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We See More Than We Can Report: "Cost Free" Color Phenomenality Outside Focal Attention

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Abstract

The distinction between access consciousness and phenomenal consciousness is a subject of intensive debate. According to one view, visual experience overflows the capacity of the attentional and working memory system: We see more than we can report. According to the opposed view, this perceived richness is an illusion—we are aware only of information that we can subsequently report. This debate remains unresolved because of the inevitable reliance on report, which is limited in capacity. To bypass this limitation, this study utilized color diversity—a unique summary statistic—which is sensitive to detailed visual information. Participants were shown a Sperling-like array of colored letters, one row of which was precued. After reporting a letter from the cued row, participants estimated the color diversity of the noncued rows. Results showed that people could estimate the color diversity of the noncued array without a cost to letter report, which suggests that color diversity is registered automatically, outside focal attention, and without consuming additional working memory resources.

Keywords

phenomenal vs. access consciousness, visual working memory, attention, Sperling paradigm, iconic memory, summary statistics

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When presented with visual displays abundant with information, observers often report having a rich phenomenal experience that involves a multitude of visual items with a variety of continuous properties, such as shape and color. Nevertheless, when subsequently asked to report the identity of the items they perceived (e.g., letters within a letter array), observers' report is limited to only three or four of those items. As first shown by Sperling (1960), approximately the same output is obtained not only in whole report, but also in partial report of a row that is retro-cued a few hundred milliseconds after the stimulus disappears: This indicates the existence of high-capacity iconic memory that decays within about half a second (Sperling, 1960). This limitation in recall is due to the bounded capacity of the attentional system in transferring information from iconic memory to visual working memory, where it is rendered durable, resistant to perceptual interferences, and accessible for report. One issue that has become the focus of recent debate is the conscious status of visual information before it is transferred into working memory.

According to the rich-experience hypothesis proposed by Block, Lamme, and colleagues (Block, 1995, 2007, 2011; Lamme, 2006), visual consciousness arises

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during the early, high-resolution stage of visual processing that precedes the relatively late stage in which the attentional spotlight transfers information into durable working memory; therefore, the report does not exhaust the phenomenal experience. According to the impoverished-experience hypothesis (Cohen & Dennett, 2011; Dehaene, Changeux, Naccache, Sackur, & Sergent, 2006; Kouider, de Gardelle, Sackur, & Dupoux, 2010; Tye, 2010), conscious experience includes detailed information only about objects that are attended and transferred to working memory, along with generic (undetailed) or fragmentary information about objects at unattended locations. According to this view, the impression of having a rich visual experience is a hyper-illusion caused by the (almost) immediate availability of rich representations when one shifts attention toward unattended items—not unlike the incorrect impression that there is always light in the refrigerator because it is visible each time one opens the door (Cohen & Dennett, 2011; Kouider et al., 2010).

To back up this interpretation, de Gardelle, Sackur, and Kouider (2009) used a modified Sperling paradigm with degraded (low-contrast) letter arrays, followed by a partial-recall cue presented after the array was masked. In some trials, the array contained a rotated or flipped letter. They found that participants could not reliably recognize the pseudoletter if it appeared outside the cued row. This result can be interpreted as supporting the impoverished-experience hypothesis, according to which letters that do not receive attentional scrutiny are not perceived to the degree sufficient for a straight/rotated discrimination (Kouider et al., 2010). This interpretation, however, can be challenged on two grounds. First, as discussed by Block (2011), the degraded nature of the visual array (low-contrast letters and a precue mask) may have considerably reduced the capacity of iconic memory, making the 10% to 15% error rate in rotation detection not very surprising. Second, it is still possible that in the absence of transfer to a durable working memory store, the rotated letter was momentarily experienced but not encoded for later report (as hypothesized in *inattentional-amnesia* theory, according to which nonattended visual objects are experienced in the present but not encoded for later report; Wolfe, 1999). This second objection points to a methodological challenge to any experimental test that uses the lack of later report to demonstrate a lack of earlier experience. We label this the methodological *experience, lost-access* (*ELA*) problem.

The aim of the present research was to examine the sensitivity of observers to one type of information—color—which we believe to be part of the phenomenal character of seeing a visual array outside focal attention, and to offer a way around the methodological ELA problem. We focused on color information because it is a major component of visual phenomenology[1] and has been argued to be lost outside focal attention (Lau & Rosenthal, 2011). Consider being confronted, as in the Sperling paradigm, with a brief array of colored letters. Obviously, if we were to ask for a report of the letters' colors, we would encounter the same capacity limitation of three to four items (Luck & Vogel, 1997). It is possible, nonetheless, that for a fleeting moment, the rich color information was consciously experienced (as per the ELA hypothesis), but because of its transient nature, it rapidly became inaccessible for report (Block, 2007, 2011). Can we find a behavioral tool to verify the presence of such fleeting but informationally complex experiences, perhaps by probing a holistic aspect of the experience?[2]

Here, we set out to do this by relying on a type of summary statistic, which rapidly compresses the high-complexity information in the visual display into a binary low/high variable that may be registered and stored while the information itself decays. Recent research has shown that people can register average properties (size, orientation) of large sets of elements in the absence of focused attention (Ariely, 2001; Cavanagh & Alvarez, 2005; Chong & Treisman, 2003; Joo, Shin, Chong, & Blake, 2009; but see Myczek & Simons, 2008). For our colored array, such averaging of properties corresponds to detecting the average color at unattended locations. Accurate averaging of colors without attention, however, is not sufficient to distinguish the two hypotheses about the richness of experience, since it is consistent with an impoverished or blurry experience of the individual colors. Knowing that the average color is dirty yellow requires much less perceptual differentiation than experiencing vivid reds, greens, and yellows. Thus, to probe the claim that visual experience encompasses richer color phenomenology, we looked for a summary statistic that necessitates differentiation between the individual elements' colors.

To this end, we focused on the experience of color diversity (a measure of variability; see the Method). We suggest that (a) color diversity can be registered and reported without costs to the recall of cued letters and (b) the availability of color diversity is best explained as resulting from the fleeting experience of the underlying individual colors. The former is due to the fact that color diversity is a low-complexity summary, the storage of which is much easier than storing specific colors (Experiments 1–4). The latter follows from the fact that without a differentiated (albeit transient) representation of the colors, it is not possible to judge diversity.

Experiments 1 Through 4: Color-Diversity Judgments in a Variant of the Sperling Paradigm

To test our hypotheses, we used a variant of the Sperling paradigm with colored letters. Participants' primary task, for which they received error feedback, was to report a letter from a precued row of the array (randomly changed from trial to trial). The cue was exogenous and was presented before the onset of the array to orient attentional resources toward the letters that needed to be encoded into working memory. A secondary task (in some of the experimental blocks) was to estimate the color diversity of either the cued row or of the noncued rows. Participants were told that there was no correct or incorrect response to this subjective measure (no feedback was given).

Several critical results could support the presence of color phenomenology during the processing of the letter array. First, would participants show sensitivity to the color diversity of the noncued rows without a detriment to performance in the primary task of cued-letter recall? Second, would the color diversity of the noncued rows affect (or contaminate) the color-diversity judgments of the cued row?

Method

Participants. Thirteen participants completed Experiment 1, 9 completed Experiment 2, 9 completed Experiment 3, and 6 completed Experiment 4 (with no overlap of participants between experiments). All participants were undergraduate students recruited through the Tel Aviv University Psychology Department's participant pool, were naive to the purpose of the experiment, and were awarded either course credit or a small financial compensation (40 NIS; equivalent to about $10). All participants had normal or corrected-to-normal vision.

Materials. Stimuli were generated using MATLAB (The MathWorks, Natick, MA) and were presented on a gamma-corrected ViewSonic (Walnut, CA) 17-in. monitor, which participants viewed at a distance of 41 cm while resting their head on a chin rest. The screen resolution was 1,024 × 768 pixels, and the monitor had a refresh rate of 60 Hz. We used an array of 24 colored letters (4 rows × 6 columns) on a black background. Each letter in the array was randomly sampled from nine possibilities[3] and was uniformly colored. The diversity of the letters' colors in the cued row and in the noncued rows was either low or high, and varied independently. In all experiments, high diversity was achieved by independently sampling each letter's color from all 19 possible colors on a color wheel (see Supplemental Method and Results in the Supplemental Material available online for a list of colors). In Experiments 1, 2, and 4, the low-diversity condition was achieved by limiting the sampling range to only six adjacent hues on the color wheel, in a range that changed from trial to trial (Fig. 1a). In Experiment 3, the low-diversity condition was obtained by sampling six colors chosen randomly from across the entire color wheel. This was done to equate the average color and color range between the low- and high-diversity conditions and to set the task at a higher level of difficulty than in the first two experiments. In all experiments, there were four possible color-diversity combinations: two in which the color diversity of letters in the cued and noncued rows was congruent and two in which it was incongruent (Fig. 1b).

Procedure. At the beginning of each trial, participants fixated on a center cross (200 ms), after which a 300-ms visual spatial cue (a white rectangle) appeared alone against a black background to cue the task-relevant row (see Fig. 1c); which row was task relevant varied randomly between trials. The cue was followed by the 24-letter array appearing for 300 ms, followed by a 900-ms blank interval. A letter-sized white square then appeared at the location of one of the letters (also chosen randomly on each trial) within the task-relevant row. The main task was to report the letter that had occupied the cued location, using a nine-key response box (with keys marked by all possible letters in the choice set). A beep signaled an incorrect response. After reporting the letter, participants were further asked to estimate the color-diversity level (low or high) of either the cued row or of the noncued three remaining rows. Every 60 trials, participants received a short, self-terminated break; after 400 trials, participants were given a 5-min mandatory break.

All four experiments started with a practice block (70 trials) with letter recall only, followed by several experimental blocks (two in Experiments 1, 3, and 4 and three in Experiment 2; see Supplemental Method and Results for details). Initially, participants were told only to remember the letters in the cued row and report the cued letter. After completing the practice trials (Experiment 1), or the practice trials and the first experimental block with letter recall only (Experiments 2 and 3), participants were shown representative examples of low and high color-diversity levels (two rows of 18 letters each, one low in diversity, the other high) and were asked to repeat the letter-recall task, with the addition that after reporting the letter, they were to estimate the color diversity of either the cued row (Experiment 1, Block 1) or the noncued rows (Experiment 1, Block 2; Experiments 2 and 3). It was strongly emphasized that the main task was to remember the letters and that the estimation of the color diversity should reflect their subjective impression; hence, there was no correct response (and feedback would not

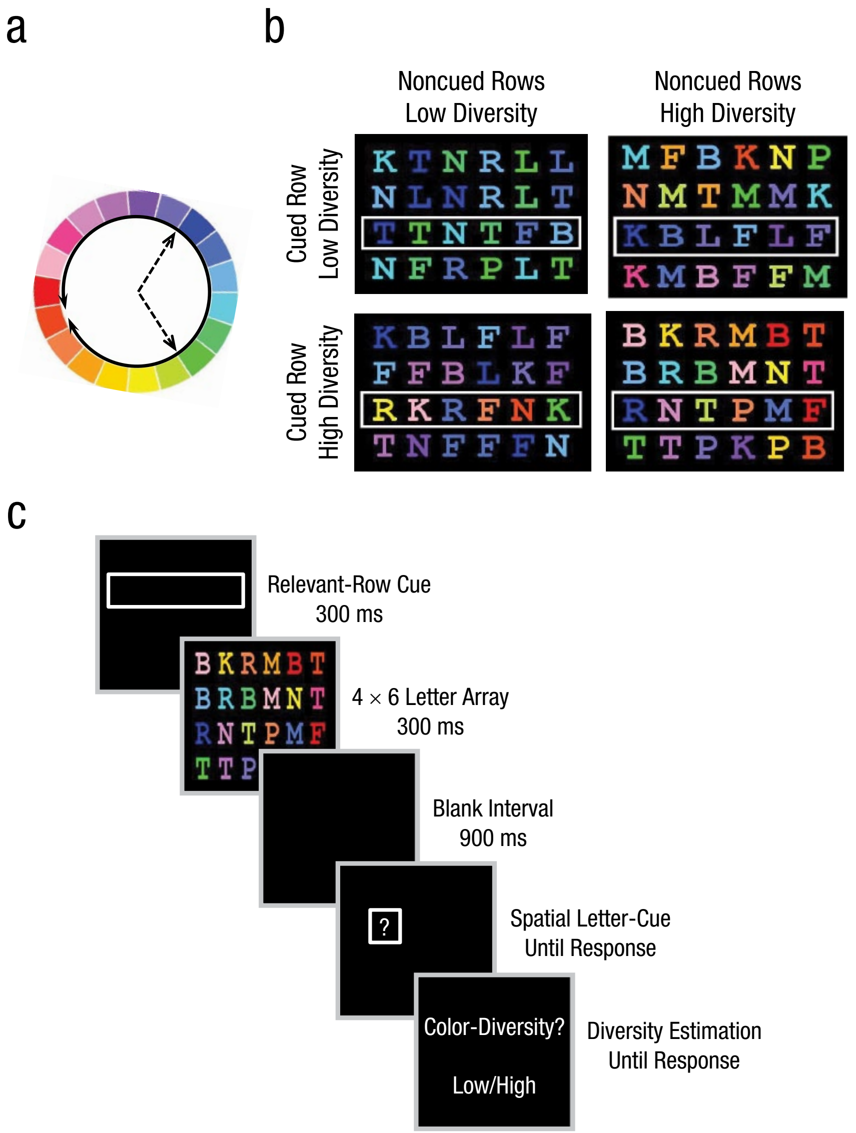

Fig. 1. Sample stimuli and trial sequence from Experiments 1 through 4. Stimuli consisted of letters whose colors were drawn (a) either from the entire spectrum along the color wheel (solid arrow; high-diversity condition) or from among six colors only (low-diversity condition). In the latter condition, the six colors were either adjacent (dashed arrows; Experiments 1, 2, and 4) or random (Experiment 3). In all experiments, stimuli were presented in an array (b) in which one row was precued (illustrated here by the white rectangle). Arrays appeared in four possible color-diversity combinations: two in which the color diversity of letters (high vs. low) in the cued and noncued rows was congruent and two in which it was incongruent. In each trial (c), the letter array appeared after a brief precue that instructed participants what row to attend. The array was followed by a blank interval and then a cue that required participants to recall a letter from the cued row by pressing a key on a response box. Participants were then asked whether the color diversity of the cued row or the noncued rows (depending on the block) was low or high.

be given) in this task. Since we wanted to probe conscious task performance, participants were instructed to press an escape button in case they had no impression of the noncued letters' colors and were discouraged from guessing the color diversity. In Experiment 3, we also introduced 10 catch trials, wherein the noncued rows were colorless (i.e., white), to probe the usage of the escape button (see Fig. S2 in Supplemental Method and Results).

In the third block of Experiment 2, participants received reversed instructions—they were instructed to first estimate the noncued rows' color diversity and then

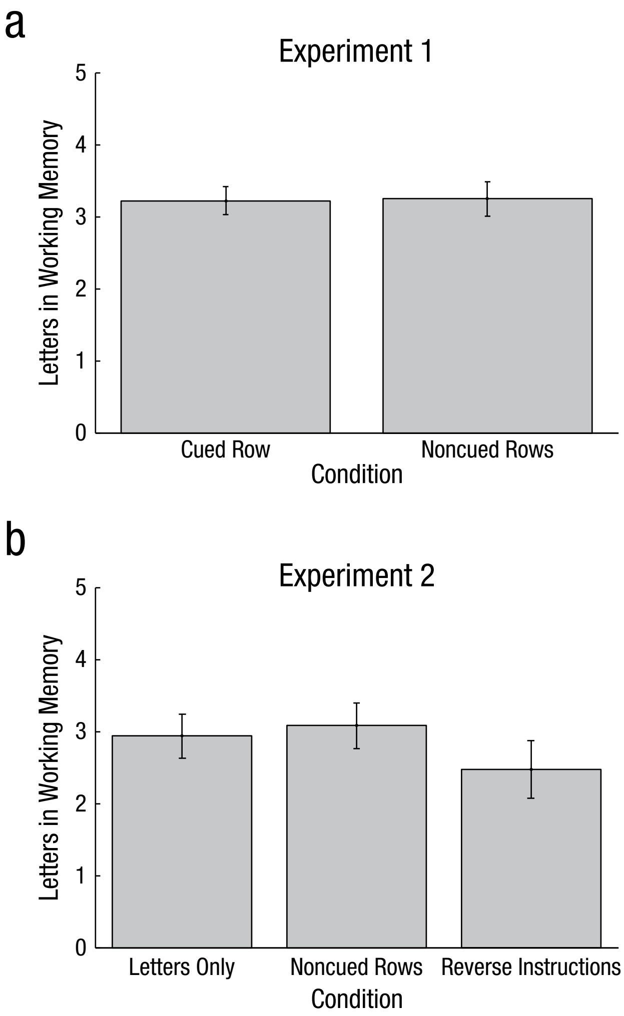

Fig. 2. Mean estimated number of letters that participants held in working memory as a function of condition, separately for (a) Experiment 1 and (b) Experiment 2. Error bars denote ±1 *SEM*.

to remember the letters. The reverse-instructions condition was introduced to test the hypothesis that participants carry out the combined task by first paying attention to the colors across the array and only then reorienting to the cued row to encode the letters. We reasoned that if participants are able to make such shifts spontaneously and free of cost, they should be able to do so even better when instructed to.

Experiment 4 was identical to Experiment 2, except that immediately after the offset of the letter array, three 100-ms Mondrian masks were presented consecutively (instead of a blank interval; see Fig. S3 in Supplemental Method and Results). Following the masks, participants either reported only the cued letter (Block 1) or reported the cued letter and also made a color-diversity judgment (Block 2).

Results

Data from 1 participant in Experiment 1 who showed a very low working memory capacity (~1.4 items, more than 2 *SD* below the group average) were discarded. Discarding this participant's data did not influence any of the conclusions.

Letter recall. We estimated the number of letters maintained in working memory (working memory capacity, or WMC) for each experimental condition (see Supplemental Method and Results for the method used to calculate WMC). As shown in Figure 2, WMC in Experiment 2 was not significantly reduced when participants had to judge the color diversity of the noncued rows ($M = 3.08$) concurrently with the letter task, compared with carrying out only the letter task ($M = 2.94$), $t(8) = -1.1$, $p = .3$ (see WMC Results in Supplemental Method and Results for replication of these findings in Experiment 3). In Experiment 1, WMC was the same when participants estimated the color diversity of the cued row ($M = 3.29$) or of the noncued row ($M = 3.32$), $t(11) = -0.2$, $p = .81$, and also did not vary between congruent and incongruent color-diversity relations of the cued and the noncued rows (see Fig. S5 in Supplemental Method and Results). The only condition in which we obtained a reduction in WMC for the letter task was the reverse-instructions condition in Experiment 2 ($M = 2.47$, compared with letters only: $M = 2.94$), $t(8) = 2.63$, $p = .03$, Cohen's $d = 0.88$. This indicates that the diversity-estimation task consumed additional attentional and working memory resources only when participants were instructed to pay attention to the colors, but never in the spontaneous mode of all our other conditions. (See Supplemental Method and Results for additional WMC results.)

Color-diversity estimations. Looking first at Experiment 1, we found that participants were sensitive to color diversity both for the cued row and the noncued rows. Figure 3 shows the color-diversity psychometric functions—the proportion of "high color diversity" judgments as a function of the objective color-diversity level of the task-relevant part of the display: the cued row (Fig. 3a) and noncued rows (Fig. 3b). In both conditions, participants responded predominantly "low" when the relevant diversity level was low and increased their frequency of "high" responses as the relevant diversity level increased. There was also a contamination effect: The irrelevant diversity level affected the judgment of the relevant diversity level. Nonetheless, when estimating the color diversity of the noncued rows, participants exhibited above-chance sensitivity at both levels of cued-row diversity—high: $t(11) = -3.41$, $p = .007$, Cohen's $d = -1.03$;

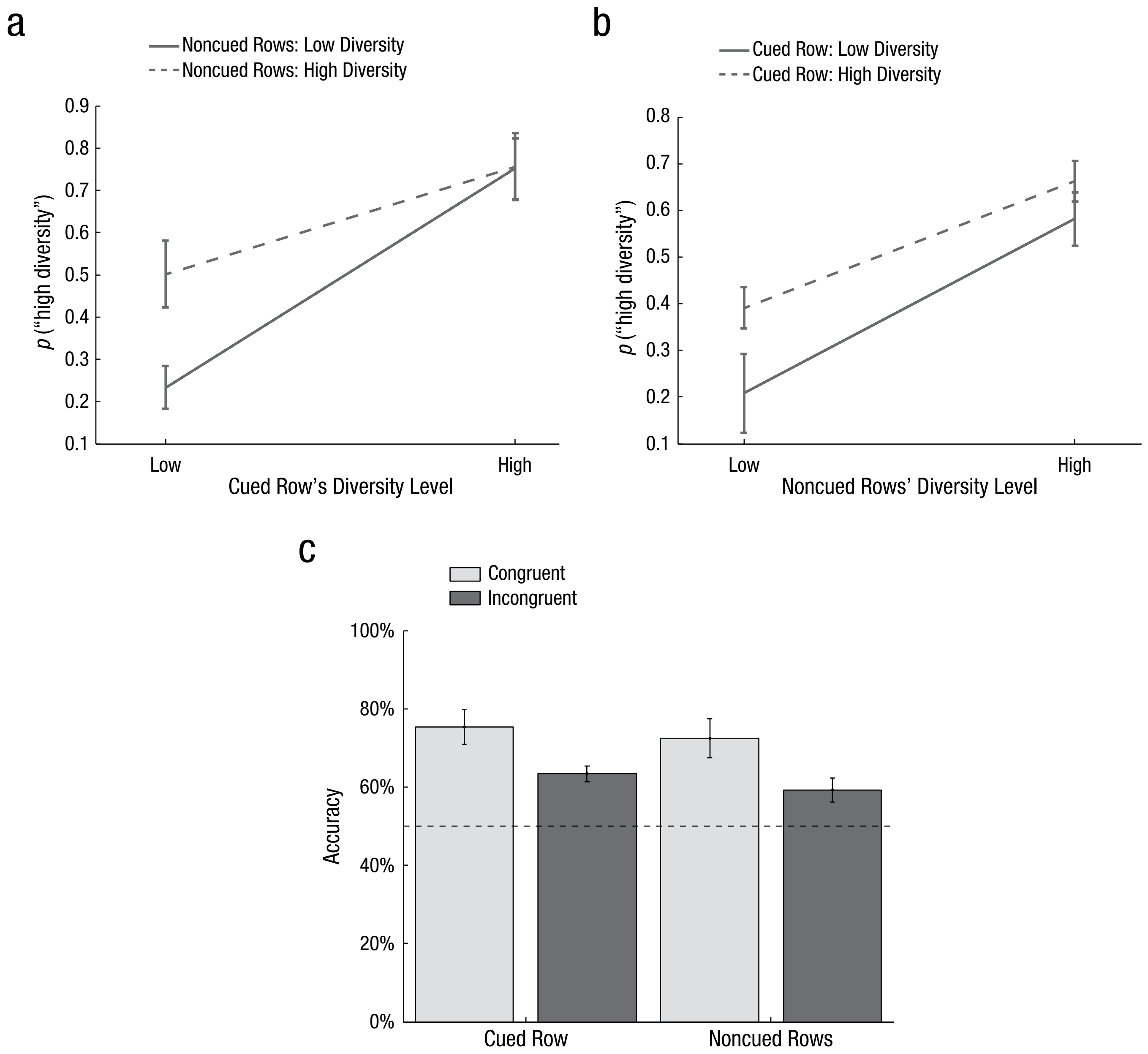

Fig. 3. Participants' color-diversity sensitivity in Experiment 1. The graphs in (a) and (b) show the probability of responding "high diversity" for the cued row and for the noncued rows, respectively, as a function of the relevant row's color diversity and the irrelevant row's color diversity. The graph in (c) shows mean accuracy in reporting color diversity for cued and noncued rows as a function of whether the color diversity between those rows was congruent or incongruent. The dashed line indicates chance performance. Error bars denote ±1 *SEM*.

low: $t(11) = -4.26$, $p = .002$, Cohen's $d = -1.28$. We quantified these effects by collapsing across the "low" and "high" judgments and computing a single dependent variable of accuracy in color-diversity estimation (Fig. 3c).

Participants' ability to correctly estimate the color-diversity level of the cued row changed as a function of the relation between the relevant color diversity (that of the cued row) and the irrelevant one (that of the noncued rows). When both cued and noncued rows had the same color-diversity level (congruent), performance was higher than when the color diversity of the cued row was incongruent with that of the rest of the array—congruent: $M = 75\%$ correct, incongruent: $M = 63\%$ correct; $t(11) = 3.1$, $p = .01$, Cohen's $d = 0.89$, which indicates that participants were affected by the diversity of the noncued rows—even when fully attending the cued row. Moreover, participants' accuracy in estimating the color diversity of the noncued rows ($M = 66\%$

correct) was higher than chance, $t(11) = 4.39$, $p = .002$, and not different from their accuracy in estimating the color diversity of the cued row (M = 69% correct), $t(11) = 1.06$, $p = .31$.

In Experiments 2 and 3, we replicated these results: Participants had above-chance sensitivity for the color diversity of the noncued rows at both diversity levels of the cued row (see Fig. S6 in Supplemental Method and Results). However, in the reverse-instructions condition of Experiment 2, participants' color-diversity sensitivity significantly increased (M = 75% correct) compared with the spontaneous condition (M = 65% correct), $t(8) = -4.22$, $p = .003$, Cohen's $d = -1.4$, which suggests that under explicit endogenous orientation of attention, color diversity improves at the expense of WMC.

One possible explanation for the remarkable ability to judge the color diversity of noncued rows while attention is allocated to the cued letters is that on some trials, participants attended to the letters and ignored the color-diversity task, while on other trials, they ignored the letters and focused on the color-diversity task. If this were the case, one should expect a negative correlation between performances in the two tasks. We found no such correlation (across all experiments and in all the different conditions, this correlation was null). To rule out a potential account of the results on the basis of color afterimages, we replicated the results of Experiment 2 in Experiment 4, in which we used a Mondrian color mask presented immediately after the array (instead of the blank interval).

Another possible interpretation of the results is that although participants were able to estimate the color diversity of the noncued array without a cost to letter recall, they did not consciously perceive the colors of the letters at those noncued locations but were nevertheless able to guess them subliminally. This explanation is unlikely, as no participant used the escape button to indicate lack of color perception in any of the regular color-array trials, yet 6 out of 9 participants in Experiment 3 responded appropriately (mean detection rate = 93%) on the colorless catch trials (see Supplemental Method and Results). Nonetheless, to explicitly test whether accurate color-diversity judgments can be made based on unconscious processes, we carried out an additional experiment (Experiment 5), in which subjective perception levels were reported.

Experiments 5 and 6: Can Color-Diversity Estimations Be Made Subliminally?

In Experiment 5, we tested whether accurate color-diversity judgments can be supported by unconscious color processing by briefly presenting participants (N = 12) with either low- or high-color-diversity letter arrays (16.7 ms) followed by a color mask (three different Mondrian textures, presented for 100 ms each; see Fig. 4a). The interstimulus intervals (ISIs) between the letter array and mask were 0, 33, or 67 ms (randomly chosen on each trial). Participants were first asked to report their subjective visibility experience of the letter array (1 = *did not see the colors*, 2 = *partially saw the colors*, 3 = *saw the colors well*) and then estimate the color diversity of the letter array.

We found that when participants gave the lowest visibility rating (1), they were unable to correctly estimate the color diversity of the array (accuracy was 47%, not significantly different from chance), yet when reporting partial or full visibility (ratings 2 or 3), accuracy was significantly above chance (68% and 84%, respectively), $t(11) = 8.3$, $p < .0005$; $t(11) = 10.99$, $p < .0001$ (see Fig. 4b).[4] Furthermore, we found identical results when applying the same analysis specifically to the trials in which the ISI was 33 ms and for which most observers had substantial variability in their subjective rating: No color-diversity sensitivity was observed when participants gave the lowest visibility rating (M = 51%), $t(11) = 0.16$, $p = .88$, yet above-chance performance was observed when participants indicated that they partially or fully saw the colors (M = 73%), $t(11) = 6.4$, $p < .0001$ (see Fig. 4c).

To exclude the possibility that our masking procedure prevented any color processing, we ran a control experiment (Experiment 6; N = 13; different participants), in which we presented participants with a similar yet slightly stronger masking protocol (see Supplemental Method and Results), and instead of low or high color diversity, we used red and blue colored letters and tested the ability to detect the dominant color (16 out of 24 letters were randomly chosen on each trial to be either blue or red). We employed the exact analysis as in Experiment 5 and observed above-chance performance even when participants reported no conscious experience of the colors (see Supplemental Method and Results). Thus, unlike the discrimination of average color, which can be carried out subliminally, the evaluation of color diversity appears to require some degree of subjective consciousness.

While the factor that limited perception in Experiment 5 (masking) differed from that in Experiments 1 through 4 (attentional load; see Kanai, Walsh, & Tseng, 2010), in combination with the sensitivity to colorless catch trials (Experiment 3) and the lack of "no-color" responses in color trials, these results suggest that estimation of color diversity is not supported by unconscious color processing and hence requires participants to be aware of the colors. This conclusion was further supported by computer simulations showing that unlike average-color estimation, color-diversity estimation is not robust to noise in the representation of the individual elements (degraded

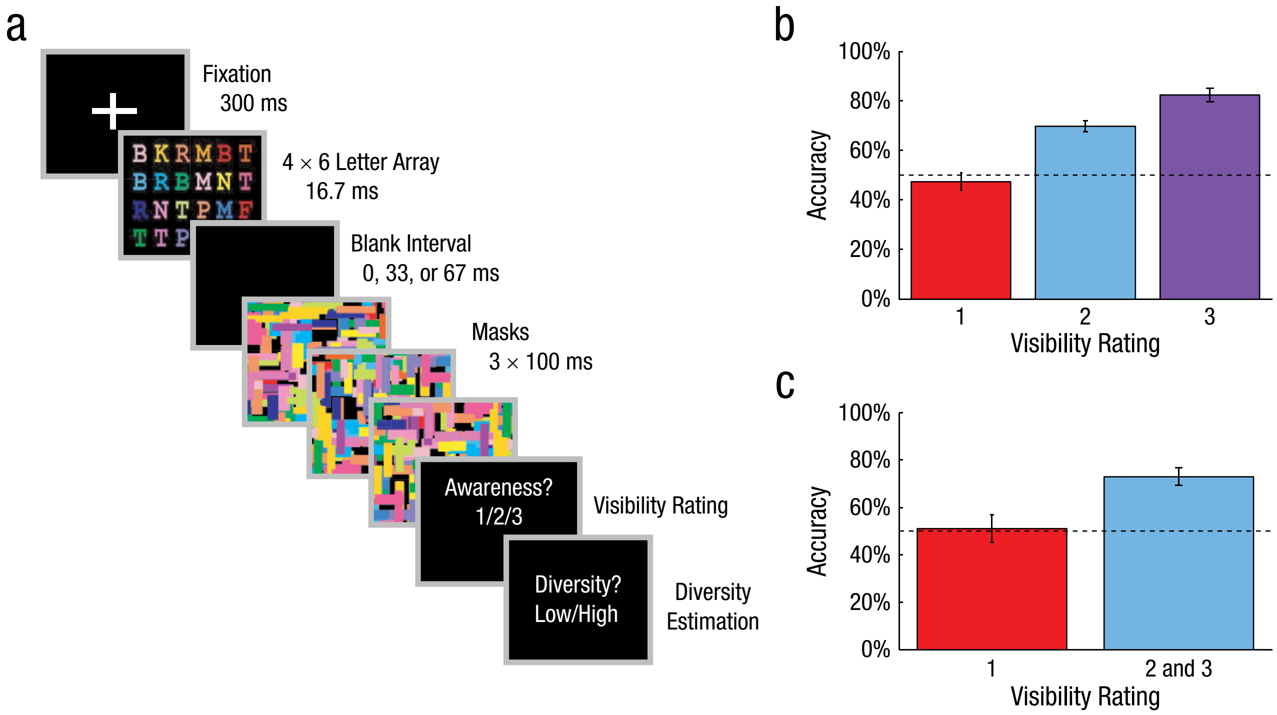

Fig. 4. Trial sequence and results from Experiment 5. In each trial, (a) the letter array was similar to that used in Experiments 1 through 4; however, no cue preceded it. A blank interval of varying length followed the letter array, and then three Mondrian masks appeared consecutively. Participants then rated on a 3-point scale how clearly they saw the colors of the stimulus array. They then responded to the color-diversity question used in the previous experiments. The graph in (b) shows mean accuracy in estimating the color diversity of the letter array for the three visibility ratings, whereas (c) shows mean accuracy in estimating the color diversity of the letter array specifically in trials with the 33-ms interstimulus interval, and with ratings 2 and 3 collapsed. The dashed line indicates chance performance, and error bars denote ±1 *SEM*.

or blurred colors; see the simulation studies in Supplemental Method and Results), which implies that one cannot accurately judge color diversity from blurred or degraded individual colors.

Discussion

These experiments show that observers are sensitive to a type of complex visual information—color diversity—outside the cued row of a colored-letter array, with no expense to their capacity to encode the letters from the cued row and report them. Remarkably, the capacity was the same when observers carried out the letter recall as a single task as when they had to additionally report the color diversity of either the cued row or the noncued rows as a secondary task. By contrast, the only condition in which there was a decrease in letter capacity was the one in which participants were explicitly instructed to attend to colors before attending to the to-be-reported letters. This indicates that in a Sperling paradigm with colored-letter arrays, color diversity is experienced spontaneously and without cost: It is encoded very quickly and efficiently and is even resistant to subsequent masking (Experiment 4), without requiring a shift of attention away from the primary task. This conclusion is also consistent with studies of divided attention, which have shown that observers can detect visual information in the absence of focal selective visual attention (Cavanagh & Alvarez, 2005; Koch & Tsuchiya, 2007; Li, VanRullen, Koch, & Perona, 2002; see van Boxtel, Tsuchiya, & Koch, 2010, for a review).^{5}

There are a few novel aspects to our investigation. First, we demonstrated that such perception without focal attention takes place in a Sperling-type paradigm in which targets are precued and that requires observers to devote attentional resources to encoding cued letters into visual working memory, thus validating the introspective reports traditionally made by participants that they saw more information than they were able to report. Second, our results support the conclusion that the detection of this nonattended information is based on a conscious experience of the underlying elements, as observers were unable to (subliminally) guess the color diversity of the array when they reported having no experience of the colors. Third, we showed that the perceived nonattended information involves one type of complex visual property: color diversity. This is a statistical property of the display that would be lost if the colors of the elements at the unattended locations were averaged out or analyzed at a very low resolution (Cohen & Dennett, 2011; Lau & Rosenthal, 2011; see Supplemental Method and Results for a computational illustration).

One possible interpretation of the results is in agreement with the rich-phenomenal-experience hypothesis (Block, 2007, 2011; Lamme, 2006), which asserts that during exposure to an array of letters, observers initially experience more visual information than is subsequently available for subjective report. This information is encoded in fragile visual short-term memory and decays before it can be encoded into durable working memory for later report. This interpretation is consistent with findings indicating that preattentive memory has a perceptual nature (Vandenbroucke, Sligte, Fahrenfort, Ambroziak, & Lamme, 2012), and with studies showing that transcranial magnetic stimulation of the right dorsolateral prefrontal cortex disrupts visual working memory while leaving fragile short-term memory intact (Sligte, Wokke, Tesselaar, Scholte, & Lamme, 2011).

Obviously, color-diversity estimation involves some form of access, because participants inevitably report it.[6] We believe this is possible because it involves a holistic low-information summary of high-complexity information, perhaps mediated by a nonselective visual pathway (Wolfe, Võ, Evans, & Greene, 2011), with the specific color contents decaying before they can be reported. This conclusion needs to be taken with caution. First, further experiments are needed to confirm that the specific color information at unattended locations decays during the letter report. Second, this conclusion is, so far, limited only to color information. Other types of information may still require attention in order to become consciously analyzed (Kouider et al., 2010). Future studies are needed to examine whether other types of complex visual information (e.g., holistic aspects of shape or motion properties) can also be reported at no cost to the encoding capacity of the primary task.

Author Contributions

Z. Z. Bronfman, N. Brezis, and M. Usher conceived and designed the experiments; Z. Z. Bronfman and N. Brezis ran the experiments and analyzed the data; and Z. Z. Bronfman, N. Brezis, H. Jacobson, and M. Usher wrote the manuscript. Z. Z. Bronfman and N. Brezis share credit as first authors.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Supplemental Material

Additional supporting information may be found at http://pss.sagepub.com/content/by/supplemental-data

Open Practices

All data have been made available at https://www.dropbox.com/sh/s8owgz5ps8o76er/74sF1OpTjy. The complete Open Practices Disclosure for this article can be found at http://pss.sagepub.com/content/by/supplemental-data.

Notes

1. Almost any philosophy-of-mind textbook on qualia uses color experience as an example.
2. In philosophy of mind, holism is one of the properties associated with conscious experience (Searle, 2000).
3. The possible letters were “R,” “T,” “F,” “N,” “B,” “P,” “L,” “M,” and “K.”
4. The mean percentage of visibility ratings 1, 2, and 3 across participants was 22%, 44%, and 34%, respectively
5. The inattentional-blindness phenomenon challenges the existence of perception without attention (Mack, 2003). An alternative account—the inattentional-amnesia phenomenon—allows for perception without attention, as long as the nonattended perception is not remembered (Wolfe, 1999). While we prefer the latter interpretation of our findings, our main conclusion—that observers see more than they can encode into working memory and report—does not depend on this assumption.
6. We support a weak rather than a strong distinction between phenomenal and access consciousness. The strong distinction is untestable, as without any type of access to the functional-cognitive system, it is impossible to probe experience (Dennett, 1995). According to the weak version, phenomenal consciousness provides a fragile and brief access to a special type of information involving analog magnitudes.

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