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# Masked priming for the comparative evaluation of camouflage conspicuity

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ABSTRACT

Human observer test and evaluation of camouflage patterns is critical for understanding relative pattern conspicuity against a range of background scenes. However, very few validated methodologies exist for this purpose, and those that do carry several limitations. Five experiments examined whether masked priming with a dot probe could be used to reliably differentiate camouflage patterns. In each experiment, participants were primed with a camouflaged target appearing on the left or right of the screen, and then made a speeded response to a dot probe appearing on the same (congruent) or different (incongruent) side. Across experiments we parametrically varied prime duration between 35, 42, 49, 56, and 63 ms. Results demonstrated that as prime duration increased, a response time disadvantage for incongruent trials emerged with certain camouflage patterns. Interestingly, the most conspicuous patterns showed behavioral differences at a relatively brief (49 ms) prime duration, whereas behavioral differences were only found at longer prime durations for less conspicuous patterns; this overall results pattern matched that predicted by a visual salience model. Together, we demonstrate the viability of masked priming for the test and evaluation of camouflage patterns, and correlated outcomes for saliency models and primed object processing.



## 1. Introduction

Camouflage offers civilians and military personnel a first level of concealment against detection by effectively emulating the colors and patterns of a local background (Cuthill et al., 2005; Merilaita and Stevens, 2011). In military contexts, the test and evaluation of prospective camouflage patterns is a costly and time consuming process, typically reliant on outdated or unstandardized human observer methodologies (Peak et al., 2006). Recent research has suggested value in complementing existing techniques with image processing and modern cognitive science approaches including eye tracking, virtual reality, and event-related potentials (ERPs) (Augustyn et al., 2008; Eddy et al., 2015; Stevens and Cuthill, 2006). In the present study, we extend this recent research by examining whether camouflage patterns presented in a manner limiting explicit processing might differentially orient exogenous attention as a function of objectively assessed (i.e., using salience maps) camouflage conspicuity. If so, this technique may prove valuable for increasing the experimental rigor and reducing the time and cost of current camouflage test and evaluation practices reliant on human observers.

## 2. Camouflage test and evaluation

Military research organizations are continually engaged in the test and evaluation of prospective camouflage patterns, seeking to maximize concealment while also considering the background heterogeneity of diverse operational contexts. Human factors and ergonomics practitioners rely strongly on observer testing standards issued by the North Atlantic Treaty Organization (Peak et al., 2006). This methodology involves showing an observer a sequence of images containing a camouflaged human target, with each successive image depicting the target at a closer distance. The observer has a 14-s time window per scene to detect a target, and the

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primary outcome is the distance at which observers achieve a 50% detection rate. Camouflage patterns that require presentation at closer distances to achieve 50% detection indicate greater concealment effectiveness. While representing a substantial step forward toward standardizing camouflage test and evaluation methodologies, the technique has several disadvantages; these include the lack of null (target absent) trials, near-ceiling detection effects due to the long exposure duration, subjectively determined target presence, and time-consuming field photography collection and test administration. Furthermore, research has demonstrated limited sensitivity of this technique in differentiating the conspicuity of camouflage patterns within a given pattern class (e.g., desert, woodland, transitional) (Rock et al., 2009).

To accommodate these limitations, recent research has begun to explore the value of more advanced methodologies for camouflage test and evaluation. For instance, Lin and colleagues demonstrated that certain eye-tracking metrics, including first saccade amplitude and fixation duration, can objectively differentiate camouflage pattern conspicuity (Lin et al., 2014). Eddy and colleagues demonstrated that the P300 component of event-related potentials (ERPs) can also objectively differentiate camouflage pattern conspicuity, with smaller amplitude and later latency P300's when viewing less conspicuous patterns (Eddy et al., 2015). In each of these cases, the authors demonstrate potential value in novel, objective metrics for quantifying camouflage conspicuity. We extend this recent research by evaluating the utility of an experimental paradigm incorporating exogenous attention orienting via masked priming, and the dot-probe methodology.

## 3. Attention orienting and dot-probe

Spatial attention involves the overt (endogenous) and covert (exogenous) orienting of cognitive resources toward particular regions of space (Posner, 1980). Overt orienting is guided by top-down control to strategically redirect the head and/or eyes toward regions of space that are of interest. In contrast, covert orienting is considered automatic and outside of conscious, strategic control, for instance as elicited by the abrupt onset of a salient stimulus (McCormick, 1997; Mulckhuyse and Theeuwes, 2010). To trigger the covert orienting of spatial attention, we used masked priming. Masked priming involves the very brief presentation of a stimulus that is flanked by forward (preceding the prime) and backward (following the prime) masks, typically in the form of a scrambled incoherent version of the prime (Forster et al., 2003). Critically, masked priming presents the prime for such a brief duration that participants are largely unaware of its presence or characteristics. The masked prime and brief exposure duration limits the extent of processing, largely limiting explicit processing of the prime. In this manner, masked priming can reveal the influence of very early perceptual processes (Dehaene et al., 2006), though prime duration has a large impact on the extent of perceptual and semantic processing of a prime. For instance, Eddy and Holcomb manipulated masked picture prime duration between 30, 50, 70, and 90 ms (Eddy and Holcomb, 2010). They found evidence that semantic processing of primes increases in a linear manner at lengthier prime durations (50–90 ms), and that the prime does not become perceptible to participants until approximately 70 ms. In the present study, we leverage masked priming to orient spatial attention in particular directions, while limiting the influence of conscious-level strategic processes. Specifically, we prime participants with a camouflage target with variable conspicuity as determined by salience maps, and then measure the impact of this priming on a subsequent dot-probe response.

The dot probe task is a commonly used method for measuring the impact of an exogenously cued shift of spatial attention. Predominantly used in the emotion sciences to assess covert orienting toward threatening stimuli (e.g., angry faces), the dot probe involves responding to the location of a probe that is either congruent or incongruent with the location of a preceding prime (Carlson and Reinke, 2008; MacLeod and Mathews, 1988). The premise is that an exogenous shift of attention toward a particular region of space will cause faster responses to a dot probe appearing in that same region of space, relative to it appearing in a different region of space. Though the dot probe technique has its origin in the emotion sciences literature, it has been applied across a variety of stimuli including objects of addiction, portions of faces, frequency-specific visual flicker, visual motion, and food cues (Bar-Haim et al., 2006; Bauer et al., 2009; Field et al., 2004; Kemps et al., 2014; Shimojo et al., 1997). The notion of priming regions of space associated with a subsequent action is also described by the Direct Parameter Specification (DPS) model (Klotz and Neumann, 1999; Klotz and Wolff, 1995). In this model, subconscious primes can facilitate subsequent motor responses if they are relevant to a top-down response goal (Ansorge et al., 2002; Scharlau and Ansorge, 2003).

## 4. The present study

The present research extends earlier work on assessing camouflage conspicuity in three primary ways. First, we reduce the contribution of conscious-level strategic processes by leveraging masked priming techniques that present visual stimuli briefly enough to limit explicit processing of the prime. The commonly used NATO technique relies on subjective, conscious-level strategic processes, with yet-unknown influences on camouflage target detection (Van den Bussche et al., 2009).

Second, we make direct comparisons between our human observer data and algorithmically generated salience map data. This approach affords understanding how salience maps compare to human behavior when processing is restricted to relatively low-level stimulus features (Toet, 2011). Salience maps are produced through a computational approach that topographically maps the local conspicuity across a visual scene; local conspicuity is typically determined by relative color, brightness, and feature orientations (Itti and Koch, 2001). The extent to which a local region differs along one or more of those dimensions determines its visual salience. This biologically-inspired model conforms with predictions made by feature integration theory (Treisman and Gelade, 1980) and the guided search model (Wolfe, 2007), specifically that understanding low-level image features alone can produce realistic, human-like search behavior. In other words, salience maps can predict a high degree of human visual behavior. For instance, eye fixations are more likely to occur in salient versus control regions, and more fixations occur on salient regions than expected by chance alone (Foulsham and Underwood, 2008; Parkhurst et al., 2002). Of course, conspicuity-based visual salience alone cannot account for all human visual behavior, and no models of visual attention can perfectly predict natural behavior (Rothkopf et al., 2007; Tatler et al., 2010). These models do, however, provide a reliable mechanism for producing quantitative understandings of relative pattern conspicuity; the extent to which these understandings reliably predict pattern detection outcomes in the real world is currently unknown, a limitation worth considering.

Finally, we use an experimental methodology that incorporates both target present and absent (null) trials, reducing the possibility that participants will come to realize omnipresent targets and develop strategic response strategies. For hypotheses, we predict slower response times when a dot probe appears in a location incongruent with the primed location. This should especially be the case when camouflage patterns are relatively conspicuous