounding differences in presentation parameters. This sort of commentary is excellent – it provides the overarching motivation for ‘why visual masking at all?’ I do feel, however, that this sort of context could have been communicated earlier for the uninitiated reader. As someone intimately familiar with the literature of visual masking, reading this book felt like cosying up with a well-loved photo album: I knew where it was going, and where it was left implicit, I had the broader understanding of what was going in order to enrich the narrative. But for an audience like me, this book is preaching to the converted. I think, therefore, that one thing it could have done earlier in the book, more centrally and comprehensively was to *explicitly* provide the rationale for visual masking, to stimulate excitement and incite the fascination with visual masking that we as active researchers in the field implicitly share, to better encourage those who might be encountering it for the first time.

I recall an incident while I was a student in which one of my most respected mentors became indignant when someone referred to him as an ‘attentional blink researcher’, because he had conducted some very seminal work on attentional visual attention and cognitive control, often employing the attentional blink paradigm to do so. He considered that an insult, and emphasised to me that one should never cast themselves as a researcher of a paradigm, but as a specialist of particular psychological process (such as attention or perception), and one should always select the best tool or technique to answer a given research question about that process, rather than being wedded to any given paradigm. Exclusively researching a paradigm for its own sake meant one was guilty of becoming mired in minutiae, losing the

forest for the trees. Bachmann and Francis' book is peppered throughout with wonderful insights into the utility of visual masking, identifying its advantages and potential pitfalls, and explains the knowledge that this has provided to us about visual perception and attention, and the sorts of questions for which it can continue to be valuable in the future. These insights, however, could have been better sandwiched between, say, an introduction and conclusion overview sections that more compellingly made the case for where visual masking fits in the broader study of visual perception and cognition in order to broaden the potential appeal of the book.

Chapter 8 addresses masked priming and unconscious processing. Here the authors judiciously provide a cautionary note to the reader about the interpretation of such studies. The authors point out how at times researchers have placed avid faith in the notion that visual masking is completely effective in suppressing targets from visual awareness, without always being cognisant of wide variability in mask effectiveness. Simply because a stimulus is presented briefly and masked does not always prevent it from reaching conscious awareness, although sometimes visual masking is applied and interpreted as though this is the case. This is particularly noteworthy in relation to object-substitution masking, in which suppression is usually less severe than for other types of visual masking. For example, in one study of 'implicit' processing of the target in OSM, in the masked condition, accuracy was 70% - well-above the chance-level performance of 50% (Reiss & Hoffman, 2006). Yet these trials were all lumped together in the analysis as 'masked' trials, thus clouding the interpretation of implicit processing (for a review, see also Goodhew, Pratt, Dux, & Ferber, 2013).

Continuing along this theme, Bachmann and Francis explore how masking depends on the visual characteristics of the target and mask stimuli in Chapter 9. This

section tips its hat to Herzog and Koch's (2001) seminal paper on how the properties of an invisible masked object can modify the visible features of the mask (called feature inheritance or feature attribution). Chapter 10 is devoted to the stages of visual processing as revealed by masking, while Chapter 11 examines novel approaches to visual masking. Chapter 12 then focusses on one in particular: masking by transcranial magnetic stimulation (TMS). TMS applied to an occipital cortical area results in a suppression of visual perception. Here the authors point out that despite interfering with normal neural processing, the effect of TMS is typically studied on behaviour only, but a fuller understanding could be provided by also examining the effect of TMS on neural processes themselves (such as on EEG). In the final few chapters, the book explains the theoretical accounts and models of visual masking (Chapter 13), documents psychopharmacological and genetic factors in masking (Chapter 14), and highlights some of the applied aspects of masking research, in disciplines such as medicine and technology. For example, an extensive literature has emerged around using visual masking to study impairments in visual processing that characterise schizophrenia. This trend began in decades ago in the 1970s and 1980s using backward pattern masking, first with a focus on differences in visual processing time, and more recently encompassing also metacontrast masking as a tool to study selective deficits in magnocellular and dorsal-stream function that are believed to be core to the disorder (e.g., Herzog & Brand, 2015).

One somewhat blinkered but seductive and therefore widespread conceptualisation of visual masking is that it is revealing some inherent flaws or limitations in the system of visual processing. In the way that masking studies are often designed, participants give an incorrect answer about the presence or identity of the target on (successfully) masked trials. But this does not necessarily have to reflect

an intractable limitation in the resolution of visual processing. Indeed, a number of studies reveal that at times, stimuli presented at the same rate can yield ‘accurate’ perception of the target, when they are presented in such a way as to encourage treating the target and mask as distinct, such as the target and mask sharing some properties in common versus not (Goodhew, Edwards, Boal, & Bell, 2015; Luiga & Bachmann, 2008; Moore & Lleras, 2005), or such that when it is easier to segment the mask from the target due to systematic structure in the mask (Coltheart & Arthur, 1972). Moreover visual perception is a process that has been honed over millions of years of evolution for the organism’s survival, and our subjective sense of our perceptual construction of the world around us is so seamless. An alternative way of conceptualising visual masking, particularly forms such as OSM are that they reflect the functioning of adaptive perceptual mechanisms. The mechanisms that unite objects over time and thus make us susceptible to visual masking, are the very same ones that allow us to perceive object identities as continuing over time. If the system did not do this, while we would escape visual masking, every time a friend walked behind a tree and then emerged on the other side, we would perceive this as two distinct objects, rather than two instances of the same object. This should be kept in mind in the study of visual masking: the presence of masking does not necessarily highlight intractable flaws or limitations, instead it offers a window into visual perception and cognition, processes that serve us well in everyday tasks, allowing us to navigate the world around us, drive a car, read a book, and recognise a friend across different perceptual instances.

In conclusion, Bachmann and Francis’ book *Visual Masking* provides an excellent introductory overview to the field of visual masking techniques and their use to answer questions about visual perception and cognition. Its coverage is

comprehensive and even-handed. The intended audience is those relatively new to the field of visual masking, which it by and large it is well-suited for, but could have further emphasised why visual masking is such a useful technique, and what it tells us about visual perception. After all, visual masks can reveal more about perception than the objects they obscure.

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