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Scene masking is affected by trial blank-screen luminance

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ABSTRACT

The current study investigated the role of the inter-screen luminance contrast (ISLC) of trial blank screens between target and mask screens in visually masking scenes. Participants performed a scene gist recognition task in which we varied mask strength, blank screen luminance, and stimulus onset asynchrony (SOA). Results showed that the more luminant white, and less luminant black, blank screens produced greater masking than intermediate luminance gray blank screens adjusted to the mean luminance of the target screens, specifically for black screens at SOAs < 36 ms and for white screens at all SOAs. Our findings suggest that researchers interested in controlling for 'extraneous factors' should use gray blank screens as they eliminate any contribution of the ISLC component of masking. However, researchers interested in creating and examining differences in processing at early SOAs (< 36 ms) should use black blank screens as these were shown to increase variation in the SOA function.

1. Introduction

Recently, there has been a surge in interest in studying real world scene perception [1] often using photographs of scenes as stimuli, and investigating issues such as scene gist perception, attention in scenes, and memory for scenes. These studies often involve the use of visual masks to manipulate the time course of processing. The study of visual masking has a long, rich, and deep history (for reviews, see [2-5]). However, much research on visual masking has used relatively simple stimuli (e.g., letters, disks, or sinusoidal gratings) and so the degree to which basic principles of visual masking derived from these studies scale up to the masking of photographic real-world scenes and meaningful tasks is not well understood (cf. [6-10]). Consequently, the use of visual masks in *scene perception* research often goes unexplained, with little if any rationale given for selecting various temporal or spatial masking parameters. The current exploratory study addresses a rather surprising gap in our knowledge of visual scene masking: Does it matter whether the blank screen shown before and after the target and, after the mask, creates *inter-screen luminance contrast* (ISLC[2]) with the target and mask, and if it does matter, what is the nature of this effect? The answers to these basic questions could potentially influence the interpretation of the results of scene perception studies using visual masks.

In addition, the answers to these questions have implications for real-world technology applications. For example, the recent production of ultra-high-definition displays (e.g., 4K televisions and monitors) rely on increased luminance and contrast levels. The present

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[2] The term inter-screen luminance contrast (ISLC) refers to the discrepancy in mean luminance between target/mask trial screens and the blank screens in a typical masking experiment trial.

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research could contribute to a better user experience for consumers of this technology by enriching understanding of how display luminance and contrast impacts users' perception of rapid changes presented on such displays (e.g., scene cuts and briefly flashed imagery). Similarly, emerging 3-D and virtual reality technologies capitalize on stereoscopic vision via rapid alternation of images to each eye. The present study could inform how variance in luminance and contrast of stereoscopic imagery impacts the 3-D and virtual reality user experience. Lastly, some night vision technology (e.g., image-intensifier applications that are often employed by the military) collects and amplifies ambient light to generate the images projected to the user's retina. As such, rapid changes in ambient light (e.g., [17]) may produce similar masking effects observed in scene perception experiments. The present study may therefore inform future development of night-vision technology software in terms of how the equipment processes rapid changes to ambient light to mitigate masking of the image projected to the user's eye.

In a typical scene masking paradigm, the experimental subject is presented with black, white, or neutral gray blank screens during the inter-stimulus intervals (ISI) that occur before, in between and, after stimulus presentations. In fact, whether the ISI blank screens are black, white, or neutral gray is generally not reported in scene perception studies, though it is often illustrated in figures showing the events in a trial. From such evidence, it appears that black blank screens are a common default option [6,7,11,12]. However, many researchers choose an alternative technique of presenting a neutral gray blank screen, set either to the middle gray level (e.g., 127 pixel value of an 8 bit image), or matched to the mean luminance value of the target and mask images [13,14]. Still other perception research has used white backgrounds (e.g., [15,16]). Because no explanation is usually given for choosing to use black, white, or neutral gray blank screens, it appears that the decision to use a neutral gray blank screen is made if the researcher is concerned about the effects of ISLC between the blank screens, target, and mask. However, to our knowledge, no study has been done to determine whether global luminance contrast between the blank screens, target, and mask actually affects scene image masking results, and if so, how.

A black blank screen, together with a higher mean luminance target and mask, may affect scene masking by creating ISLC at the on- and offset of the target, the onset of the mask (i.e., the offset of the black ISI screen), and the offset of the mask (i.e., the onset of a second black screen). The same could be true for white blank screens paired with a lower mean luminance target and mask. It therefore seems plausible that the ISLC produced at these points in time could potentially cause differences in low-level masking processes. Conversely, an intermediate (or mean) luminance gray blank screen, relative to black or white blank screens, would greatly reduce such ISLC. Therefore, any low-level masking differences caused by ISLC would be minimized by using mean luminance gray blank screens. Past research using simpler stimuli [17,18] suggests that the different levels of ISLC produced when using mean luminance gray versus contraluminant blank screens (relative to target and mask screens) could indeed produce important perceptual differences between the two methodologies.

In a classic study, Crawford [17] investigated the time course of dark adaptation, by briefly presenting a target either before or after a luminant disk conditioning-stimulus that served as a mask. Crawford's research revealed several findings relevant to the exploratory predictions of the current study. First, the more rapidly the conditioning field offset followed the test stimulus onset (and vice versa), the stronger the masking. This suggests that closer temporal proximity of luminance changes causes greater masking. Second, increased luminance contrast between the test and conditioning stimuli resulted in stronger masking. Third, Crawford compared the use of a black disk on a gray background versus a white disk on a gray background and found no differences between the two conditions. This suggests that the magnitude of the contrast, not its direction, is responsible for the masking effects. These results were replicated in a follow-up study using detection of objects in natural scenes as the test stimuli following exposure to the same conditioning stimuli as in the original study.

In sum, Crawford [17] attributed the observed masking effects to the time course of the conditioning stimulus offset, as well as the magnitude of the luminance contrast between the conditioning and test stimuli, but not its direction. Crawford [17] argued that, in the case of backward masking, the "relatively strong conditioning stimulus overtakes the weaker test stimulus on its way from the retina to brain and interferes with its transmission" (p. 285). This concept was echoed later by Breitmeyer and Kersey [19] who similarly found that the timing of the offset of the mask relative to the onset of the target could affect masking of the target. Like Crawford [17], they showed that shorter times between target onset and mask offset resulted in more effective masking.

A recent study by Tucker and Fitzpatrick [18] provided physiological evidence (from the primary visual cortex of the tree shrew) of visual masking via stimulus onset and offset. Using single cell recording techniques, the authors found that a sudden increase or decrease in mean luminance of a visual stimulus was accompanied by a decrease in cortical activity. Similar to the performance data from the human psychophysical results of Crawford [17], the authors found that the visual cortex cells were sensitive to the magnitude of a luminance change (i.e., contrast), but not its direction (either more or less luminant). Thus, larger luminance swings produced larger inhibitory responses of the cells, whereas mean luminance stimulus changes did not.

2. Exploratory hypotheses

2.1. Blank screen contrast

Our review of the literature provides a basis for predicting differences in masking between black or white blank screens versus neutral gray blank screens (whose mean luminance is the same as that of the target and mask stimuli). We predict that mean luminance gray blank screens should reduce masking effects by minimizing the ISLC between blank screens, target, and mask. Conversely,