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Saccadic Selection Does Not Eliminate Attribute Amnesia

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Attribute amnesia (Chen & Wyble, 2015, 2016) demonstrates that we may not always be able to spontaneously retrieve a simple attribute of a visual object (e.g., its color) for conscious report, even though the object had just been the target in a visual task. Attribute amnesia has been suggested to reflect a lack of consolidation of the task-irrelevant attribute in visual working memory. Here we tested whether saccadic selection eliminates or attenuates attribute amnesia. Saccade targets have been shown to be preferentially encoded into visual working memory and may therefore be spared. We used simple color pop-out displays, asking participants to indicate the location of the color singleton letter target on each trial either by keypress or by making a saccade toward it. After a couple of trials and unannounced to the participants, we asked for the color and identity of the last target letter on a surprise trial. We found that saccade targets were not spared from attribute amnesia: Participants were as bad in correctly reporting the color in the saccade as in the keypress condition. For letter identity, the effect was attenuated but not abolished when the target was foveated for a short period of time. We argue that the current results do not refute an obligatory coupling between saccadic selection and encoding in visual working memory. However, the encoded information may not necessarily be stored in a manner that is robust enough to persist in the face of a surprise question.

Keywords: attribute amnesia, saccades, visual working memory

If we give directions to a person in the street, would we be able to report the color of the person's coat if asked about it afterward? How much of the information we have just encountered in our environment can we spontaneously retrieve from memory? Laboratory experiments have demonstrated that we may not always be able to retrieve this information for conscious report. For instance, in a recent series of experiments, Chen and Wyble (2015, 2016) have described the phenomenon of attribute amnesia (see also Chen, Swan, & Wyble, 2016; Jiang, Shupe, Swallow, & Tan, 2016; Swallow, Jiang, & Tan, 2017; Swan, Wyble, & Chen, 2017; Wyble & Chen, 2017). In a typical experiment (e.g., Chen & Wyble, 2015), participants were asked to report the location of a letter shown briefly among three numbers. After some trials, participants were unexpectedly asked to report the identity of the last target letter on a surprise question. When required to select it from a choice set of four letters, only around 30% of the participants chose the correct letter. The performance level dramatically increased to around 65–95% correct on postsurprise trials in which participants were asked to report both location and identity of the target letter. In other words, as soon as participants had formed an expectation that they may also have to report the letter identity, they were able to do so easily.

These findings are surprising because to report the location of the response-relevant object, it has to be voluntarily attended. Classic theories of attention and perception like feature integration theory (Treisman & Gelade, 1980) or object file theory (Kahneman, Treisman, & Gibbs, 1992) propose that when an object is attended, its different features are bound together to form an integrated representation of the object. Thus, attentional selection of the target is expected to make its task-irrelevant features accessible for conscious report. To account for the surprising inability to report features of attended objects, one may argue that bottom-up attention is necessary for conscious report of visual experiences (Chica & Bartolomeo, 2012). However, attribute amnesia also occurred with stimuli that were highly salient (Chen & Wyble, 2015; Experiment 3), which should have attracted attentional resources in an automatic, bottom-up way (e.g., Itti & Koch, 2000; Theeuwes, 1991) or at least allowed for a quick and efficient guidance of attention toward the target (e.g., Wolfe & Horowitz, 2004). For instance, only 35% of the participants were able to

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select the correct color of a color pop-out target on the surprise trial after having indicated its location on a number of presurprise trials (Chen & Wyble, 2015; Experiment 3; see also Figure 1). Thus, neither top-down nor bottom-up attention may be sufficient for conscious report of irrelevant features (Chica et al., 2012).

Indeed, Chen and Wyble (2016) proposed that attribute amnesia may not be an attentional phenomenon but rather reflects a lack of consolidation in working memory. Even though the irrelevant attributes were attended, they are not maintained in visual working memory. Accordingly, in an experiment in which participants were asked to report the identity of a target letter that had the same color as a central color cue, only 45% of participants were able to report the last target's color on a surprise trial when the color cue had appeared and disappeared simultaneously with the target display. In contrast, when the color cue was presented and extinguished shortly before the target display, the percentage of participants that were able to report the color on the surprise trial increased to 80% (Chen & Wyble, 2016; Experiment 3, a–c). The authors argue that the crucial difference between preceding and simultaneous presentation is that the color of the central cue (and therefore the target color) needed to be encoded and consolidated in working memory for a short period, which led to a more robust memory representation of the target color in the preceding condition. They concluded that for an attribute to be reportable on a surprise question, the task needs to require memory consolidation of the attribute (see Jiang et al., 2016; Swallow et al., 2017; Swan et al., 2017; Wyble et al., 2017 for a discussion on the cause of the report failures on the surprise test).

In the current study, we examined whether saccade targets are spared from attribute amnesia. Saccades are accompanied by attention shifts toward the saccade target that enhance its perceptual representation compared with nontarget items (Deubel & Schneider, 1996; Hoffman & Subramaniam, 1995; Kowler, Anderson, Dosher, & Blaser, 1995; Puntiroli, Kerzel, & Born, 2015). Moreover, saccade targets are preferentially processed in visual working memory (Bays & Husain, 2008; Henderson & Hollingworth, 2003; McConkie & Currie, 1996). It has been suggested that encoding of the saccade target may in fact be obligatory: Although irrelevant for the memory task, the saccade target is automatically encoded, even at the expense of task-relevant items (Schut, Van der Stoep, Postma, & Van der Stigchel, 2017; Shao et al., 2010; Tas, Luck, & Hollingworth, 2016). Some have argued that prioritizing the saccade target has a functional role for the maintenance of object correspondence and visual stability across eye movements (Henderson et al., 2003; Hollingworth, Richard, & Luck, 2008; Irwin, 1996; McConkie et al., 1996; Van der Stigchel & Hollingworth, 2018). Saccade target information in visual working memory is thought to be represented in a format that, at the very least, is resistant to masking from postsaccadic sensory input (Van der Stigchel et al., 2018). Finally, selecting an object as potential target for an eye movement can even foster memory for another object, previously presented at the same location (Hanning, Jonikaitis, Deubel, & Szinte, 2016; Melcher & Piazza, 2011). Saccade targets may thus be immune to attribute amnesia, but this has never been tested.

In one previous study (Chen et al., 2016), participants watched short movies (5–59 s) of actors passing two colored balls and were asked to count the passes for one of them. Note that participants were watching the clips without constraints, that is, they could (and almost certainly did) follow the ball with their gaze. After the 32nd movie, they were unexpectedly asked for the color of the ball they had just tracked. Only around 65% of observers responded correctly, indicating that making eye movements as such may not eliminate attribute amnesia completely. It remains unclear, however, whether the relatively high percentage of correct responses was due to gaze tracking of the target or simply due to the much longer duration and dynamic nature of the movies because a control condition without eye movements was not included in the study. It is further not clear how strongly attribute amnesia may be attenuated for saccade targets in sparse displays, like the ones used in the other attribute amnesia studies and, for that matter, in many of the studies on attention, visual working memory, and eye movements. It has been demonstrated that under conditions of low perceptual load (i.e., with sparse displays), irrelevant visual information becomes accessible for conscious report on a surprise question more easily (Cartwright-Finch & Lavie, 2007; Eitam, Shoval, & Yeshurun, 2015).

In the current experiments, we therefore tested for attribute amnesia effects in simple color pop-out displays and compared saccade and fixation conditions. Given the evidence for strong or even obligatory coupling between saccade selection, attention, and visual working memory that has been revealed using rather sparse displays with static objects (e.g., Deubel et al., 1996; Schut et al., 2017; Shao et al., 2010; Tas et al., 2016), we expected attribute amnesia to be eliminated or at least greatly reduced for objects selected as the target of a saccadic eye movement. To anticipate the results, although attribute amnesia could be reduced under some circumstances (for target identity and if the target was foveated), saccade selection did not eliminate attribute amnesia.

Experiment 1

Method

Participants. In total, 81 participants (aged between 18 and 45 years) were tested in Experiment 1: The fixation condition was run on 40 participants, the saccade condition on 41 participants. Previous studies used a fixed sample size of 20 participants per group to demonstrate attribute amnesia (Chen & Wyble, 2015, 2016; Jiang et al., 2016). Given our strong hypothesis that saccade selection would eliminate the effect, 20 participants should be sufficient in our setup as well. Nevertheless, in Experiment 1, we also wanted to give medium-sized modulations a chance to become statistically significant and therefore decided to double the number of participants. Statistical power for an effect size of around $\phi = 0.30$–0.35 ranges between $1 - \beta = 0.77$–0.88 with 80 observers. Participants were mostly first-year psychology students receiving course credit. Several doctoral-level students and postdocs from the psychology department were also tested. None were familiar with the attribute amnesia paradigm. For both experiments reported in this study, the procedures followed the principles laid down in the Code of Ethics of the World Medical Association (Declaration of Helsinki) and were approved by the Ethics Committee of the Faculté de Psychologie et des Sciences de l'Education of the University of Geneva (title of study: "Amnésie de l'attribut dans le cadre du mouvement oculaire"; date of acceptance: February 9, 2016).

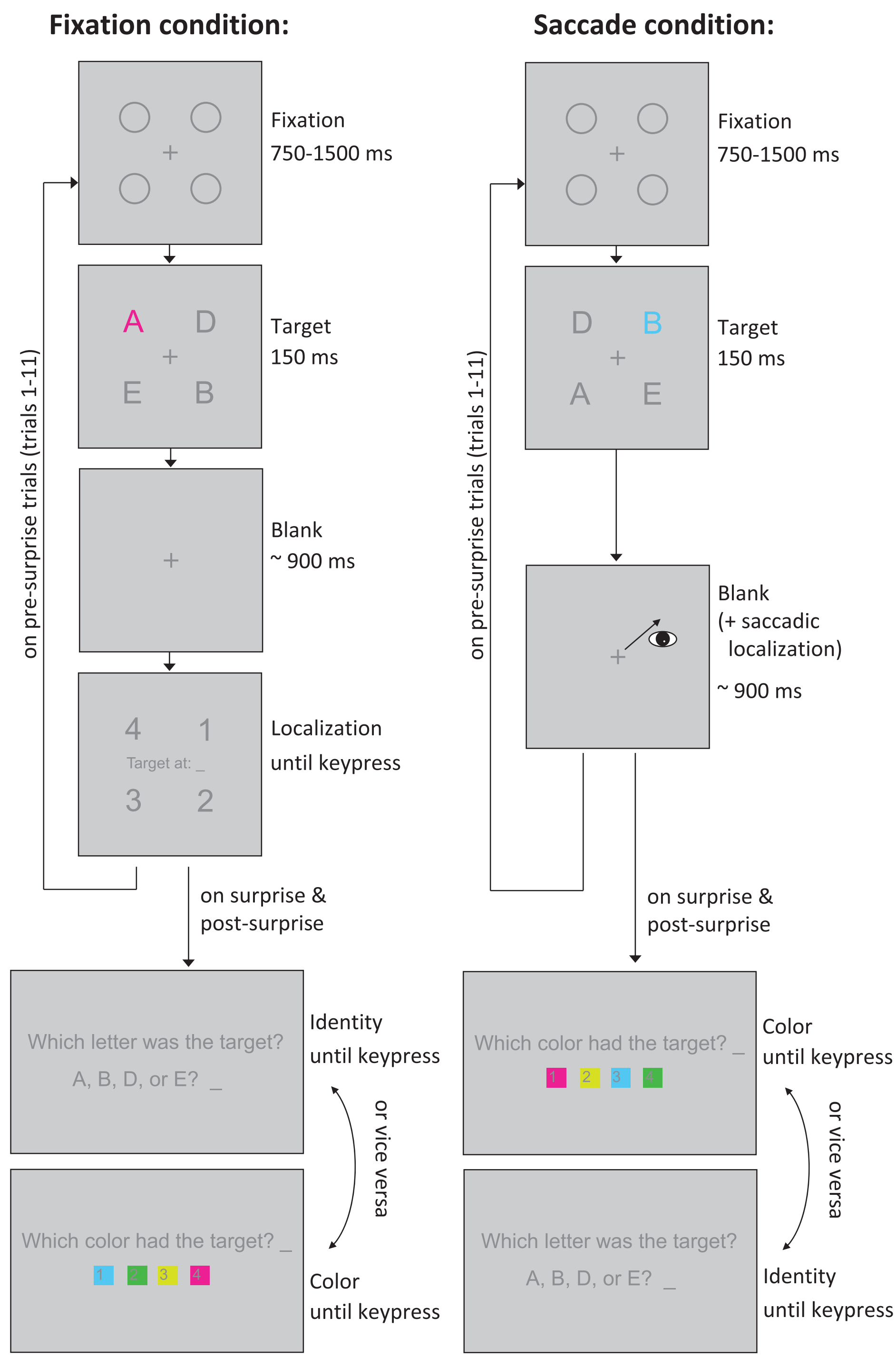

Figure 1. Procedure for Experiment 1 in the fixation and saccade conditions. After a variable fixation interval of 750–1,500 ms, the four capital letters A, B, D, and E were presented for 150 ms at the same locations previously occupied by placeholder circles. The target display was followed by a blank screen for approximately 900 ms. Participants had to localize the target by means of a keypress or by making a saccade. After 11 trials, participants were additionally asked to report the target's identity and color. The first time, these questions came as a surprise to the participants. Stimuli are not drawn to scale. Note that color and identity response displays contained an additional notice on the surprise trial ("ATTENTION!!! This is a SURPRISE memory test:"), displayed above the color or identity question. (English used for illustration; all instructions were in French). See the online article for the color version of this figure.

Apparatus and software tools. Experiments were programmed in Matlab (The MathWorks Inc., Natick, MA) using the Psychophysics and Eyelink Toolbox extensions (Cornelissen, Peters, & Palmer, 2002; Kleiner, Brainard, & Pelli, 2007). Stimuli were displayed on a 21-inch CRT monitor (NEC MultiSync FE2111SB) running at 85 Hz with a resolution of 1280 × 1024 pixels. Eye movements were recorded using an EyeLink1000 desk-mounted eye tracker (SR Research Ltd., Ottawa, ON, Canada) at a sampling rate of 1000 Hz. Participants were seated in a dimly lit room. Viewing was binocular but only the right eye was monitored. The participant's head was stabilized by a chin and a forehead rest at 72 cm from the monitor. All statistics were conducted using Statistica 64 (TIBCO Software Inc., Palo Alto, CA).

Stimuli, design, and procedure. We used a color singleton display, similar to the one described by Chen and Wyble (2015; Experiment 3). The procedure and timing of each trial are illustrated in Figure 1. Stimuli were displayed on a light gray background ($x = 0.29$, $y = 0.30$, 46 cd/m^2). The fixation cross (subtending 0.3°), outline placeholder circles (0.8° in diameter, 5° from fixation), and distractor letters were shown in the same dark gray ($x = 0.29$, $y = 0.30$, 13 cd/m^2). The four capital letters A, B, D, and E were presented on each trial, but their distribution over the four locations changed randomly from one trial to the next. They were printed in Arial font, size 32 point (approximately 0.8°). One of the letters was randomly chosen as the color singleton target for the current trial. This letter was presented in one of four possible colors: green ($x = 0.29$, $y = 0.61$, 32 cd/m^2), cyan ($x = 0.19$, $y = 0.22$, 41 cd/m^2), yellow ($x = 0.39$, $y = 0.53$, 70 cd/m^2), or magenta ($x = 0.44$, $y = 0.23$, 20 cd/m^2). The duration of the posttarget blank display varied in a range between 838 and 1066 ms. This was due to analysis of the eyetracking data for the trial, initiated 400 ms after blank onset. Execution of this analysis script, during which the screen remained blank, varied slightly in time.

Participants were instructed to locate the color singleton target on each trial. In the saccade condition, they were asked to give their response by making an eye movement toward the target upon its appearance. In the fixation condition, an additional response screen was shown after the blank interval (see Figure 1). Participants were asked to type in the number that corresponded to the target's location on a conventional keyboard. Their answer was displayed on screen and they were asked to confirm their response by pressing the space bar, which also initiated the next trial. In both groups, if an error in gaze behavior was detected (see below for criteria), participants were informed through a written feedback message.

In saccade as well as fixation conditions, the experiment started with eyetracker calibration, and then observers completed around 5–10 practice trials. After another calibration check, the experimental block was initiated. The experimenter remained in the room with the participant during the entire experiment to control calibration (which was also the reason given to the participants) but also to guide and instruct the participants on the surprise trial. In the experimental block, participants first completed 11 trials in the localization task, as instructed. If localization was correct and no gaze error detected on the 12th trial, two surprise questions immediately followed the localization task. If localization was incorrect or a gaze error was detected, then the surprise questions were postponed until the next trial with a correct localization response and accepted gaze behavior. This was done to ensure that the target had been processed. The two surprise questions appeared in written form on the screen along with a notice saying "ATTENTION!!! This is a surprise memory test" (all in French). Participants were asked to indicate the color and the identity of the last target letter. The order of the two questions was counterbalanced across participants. In both cases, the attribute had to be chosen among four possibilities presented on screen. Upon appearance of the first surprise display, the experimenter additionally gave verbal instructions in French, close to the following: "Please do not move [from the chinrest]. This is a surprise memory test. Which color/letter had/was the last target? Please type in/tell me your answer." In the fixation group, observers had to type in the number or letter corresponding to their answer. The response appeared on screen and they confirmed with the space bar, just as they had done for the localization response. In the saccade group, given that participants until then had not yet used the keyboard, the experimenter asked for the observers' response and typed it in for them. Just as in the fixation group, the answer appeared on screen and the experimenter asked for confirmation (e.g., "Did you say green?" or "Did you say E?"). Participants confirmed verbally, upon which the experimenter pressed the space bar. Then the second surprise question was shown, which the experimenter introduced with "And what about the letter/color of the target?" Naturally, some participants' first reaction was to say something along the lines of "Oh, I don't know/remember." If they did not give a response on their own accord, the experimenter prompted a response by saying: "[Well, it is not easy.] What would you say?" or words to this effect. If they still did not respond, they were asked to guess. Note that this did not happen only in the saccade condition in which the experimenter had to get a verbal answer from the participant. Participants in the fixation condition also frequently commented spontaneously on their uncertainty and withheld a response until finally asked to guess. After the surprise trial, participants were told that four more trials followed on which they would be asked to report all three attributes (location, color, identity) in the same order and in the same manner as on the surprise trial. The experiment took around 5–10 min to complete.

Gaze error criteria. Gaze behavior was checked after each trial and feedback given if a gaze error was detected. In the fixation group, eye gaze was analyzed in a time window starting 500 ms after fixation onset until 400 ms after blank onset. A trial was marked with an error if gaze deviated by more than 1.5° from the center of the screen (break of fixation) or if a blink was detected. In the saccade group, the first saccade after target onset with an amplitude larger than 1° was taken as the participant's response on each trial. A trial was marked with an error in the following cases: If fixation was broken in a time window starting 500 ms after fixation onset until saccade onset; if a blink was detected until blank onset; if saccades were initiated less than 80 ms after target onset (anticipations); or if no saccade with an amplitude larger than 1° was detected within 350 ms after target onset (late or no response). Because responding by eye movement is a somewhat unnatural task and participants may initially not be aware of where and when they moved their eyes, we also presented an error feedback message when the first saccade after target onset was directed into the wrong quadrant. This was not registered as a gaze error but as a wrong localization response (i.e., an error in the primary task).

Results and Discussion

Gaze behavior. In the fixation group, breaks of fixation or blinks occurred on 8.4% of trials. For none of the 40 participants was a gaze or localization error detected on the 12th trial. Thus, the surprise questions were always asked on the 12th trial. Because of the additional criteria regarding the saccade, gaze errors were more frequent in the saccade condition, occurring on 27.3% of trials. Of note, 69.6% of gaze errors in the saccade condition resulted because no saccadic response was detected before the eyetracker recording was stopped 400 ms after blank onset. This is not surprising because in everyday life, people do not use their eye movements willfully and under strict time constraints to point to objects. To ensure that the color pop-out was properly selected as saccade target on the surprise trial, we postponed the surprise questions to the next trial when a gaze error was detected on the 12th trial. This was the case for 12 participants (29.3%). Accordingly, the surprise questions were postponed to the 13th trial for eight participants, to the 14th trial for one participant and to the 15th trial for three participants (because of multiple successive trials with gaze errors). Saccades on trials with valid gaze behavior were executed with a median saccade latency of 219 ms.

Primary task: Localization. Figure 2 (panels A and B) show the percentage of participants who gave a correct response on a given trial, provided no gaze error was registered (green lines with diamonds). Note that error bars are missing because data were not averaged across participants (because for each trial we only have one data point per participant). One surprising aspect of attribute amnesia is that it occurs even for tasks in which the targets are easily distinguished from the distractors and the primary task is easy. Accordingly, in the fixation group (Figure 2A), wrong localization responses were very rare. In fact, we recorded only one incorrect response (on Trial 11). Figure 2B shows the data from the saccade group. Just as for the fixation group, performance was nearly perfect, with only one incorrect response on Trial 10 and one on postsurprise trial P4. Recall, however, that on approxi-

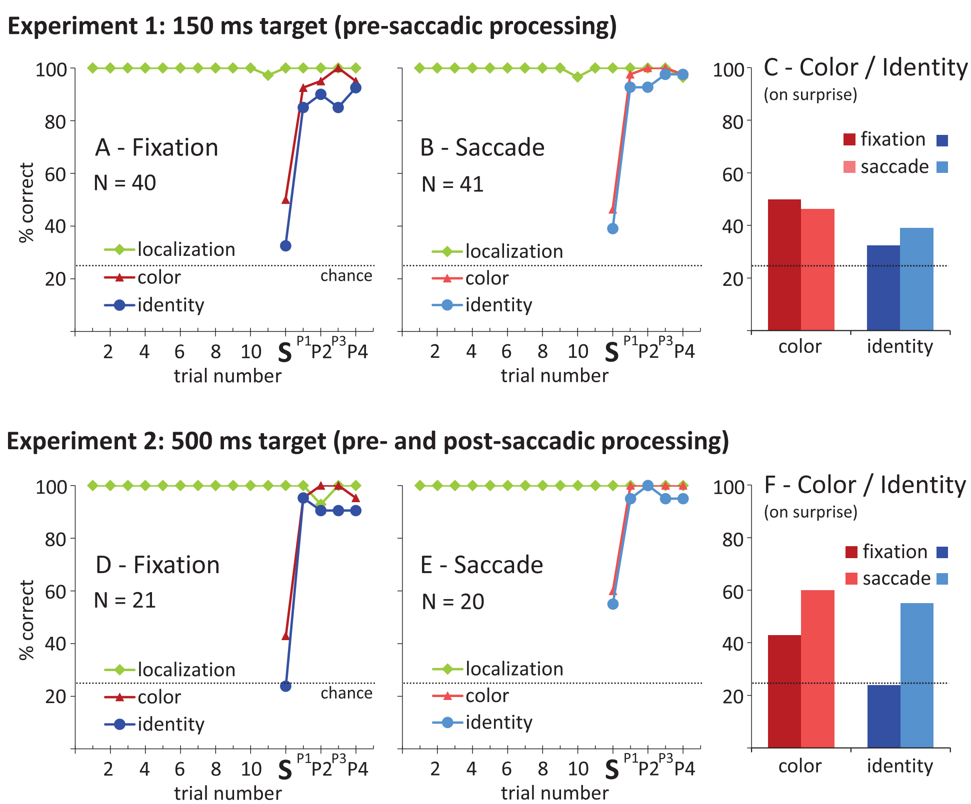

Figure 2. Results of Experiments 1 and 2 are shown in the upper and lower panels, respectively. Percentage of participants giving a correct response as a function of trial number and surprise attribute (color or identity of letter) are shown separately for groups with fixation (left panels: A and D) and saccade instructions (middle panels: B and E). To summarize the most important aspects of the data, the percentage of participants giving a correct response on the surprise trials is plotted as a function of eye movement (fixation, saccade) and asked-for attribute on the surprise trial (color or identity) in panels C and F. Color conventions are as follows. Primary localization task = green, color naming task = red (fixation = dark red, saccade = light red), letter identification task = blue (fixation = dark blue, saccade = light blue). Horizontal gray line represents chance performance (25%). S = surprise trial; P1–P4 = postsurprise Trials 1–4. See the online article for the color version of this figure.

mately 20% of trials, no saccadic response could be detected before the eye tracker recording was interrupted 400 ms after blank onset (those were omitted before calculating the percentages shown in Figure 2B). These trials are obviously ambiguous, but we do not think that finding the target as such was more difficult in the saccade condition. It is more likely that the speeded response by eye movement in the saccade condition was harder to produce than the relatively unconstrained keyboard response in the fixation condition.

Color and identity responses on surprise and postsurprise trials. Figure 2 (panels A and B) also illustrates the percentage of participants giving correct responses on the target's color (in red) as well as letter identity (in blue) on the surprise trial and the four subsequent postsurprise control trials (all data, irrespective of gaze or localization error). Attribute amnesia seems to be present in all conditions: On the surprise trial, performance is rather poor but increases dramatically on the postsurprise trials when participants were explicitly informed that they additionally had to report the two attributes at the end of a trial. Analogous to Chen and Wyble (Chen et al., 2016; Chen & Wyble, 2015, 2016; Swan et al., 2017), we first compared performance on the surprise trial to performance on the first postsurprise trial (P1) using maximum likelihood (M-L) χ^2 tests, separate for the two response attributes. These confirmed that attribute amnesia, that is, a lower proportion of correct responses on the surprise trial, compared with the first postsurprise trial, was indeed present for both attributes: When asked for the color of the target, only 48.2% of participants (39/81) responded correctly on the surprise trial, but 95.1% of participants (77/81) were correct on the first postsurprise trial, M-L $\chi^2(1, N = 162) = 49.27$, $p < .001$, $\phi = 0.52$. Similarly, for the identity of the target, only 35.8% of participants (29/81) responded correctly on the surprise trial, but 88.9% (72/81) were correct on the first postsurprise trial, M-L $\chi^2(1, N = 162) = 52.42$, $p < .001$, $\phi = 0.55$.

Comparing Figure 2A and B (see also Figure 2C), suggests that performance on the surprise trial was similar in fixation and saccade conditions. For color, 50.0% of participants (20/40) responded correctly in the fixation and 46.3% (19/41) in the saccade condition. For letter identity, 32.5% of participants (13/40) responded correctly in the fixation and 39.0% (16/41) in the saccade condition. Accordingly, the corresponding M-L χ^2 tests comparing performance on the surprise trial across fixation and saccade conditions reached significance neither for color, M-L $\chi^2(1, N = 81) = 0.11$, $p = .742$, $\phi = 0.04$, nor for letter identity, M-L $\chi^2(1, N = 81) = 0.38$, $p = .540$, $\phi = 0.07$. In sum, we replicated attribute amnesia in the fixation condition, even though the target was a salient color pop-out stimulus (Chen & Wyble, 2015; Experiment 3): Performance for color and letter identity was markedly lower on the surprise trial than on the first postsurprise trial. Performance in the color report was slightly higher, compared with previous studies (e.g., 30–40% correct with 155 presurprise trials, Chen & Wyble, 2015; 35–45% correct with 11 presurprise trials, Chen & Wyble, 2016), whereas performance in the identity report was in the same range as in previous studies (25–35% correct with 155 presurprise trials, Chen & Wyble, 2015; 40% correct with 11 presurprise trials, Chen & Wyble, 2016). Additionally, we found that attribute amnesia was not eliminated or strongly attenuated in the saccade condition.

Experiment 2

One may object that the conditions for attentional processing, automatic encoding and consolidation of the saccade target's attributes were not optimal in Experiment 1. The target was presented for only 150 ms, that is, it was extinguished before the eyes could land on it. This procedure was adopted from previous presaccadic attention and working memory studies, for which it was critical that participants had not foveated the target (e.g., Bays et al., 2008; Deubel et al., 1996). To examine whether directly looking at the target would eliminate attribute amnesia in our setup, we presented the target for a longer duration in Experiment 2 and made sure that it remained on screen for some time after the saccade had been initiated.

Method

Participants. In total, 41 first-year psychology students (between 17 and 38 years) participated for course credit. None were familiar with the attribute amnesia paradigm or had participated in Experiment 1. The fixation condition was run on 21 participants and the saccade condition on 20 participants. Thus, in Experiment 2, we used the same sample size as in previous studies (Chen & Wyble, 2015, 2016; Jiang et al., 2016).

Apparatus, stimuli, design, and procedure. Apparatus, stimuli, design, and procedure were the same as in Experiment 1 with the following exceptions. In the fixation condition, the target duration was prolonged to 500 ms. In the saccade condition, the target was shown until a saccade was detected online (or no saccade was detected for 400 ms) and then prolonged for another 160–250 ms after the saccade (variations because of technical issues), such that it was still visible when the eyes landed. The online saccade detection criterion was a gaze deviation of more than 1.5° horizontally or vertically from the screen center. As before, the target was followed by a blank interval of approximately 900 ms during which a more detailed gaze error analyses script was run.

Results and Discussion

Gaze behavior. In the fixation group, breaks of fixation or blinks occurred on 18.2% of trials. For four participants (19.0%), a gaze or localization error was registered on the 12th trial. Thus, the surprise questions were postponed to the 13th trial. In the saccade group, gaze errors were detected on 18.4% of trials, and 53.3% of gaze errors were accounted for by the absence of a saccade until the eyetracker recording was stopped, 400 ms after blank onset. For four participants (20.0%), a gaze or localization error was registered on the 12th trial. Thus, the surprise questions were postponed to the 13th trial for three participants and to the 15th trial for one participant. Saccades on trials with valid gaze behavior were executed with a median saccade latency of 222 ms. The median duration of target presentation on those trials was comparable but slightly shorter than in the fixation condition: 477 ms (range: 333–575 ms; median saccade duration: 42 ms).

Primary task: Localization. In the fixation group (Figure 2D), there was only one incorrect response on trial P2, provided there was no gaze error. In the saccade group (Figure 2E), there was no wrong localization response for trials with no gaze error.

Color and identity responses. Figure 2 (panels D and E) also illustrates that attribute amnesia, that is, markedly poorer performance on the surprise trial compared with the first postsurprise trial, occurred again for both attributes. Accordingly, the respective M-L χ^2 tests across those two critical trials were significant for color, 51.2% (21/41) versus 97.6% correct (40/41), M-L $\chi^2(1, N = 82) = 27.09$, $p < .001$, $\phi = 0.53$, and identity, 39.0% (16/41) versus 95.1% correct (39/41), M-L $\chi^2(1, N = 82) = 33.09$, $p < .001$, $\phi = 0.60$. Comparing Figure 2D and Figure 2E, there seemed to be slightly better performance on the surprise trial in the saccade condition for both attributes (see also Figure 2F). For color, 42.9% of participants (9/21) responded correctly in the fixation and 60.0% (12/20) in the saccade condition. However, the corresponding M-L χ^2 tests test did not reach significance, M-L $\chi^2(1, N = 41) = 1.21$, $p = .271$, $\phi = 0.17$.[1] For letter identity, 23.8% of participants (5/21) responded correctly in the fixation and 55.0% (11/20) in the saccade condition. This difference was statistically significant, M-L $\chi^2(1, N = 41) = 4.27$, $p = .039$, $\phi = 0.32$. Nonetheless, letter identification in the saccade condition remained worse than on the first postsurprise trial, 55.0% (11/20) versus 95.0% correct (19/20), M-L $\chi^2(1, N = 40) = 9.52$, $p = .002$, $\phi = 0.46$.

General Discussion

In two experiments, we found that saccadic selection was by no means sufficient to eliminate attribute amnesia. Attribute amnesia occurred regardless of saccadic selection, although it was reduced when the target was foveated for some time and the response attribute was letter identity. Comparison of saccades with and without foveation (Experiment 2 vs. 1) suggests that it was not saccade execution per se but the foveal presentation of the target that attenuated attribute amnesia. These results are consistent with a study by Eitam et al. (2015), who observed that attribute amnesia (termed seeing without knowing in their study) was absent for foveally presented objects (see their Experiment 2). Furthermore, our results complement the study of Chen et al. (2016) on attribute amnesia in dynamic natural scenes by showing that saccade or gaze targets are not spared from attribute amnesia, even in displays of comparatively low visual load. That is, overt selection does not necessarily promote the integration of object attributes in a more durable memory representation compared with covert selection, even in conditions similar to the ones used in studies that have attested obligatory links between eye movements, attention, and visual working memory (e.g., Deubel et al., 1996; Hollingworth et al., 2008; Schut et al., 2017; Shao et al., 2010; Tas et al., 2016).

Responding by willfully directing one's eyes toward an object under strict time constraints is a somewhat unnatural task and participants did not perform many trials. This could mean a higher cognitive demand in the saccade than the fixation condition. Could it be that the task taxed the working memory system more heavily, precluding a more robust memory consolidation in the saccade condition? Indeed, gaze errors were more frequent in the saccade condition in Experiment 1 in which no saccadic benefit emerged but were comparable to the fixation condition in Experiment 2, in which a small saccadic benefit was observed. Note, however, that in comparison with previous studies in which participants were asked to make an eye movements toward a specified target object while simultaneously maintaining a set of items in visual working memory (Schut et al., 2017; Shao et al., 2010; Tas et al., 2016), we think the strain on the working memory system was comparably low in our experiments.

It has been argued that prioritizing the saccade target in visual working memory has a functional role for the maintenance of object correspondence and visual stability across eye movements (Henderson et al., 2003; Hollingworth et al., 2008; Irwin, 1996; McConkie et al., 1996; Van der Stigchel et al., 2018). For instance, Hollingworth and colleagues (Hollingworth et al., 2008; Van der Stigchel et al., 2018) assume that some features of the target are encoded into visual working memory before the saccade. If those features are found in an object located near the saccade landing point after the saccade, object correspondence is established and spatial stability is experienced. At the very least, saccade target information should thus be maintained across the eye movement and withstand interference from postsaccadic sensory input. Although the visual system may not necessarily use all features for correspondence matching across saccades, the current displays did not contain many features in the first place. One may therefore wonder why target attributes were so poorly remembered, especially in Experiment 2 in which the target was visible before as well as after the saccade. We think that although saccade target attributes may be used for transsaccadic correspondence matching, they do not necessarily have to be represented in a robust enough manner to be reportable on a surprise trial. Interestingly, studies suggesting that saccade targets are automatically encoded into visual working memory demonstrated only that making a saccade toward a visual target interferes with the maintenance of nonfoveated items (Schut et al., 2017; Shao et al., 2010; Tas et al., 2016). They did not assess explicit memory of the saccade target itself, when it was irrelevant for the memory task. It is therefore possible that saccade target attributes are automatically encoded into visual working memory and represented in a manner robust enough to allow for correspondence matching. Still, the representation may be too fragile to be retrievable for explicit conscious report on a surprise question.

In agreement with this idea, it has been found that on the one hand, repeating the same target identity across two presurprise trials in an attribute amnesia setup can speed up localization and improve localization accuracy (i.e., performance in the primary task; Jiang et al., 2016). These intertrial priming effects suggest that some representation of the target's identity was preserved across trials, even though the identity of the target was not accessible for conscious report on the surprise trial. On the other hand, it has been found that, compared with the fixations of another observer, we are not better at reproducing and only slightly better than chance at recognizing our own fixation pattern in a scene we have just inspected (Foulsham & Kingstone, 2013; Võ, Aizenman, & Wolfe, 2016). Furthermore, we may not notice when our eyes are captured by a salient distractor object (Theeuwes, Kramer, Hahn, & Irwin, 1998). These examples underline that we do not necessarily form a longer-lasting explicit memory representation of the objects we have fixated, compared with other objects. This could contribute to our intuitive notion that we perceive the world

[1] One may argue that this was due to a lack of statistical power in Experiment 2. Note, however, that the required sample size for an effect of $\phi = 0.17$ would be $N = 241$ to achieve a power of $1 - \beta = 0.75$.

around us without the impression of strong differences in the perceptual quality of objects.

Although prioritization of saccade targets may not have a durable effect if not fostered, the selected objects may nonetheless have an advantage when the task demands their retention in working memory. This would explain better performance when the saccade target (or another object presented at its location) is part of the set of items to be remembered (Bays et al., 2008; Hanning et al., 2016; Melcher et al., 2011; Shao et al., 2010). Similarly, with explicit instruction to memorize the scenes, details of natural scene images from previously fixated regions are recognized more easily compared with equally salient details from nonfoveated regions of the scene (Valuch, Becker, & Ansorge, 2013). Nonetheless, attribute amnesia remains a highly surprising and fascinating phenomenon because it occurs under conditions generally thought to favor attentional processing, feature binding, and the allocation of residual memory resources to irrelevant information.

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