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Can you perceive ensembles without perceiving individuals?: The role of statistical perception in determining whether awareness overflows access

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ABSTRACT

Do we see more than we can report? Psychologists and philosophers have been hotly debating this question, in part because both possibilities are supported by suggestive evidence. On one hand, phenomena such as inattentional blindness and change blindness suggest that visual awareness is especially sparse. On the other hand, experiments relating to iconic memory suggest that our in-the-moment awareness of the world is much richer than can be reported. Recent research has attempted to resolve this debate by showing that observers can accurately report the color diversity of a quickly flashed group of letters, even for letters that are unattended. If this ability requires awareness of the individual letters' colors, then this may count as a clear case of conscious awareness overflowing cognitive access. Here we explored this requirement directly: can we perceive ensemble properties of scenes even without being aware of the relevant individual features? Across several experiments that combined aspects of iconic memory with measures of change blindness, we show that observers can accurately report the color diversity of unattended stimuli, even while their self-reported awareness of the individual elements is coarse or nonexistent—and even while they are completely blind to situations in which each individual element changes color mid-trial throughout the entire experiment. We conclude that awareness of statistical properties may occur in the absence of awareness of individual features, and that such results are fully consistent with sparse visual awareness.

1. Introduction

Two of the most central topics in visual cognition are conscious awareness and visual memory, yet how these capacities relate to each other is still not entirely clear. Do we see more than we can remember and report? One possibility is that we are aware of only that to which we attend and/or that which is encoded into memory. Another possibility, however, is that awareness "overflows" what is readily accessible in memory, such that in-the-moment percepts are richer than can be reported. The debate between these possibilities has engaged both psychologists and philosophers in recent years, in part because both possibilities seem to be supported by suggestive evidence.

1.1. Empirical measures of the richness of visual awareness?

On one hand, several stunning phenomena of visual awareness demonstrate that even highly salient events right in front of your eyes may often go unnoticed unless they are attended. For example, in demonstrations of inattentional blindness (e.g. Mack & Rock, 1998; Most, Scholl, Clifford, & Simons, 2005), many people fail to perceive stimuli such as a gorilla walking through a scene (Simons & Chabris, 1999) or a bright red cross traversing a display otherwise filled only with black and white shapes (Most et al., 2001), when attention is otherwise engaged. Such failures of awareness occur even when observers have instructions to immediately report unexpected events (in the moment, while they are occurring), confirming that this is a phenomenon of perception rather than memory (Ward & Scholl, 2015).

Similarly, in demonstrations of change blindness (e.g. Simons & Rensink, 2005), people fail to detect large changes made to scenes, when those changes do not draw attention. In one of the earliest and still most striking such demonstrations, viewers read text while having their eyes tracked, and failed to notice that every

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letter in the display was an 'X' except for the few near their fixation, as long as the changes were made during saccades (McConkie & Zola, 1979). Both sorts of phenomena seem readily explained by appeal to the sparse nature of visual awareness (though some philosophical work has challenged this assumption, e.g., Noë, Pessoa, & Thompson, 2000). In inattentional blindness, for example, attention may serve as a sort of gateway to awareness, such that we are not aware of unattended stimuli (such as the gorilla or the red cross) in the first place, even though they may be processed unconsciously. Some change blindness phenomena may be similarly explained, via the assumption that attention (and thus awareness) is often confined to the foveal region of a display. In cases such as McConkie & Zola's experiments, we may still *feel* like we see normal English text in the periphery, but in such cases that is clearly a mistaken inference, since there are no real words there (until you fixate on this region of the 'text').

On the other hand, experiments examining iconic memory suggest that our in-the-moment awareness of the world is much richer than can be reported. In the classic demonstration of such effects (Sperling, 1960), observers viewed a quickly flashed array of letters, and then were asked to report them. When asked about all of the letters, observers were only able to recall a few, demonstrating a stark limit on reportability. Those few letters that were recalled could be influenced by a cue, however: if prompted to report a specific row of letters, observers could do so. Critically, this was true even when the cue appeared *after* the offset of the letters. In such cases, observers were still reasonably accurate at reporting the letters in the postcued row, but not the others. These and related studies (e.g. Sligte, Scholte, & Lamme, 2008; Vandenbroucke, Fahrenfort, Sligte, & Lamme, 2014) have been taken to support the existence of rich visual awareness: if only some letters are reportable, but all letters are *potentially* reportable based on a postcue, then this may suggest that observers are initially phenomenally aware of all of the letters, but that only some are subsequently encoded into a memory durable enough to support subsequent report (Block, 2011; cf. Phillips, 2011). In this 'rich awareness' perspective, observers are thus aware of all the letters in the display, and the role of the postcue is simply to prompt the observers to encode a subset of them into a more durable (longer lasting, but lower capacity) memory store. (As explored in the General Discussion, this inference relies on the assumption that it is not possible for the postcue to, for the first time, pull into awareness cued letters that have been only unconsciously represented until that point; cf. Sergent et al., 2013.)

1.2. Resolving the debate by measuring statistical perception?

Ironically, though the debate between sparse vs. rich views of visual awareness was prompted in part by empirical evidence that seemed to favor both sides, the debate has proven difficult to resolve precisely because there doesn't seem to be any empirical way to directly measure the existence or nature of phenomenal awareness when there is no durable memory encoding. After all, at its core this view assumes that the contents of this form of awareness *are not reportable* (unless transferred into subsequent memory stores that also support 'access consciousness'; Block, 2011), and it is difficult to directly measure something that even in principle cannot be reported or accessed.

Recent research has attempted to resolve this debate by taking a somewhat different approach—supposing that even while the letters themselves in such situations aren't reportable, some other properties of the initial rich conscious experiences may still persist and so be measurable. As in previous studies of iconic memory, Bronfman, Brezis, Jacobson, and Usher (2014) presented observers with a brief array of (now colored) letters. Observers were precued to a specific row of letters, and then a postcue signaled the position of a single letter to be reported from the cued row. (In this design, the precue serves to orient attention to only a subset of the letters, with the others being entirely irrelevant to this task and thus presumably unreportable—though these researchers never actually directly measured the ability to report any letters from the uncued rows, and so were not directly assessing iconic memory as in Sperling, 1960.) Performance when reporting the postcued letter then serves as a measure of the degree to which other manipulations may or may not change the degree of attentional focus on the cued row, as described below.

Critically, observers also had a second task—to report a statistical property of the *colors* of the letters (in either the cued row or the uncued rows). The colors of the letters could be sampled from either a narrow region of a color wheel (low color diversity) or from the entire color wheel (high color diversity)—as in Fig. 1A—and observers were asked to report whether the specified group of letters (from either the cued row or the uncued rows) had high vs. low color diversity. As depicted in Fig. 1B, the displays were designed so that the diversity of the cued row vs. the uncued rows could vary independently. Observers in this experiment were above chance when reporting color diversity even for letters that were unattended, and color diversity judgments for unattended letters did not impair observers' ability to report the postcued letter (thus confirming that attention was still focused on the cued row).

These results led Bronfman et al. (2014) to conclude that the color diversity judgments were being made without attention, presumably on the basis of residual information from the observers' initial rich visual experience of all of the letters. Supporting this view—and purportedly ruling out an account based on unconscious visual color processing—observers in this experiment claimed to have seen the colors themselves: observers were asked to report on each trial whether they "did not see the colors", "partially saw the colors", or "saw the colors well", and the results indicated that when observers claimed to have not seen the colors, they could not accurately report the color diversity. (In other experiments, observers had an "escape" button that they could press whenever they failed to perceive the colors, but they never made use of this option.) These results were thus presented as a clear case of visual awareness overflowing access and reportability, based on the residual reportability of a statistical property of the letters: because observers could report color diversity even for the uncued rows, they must have visually experienced all of the letters. As such, this demonstration has impressed some researchers as a "dramatic advance" and an "astonishing result"—counting as a fairly decisive resolution to the debate over sparse vs. rich visual awareness (Block, 2014, p. 445).

1.3. Ensemble representation

Color diversity in these experiments is a type of statistical summary of a display, as may be stored in an *ensemble representation*. Ensemble representations are statistical summaries of features at an abstracted level that collapse across local details. In experiments on such representations, observers view an array of objects, and must report some summary statistic of the array—such as the *average* size of an array of discs (Ariely, 2001). The typical result from such experiments is that observers are impressively accurate at reporting the summary statistic, while also being generally terrible at reporting properties of any of the individual elements in the array (for reviews see Alvarez, 2011; Haberman & Whitney, 2012). The ability to form and use such 'statistical summary representations' appears to be highly general, as observers are readily able to report statistical summaries of properties ranging from size (Chong & Treisman, 2005), motion direction (Dakin & Watt, 1997), and location (Alvarez & Oliva, 2008) to facial identity (de Fockert &