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Is Source Information Automatically Available in Working Memory?

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Abstract
We often remember information without its source (e.g., word or picture format). This phenomenon has been studied extensively in long-term memory but rarely in the context of short-term working memory (WM), which leaves open the question of whether source amnesia can result from a lack of memory encoding rather than forgetting. This study provided a series of striking and novel demonstrations showing participants' inability to report the source of a color representation immediately after that color was used in a task and stored in memory. These counterintuitive findings occurred when participants repeatedly judged the congruency between two color representations from one single object (i.e., color and identity of a color word) or two distinct objects (i.e., color of a square and identity of a color word) and then were unexpectedly asked to report the source of one color representation. These discoveries suggest that source information is often not stored in WM.

Keywords
short-term memory, false memory, episodic memory, attention, open data, open materials

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In everyday life, it is commonplace to remember a fact without its source. For instance, we all have some experience of recognizing a person but being unable to recollect where or when we met that person or remembering a movie quote without remembering the movie. Most people, though, share the intuition that they will be able to remember the source of information that they have just recently encountered. Here, we explored errors that challenge this intuition, demonstrating frequent source errors for information that was attended and used to perform a task moments before.

The phenomenon of failing to remember the source of retrievable information has been variously labeled as *source amnesia, source forgetting, source-monitoring error, source misattribution, source error* and so on (Mitchell & Johnson, 2009) and has been extensively studied (e.g., Glisky, Polster, & Routhieaux, 1995; Hollins, Lange, Berry, & Dennis, 2016; Johnson, Hashtroudi, & Lindsay, 1993; Maillet, & Rajah, 2016; Mitchell & Johnson, 2009; Mitchell, Johnson, Raye, & Greene, 2004; Mitchell, Raye, Johnson, & Greene, 2006; Wilding & Rugg, 1996). *Source memory* is broadly defined as remembered information, such as perceptual (e.g., color, format of a stimulus), spatial-temporal, and affective details (Glisky et al., 1995; Johnson et al., 1993), that specifies how an event was experienced. Such memory is usually contrasted with *item memory*, which relies on less differentiated information, such as familiarity or recency (Glisky et al., 1995; Johnson et al., 1993). For example, an item memory task usually asks participants to determine whether a probed stimulus was seen before, while a source memory task typically requires participants to retrieve associated information, such as which list a word was encountered on (e.g., Wilding & Rugg, 1996), whether a learned stimulus was presented in auditory or visual modality during study (e.g., Bornstein & LeCompte, 1995), or whether a stored semantic representation was acquired from a word or a picture (e.g., Mitchell et al., 2004; Mitchell et al., 2006).

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Source amnesia has been extensively investigated using long-term-memory paradigms but has rarely been studied in short-term or working memory (WM). This might be because we intuitively believe that source information is always available immediately after stimulus processing, and source amnesia would therefore be impossible in WM. Some prior studies (Mitchell et al., 2004; Mitchell et al., 2006) seem to support this intuition by showing that participants had good memory for source information (e.g., format or location) of stimuli they had just seen several seconds before.

However, in those studies, participants had clear expectations that they would need to remember the source information. Thus, these studies did not address a critical question, which is whether participants automatically remember the source of the content that had just been experienced when there is no expectation that this source information should be remembered.

The current study attempted to address this issue by using an immediate surprise memory test developed in studies of inattentional blindness (e.g., Mack & Rock, 1998; Most, Scholl, Clifford, & Simons, 2005; Simons & Chabris, 1999), change blindness (e.g., Rensink, O'Regan, & Clark, 1997; Simons & Levin, 1998), and attribute amnesia (Chen, Swan, & Wyble, 2016; Chen & Wyble, 2015a, 2015b, 2016). The results showed that participants could not retrieve the source format (i.e., color word or physical color) of information that had just (i.e., several seconds before) been attended and used to perform a color-congruence judgment. Thus, the conclusion is that source format information is not automatically stored in WM.

Experiment 1

The first experiment investigated whether participants would automatically remember the source format of a color representation that they had just used to complete a task in the immediately preceding interval. To answer this question, we repeatedly asked participants to judge the congruency between the color and identity of a single color word (e.g., "RED" displayed in green ink color; we hereafter use "ink" to refer to the color of phosphors on a CRT display), and then on a surprise trial, we asked them to recognize the ink color of the word that they had just seen on that trial, prior to reporting the congruency.

Note that the congruency judgment task requires participants to extract semantic representations from both the ink color and identity of the word but does not require them to remember these semantic representations or link them to their original source format (i.e., ink color or word). Thus, the surprise question examines the spontaneous storage of source information.

Method

Sample size. In the current set of experiments, we used a predetermined sample size of 20 participants for each experiment or each group in between-subjects designs. This sample size was based on previous studies that indicated the magnitude of the effect that could be expected (Chen & Wyble, 2015a, 2015b, 2016). In the last replication experiment, we used a larger sample size (40 in each group) to further ensure that the findings were reliable. In this entire study, no participants were allowed to participate in more than one experiment.

Participants. Forty Pennsylvania State University undergraduates (divided randomly into two groups) completed Experiment 1 in exchange for course credits or $5. All of them reported normal or corrected-to-normal visual acuity. An additional participant completed the experiment but was removed for having accuracy in the presurprise trials lower than 60% (chance is 50%).

Apparatus. The stimuli were presented on a 17-in. CRT computer monitor with a resolution of 1,024 × 768 pixels at 75 Hz refresh rate by using MATLAB (The MathWorks, Natick, MA) with the Psychophysics Toolbox extensions (Brainard, 1997; Pelli, 1997). The viewing distance was fixed at approximate 50 cm by using a chin rest. Participants made responses using a computer keyboard.

Stimuli. There were four different color words ("RED," "BLUE," "YELLOW," and "PURPLE"), and each of them was displayed in one of four ink colors—RGB values = 200, 0, 0 (red); 0, 0, 200 (blue); 200, 200, 0 (yellow); and 190, 45, 200 (purple)—which yielded 4 *congruent words* (e.g., the word "RED" displayed in red ink color) and 12 *incongruent words* (e.g., the word "RED" displayed in green ink color). All words were displayed in a font size of 30 in Arial uppercase font. The four black placeholder circles (0.62°) were placed at the four corners of an invisible square (6.25° × 6.25°), with a black fixation cross (0.62°) appearing in its center (see Fig. 1). All these stimuli were displayed on a gray background (RGB value = 150, 150, 150).

Procedure and design. As shown in Figure 1, the trial started with the fixation display for a randomly determined duration between 1,000 and 2,000 ms. This was replaced by the stimulus display, which contained only one single congruent or incongruent word at the center of the screen for 161 ms. The stimulus word was then covered by a colored mask for 522 ms. After the offset of the mask, two black words, "Congruent" and "Incongruent," and two corresponding numbers ("1" and "2") appeared and remained on the screen until participants made a response. Participants were asked to report whether or not the word's ink

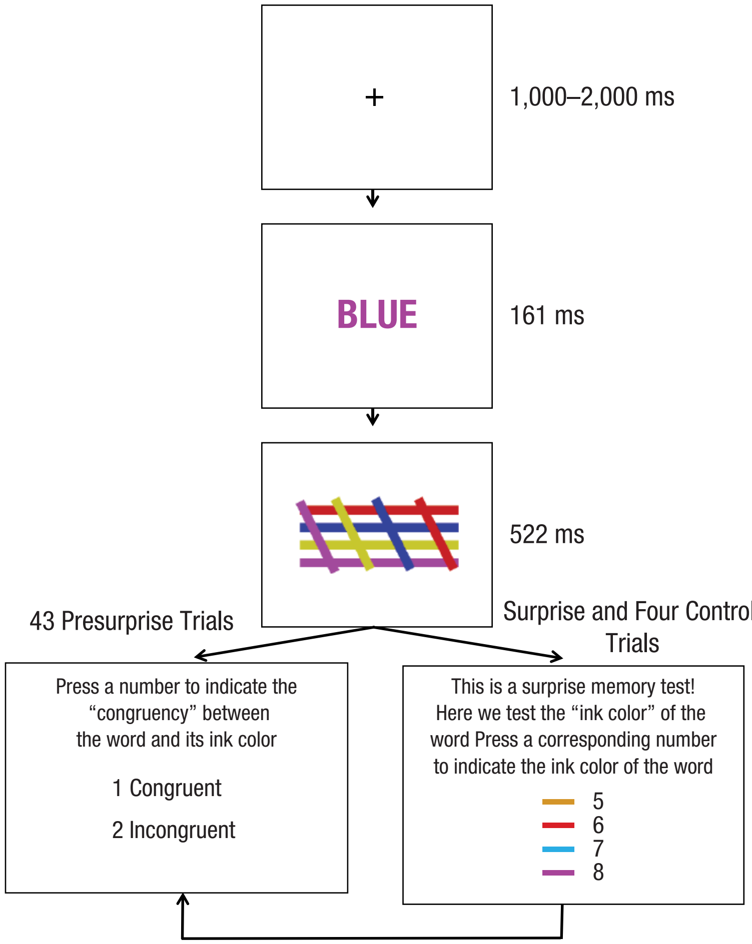

Fig. 1. Sample trial sequences in Experiment 1. The surprise question reads "This is a surprise memory test! Here we test the 'ink color' of the word. Press a corresponding number to indicate the ink color of the word."

color was congruent with its identity on these trials by pressing one of two number keys (1 or 2).

Then, on the 44th trial (i.e., the surprise trial), participants were unexpectedly presented with a forced-choice array including four different colored lines (i.e., red, blue, yellow, and purple; see Fig. 1) and asked to indicate which one matched the ink color of the word they had just seen on that trial by pressing one of four corresponding number keys (5–8). The four colored lines were presented in random order. After this surprise memory task, participants were asked to do the congruency judgment task as in previous trials. The surprise trial was followed by four control trials that had the same format as the surprise trial. All responses in this and following experiments were self-paced, with no time pressure being applied.

Participants were divided into two groups according to the types of the word used on the surprise trial: Half of them were defined as the *incongruent group*, which was shown an incongruent word on the surprise trial, while the other half were the *congruent group*, which was shown a congruent word on the surprise trial. Subsequent control trials in both groups were randomly assigned a congruent or incongruent word.

Results

The results of the incongruent and congruent groups are depicted in Table 1. For the incongruent group, participants performed well on the congruency report task on presurprise trials (3% error). However, 40% (8/20) of participants incorrectly reported the ink color of the word on the surprise trial. Moreover, of these incorrect-report participants, 75% (6/8) incorrectly selected the colored lines that matched the word's identity when asked about the word's ink color (i.e., source misattribution), a percentage that was significantly higher than the chance of guessing (1/3 = 33%; 75% vs. 33%, p = .017 in a binomial test). This indicated that participants had memories of both semantic

Table 1. Mean Error Rate in Experiment 1 (n = 20 for Each Group)

	Trial type					
Group and task	Presurprise	Surprise	Control 1	Control 2	Control 3	Control 4
Incongruent						
Congruency	3%	30%	0%	0%	10%	0%
Color		40%	5%	0%	0%	5%
Congruent						
Congruency	3%	5%	15%	5%	0%	0%
Color		10%	20%	0%	0%	0%

representations but were often confused about whether a specific semantic representation was extracted from the ink color or identity of a color word. Furthermore, participants' error rates for ink color reports on control trials (5%, 0%, 0%, and 5% error for control trials 1–4, respectively) were smaller than errors in the surprise trial (40% error), with the decrement reaching significance even on the first control trial (40% vs. 5%), $\chi^2(1, N = 40) = 7.025$, $p = .008$, $\varphi = .42$.

Contrary to the incongruent group, only 10% (2/20) of the participants in the congruent group incorrectly reported the ink color of the word on the surprise trial, which was even numerically lower (though not significantly so) than the first control trial (10% vs. 20%), $\chi^2(1, N = 40) = 0.784$, $p = .376$, $\varphi = .14$. More importantly, this error rate was significantly lower than that of the incongruent group (10% vs. 40%), $\chi^2(1, N = 40) = 4.800$, $p = .028$, $\varphi = .35$. This result was consistent with the idea that participants had memories of both colors despite a lack of memory for their corresponding source formats.

For the congruency judgment task, incongruent-group participants' error rate on the surprise trial was 30%, which was much worse than the presurprise trial (3%) and control trials (0%, 0%, 10%, and 0% errors). However, in the congruent group, the error rate on the congruency judgment task on the surprise trial (5%) was comparable with that on the presurprise trial (3%) and control trials (15%, 5%, 0%, 0%).

These findings showed that participants often could not report the source of information that had just been specifically attended and used in the immediately preceding task, indicating that source memory representations are not automatically stored. To the best of our knowledge, this is the first demonstration of source memory failure in short-term memory with young healthy participants. Another important finding is that even though participants did not remember the source format of the two colors, at least one of those two colors themselves was retrievable in response to an unexpected question.

Experiment 2

Experiment 1 showed that attending to and using particular attributes of a stimulus (i.e., semantic representation of colors) does not automatically elicit a binding of those attributes to their source formats. Experiment 2 extended this finding by examining whether the need to briefly hold information in WM prior to use would be sufficient to elicit obligatory source storage. This idea stems from a previous finding that holding information briefly in memory increased the chance that the item information would be subsequently reportable in a surprise trial (Chen & Wyble, 2016). Here, we examined whether this finding extended to the source information as well.

We tested this possibility by presenting a colored square followed by a color word, or vice versa, and asking participants to judge the congruency between the two colors until they were surprisingly asked to report the color of the square. If holding information briefly in WM causes source memory to be encoded, then, on square-first trials, participants should correctly answer the surprise source memory question. However, since the opposite ordering (word then square) requires participants only to access the square's color without holding it in memory for an appreciable duration, source information should be less available in the surprise question, as in Experiment 1.

Method

This experiment was identical to Experiment 1 with the following exceptions. Forty undergraduate students completed this experiment (divided randomly into two groups). As depicted in Figure 2, participants saw two sequential stimuli: one colored square and one black word, and judged whether the color of the square was congruent with the identity of the word in presurprise trials. Each stimulus appeared on the screen for 161 ms and was then masked for 522 ms. Thus, participants had to hold the first stimulus in WM for more than half

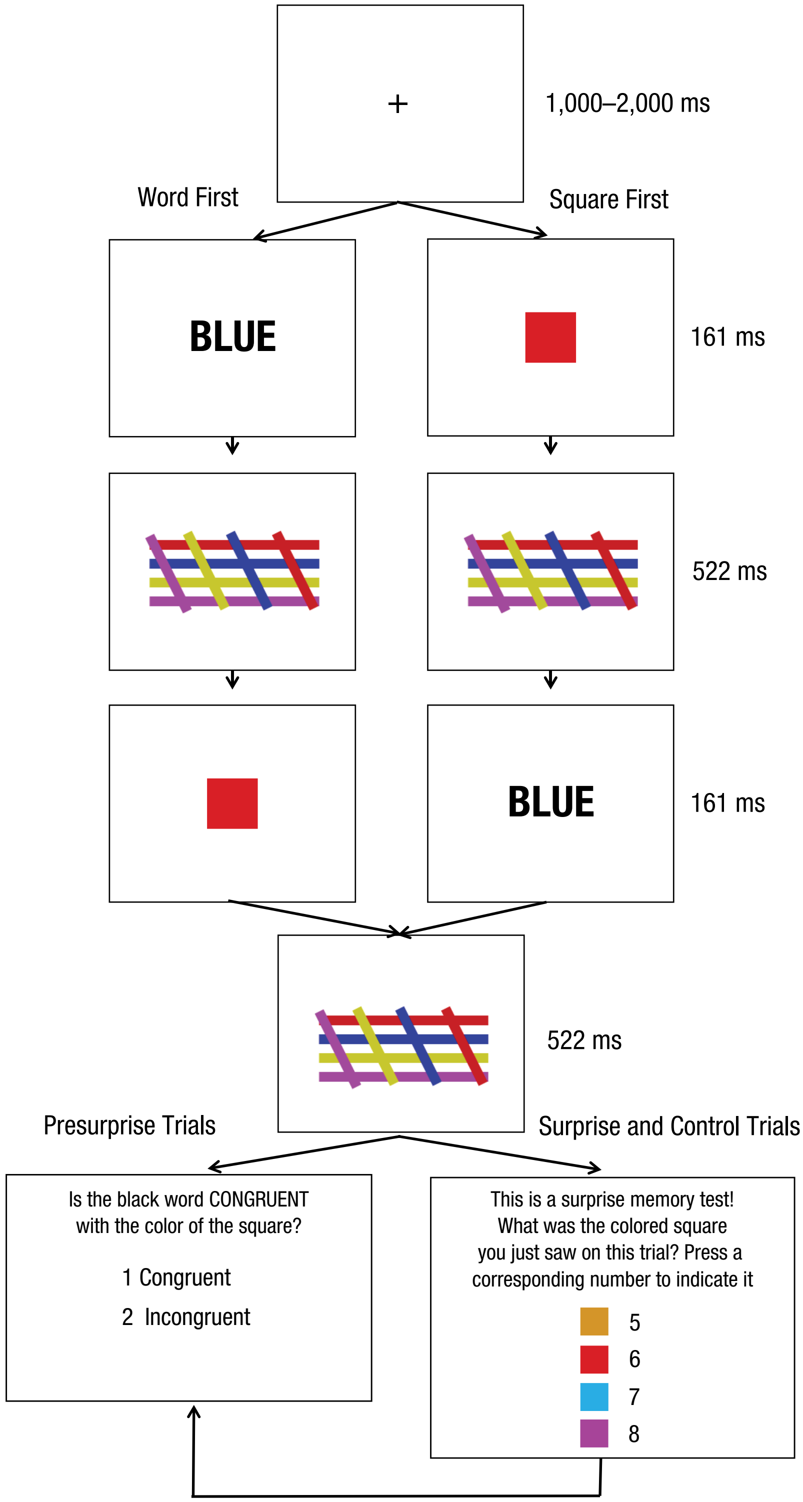

Fig. 2. Sample trial sequences in Experiment 2. The surprise question reads "This is a surprise memory test! What was the colored square you just saw on this trial? Press a corresponding number to indicate it." Note that squares and masks were presented in color in the experiment but are reproduced here in grayscale.

a second in order to make the congruency judgment. Half of the participants always saw the colored square first (i.e., square-first group), while the other half always saw the word first (i.e., word-first group). On the surprise (34th trial) and control trials, participants from both groups were required to select the exact colored square (among three distractor colored squares) they had just seen on that trial before the congruency task.

Results

The results of word-first and square-first groups are depicted in Table 2. For the word-first group, 12 of 20 (60% error) participants incorrectly selected the colored square on the surprise trial, which was substantially worse performance than on the first control trial (60% vs. 5%), $\chi^2(1, N = 40) = 13.789$, $p < .001$, $\varphi = .59$. Furthermore, consistent with Experiment 1 (incongruent group), of these 12 incorrect-report participants, 8 (67%) suffered from source misattribution (i.e., chose the square with the color referring to the identity of the word on that same trial), which was significantly higher than the chance (1/3 = 33%; 67% vs. 33%, $p = .015$ in a binomial test). Moreover, in a control experiment, we replicated this word-first-group experiment but removed the square with the color referring to the word's identity from the array of choices on the surprise question. Then, only 2 of 20 (10% error) participants incorrectly selected the target square on the surprise trial, indicating that participants could access a memory of the square's color despite lacking a specific source representation.

By contrast, only 3 of 20 participants from the square-first group incorrectly selected the target square on the surprise trial, which did not significantly differ from the first control trial (15% vs. 5%), $\chi^2(1, N = 40) = 1.111$, $p = .292$, $\varphi = .17$. More importantly, this error rate was significantly lower than that in the surprise trial in the word-first group (15% vs. 60%), $\chi^2(1, N = 40) = 8.640$, $p = .003$, $\varphi = .46$. As shown in Table 2, the performance on the congruency task was high on all trials except the surprise trial, which showed a considerable decline.

These results seem to suggest that holding a color representation in WM for a brief time is sufficient to obligatorily store its source (as shown in the square-first group), which can be contrasted with the inability to report the source format of information that had no memory requirement (as in the word-first group). However, an alternative explanation could be that participants had no source memory but were biased toward reporting the color of the first-presented stimulus when asked about the color of the square on the surprise test, which would yield a correct response in the square-first condition and an incorrect response in the word-first condition.

Experiment 3

Here, we asked whether the results of the square-first group in Experiment 2 reflected automatic source memory for an input held in WM or, alternatively, a bias to report the first presented color because of stronger activation. We addressed this issue by setting up a situation wherein a bias to report the first-presented item would not help to answer the source memory task. Word-first and square-first trials were randomly shuffled in presurprise trials. On the surprise trial, participants were asked whether a probed color was presented as a square or a word.

Method

This experiment was identical to Experiment 2 except as follows. Another 20 undergraduate students completed this experiment. In 35 presurprise trials, participants saw either a colored square followed by a black word, or vice versa, and judged congruence. On the surprise trial, the square was presented before the word, and participants were unexpectedly asked to judge whether a given probed color representation (which always referred to the square color) came from

Table 2. Mean Error Rate in Experiment 2 (n = 20 for Each Group)

	Trial type					
Group and task	Presurprise	Surprise	Control 1	Control 2	Control 3	Control 4
Word first						
Congruency	6%	25%	10%	10%	5%	0%
Color		60%	5%	10%	0%	10%
Square first						
Congruency	2%	15%	0%	5%	5%	5%
Color		15%	5%	5%	0%	5%

a square or a word by pressing one of two keys. For instance, the surprise question on the screen read "Surprise test! On the last trial, Did the color *RED* come from a square or a word? Press 3 if square, Press 4 if word." The presentation order of the answer choices (i.e., "Press 3 if square, Press 4 if word," or vice versa) on the surprise test was counterbalanced among participants. We used a different font for the color to minimize a template-based strategy. The following control trials had the same format as the surprise trial, except that the stimulus presentation sequence and the probed color representation (either from square or word) were counterbalanced among participants.

Results

The results are shown in Table 3. Participants performed poorly on the source judgment task on the surprise trial, with 9 of 20 (45% error; chance is 50%) participants being incorrect. However, their performance increased in control trials (30%, 10%, 5%, and 0% error, respectively), with the improvement reaching significance by the second control trial (45% vs. 10%), $\chi^2(1, N = 40) = 6.144$, $p = .013$, $\varphi = .39$. There was a decline in the performance of congruency task on the surprise trial.

Participants in the current experiment failed to report source format information of a color representation even when that color had been briefly held in WM. This indicates that the findings of Experiment 2 were likely due to a bias to report the color representation of the first-presented item rather than an automatic encoding of source information. Thus, source information was not automatically stored even when a stimulus was held in WM.

Experiment 4

Experiment 4 investigated whether the source amnesia would be reduced or eliminated when the possibility of source confusion was removed. Here, we replicated the incongruent group of Experiment 1 (which had shown source misattribution) but informed participants of the identity of the word on the surprise test.

Method

This experiment was identical to the incongruent group of Experiment 1 except as follows. Twenty-one undergraduate students completed the experiment, with 1 of them being excluded on the basis of the criterion reported before. In the surprise memory test and the following control trials, participants were unexpectedly presented with an array of four color words with the same identity (which always matched the word shown on that trial) but different ink colors, instead of four different colored lines as in Experiment 1. The participant's task was to select the target word that was exactly the same as the one they had just seen by pressing a number, followed by a confirmation key ("Enter"). Note that here participants could rely only on the ink-color information to select the target word.

Results

The results are depicted in Table 4. Only 4 of 20 participants (20% error) were incorrect in the surprise memory test, and this error rate did not significantly differ from that in the first control trial (20% vs. 10%), $\chi^2(1, N = 40) = 0.784$, $p = .376$, $\varphi = .14$. Furthermore, the error rate of the surprise test (20%) was numerically smaller (but not significant), compared with that of Experiment 1 (40%), $\chi^2(1, N = 40) = 1.905$, $p = .168$, $\varphi = .22$. In the following replication experiment, we further examined this effect by using a larger sample size to produce a greater power. Generally, the results showed that the observed source amnesia became weaker after removing the possible source confusion.

Experiment 5

To ensure that the previous findings were reliable and to confirm that the disambiguation procedure of Experiment 4 reduced the magnitude of source amnesia, we directly replicated Experiments 1 and 4 with a larger sample size. Experiment 5a replicated the findings in the incongruent group of Experiment 1 (which had showed source misattribution), while Experiment 5b replicated Experiment 4 (which had showed weaker source amnesia after removing source confusion).

Table 3. Mean Error Rate in Experiment 3 ($n = 20$ for Each Group)

	Trial type					
Task	Presurprise	Surprise	Control 1	Control 2	Control 3	Control 4
Congruency	4%	25%	0%	0%	5%	0%
Source		45%	30%	10%	5%	0%

Table 4. Mean Error Rate in Experiment 4 (n = 20 for Each Group)

	Trial type					
Task	Presurprise	Surprise	Control 1	Control 2	Control 3	Control 4
Congruency	5%	15%	10%	0%	0%	5%
Color		20%	10%	0%	5%	5%

Method

The methodology in Experiment 5a was exactly the same as that for the incongruent group of Experiment 1, except that there were 40, instead of 20, participants. Experiment 5b was identical to Experiment 4, except as follows: 41 undergraduate students completed the experiment, and 1 of them was excluded. Participants' responses were not shown on the screen and they did not need to press "Enter" to confirm their responses, to maximize the similarity between reporting in Experiments 5a and 5b. Note that the only difference between Experiments 5a and 5b was that in Experiment 5b, the possibility of source confusion was removed by informing participants of the identity of word on the surprise test.

Results

The results of Experiments 5a and 5b are depicted in Table 5.

Experiment 5a. The results replicated the findings in the incongruent group of Experiment 1. Twenty of 40 (50% error) participants were incorrect in the surprise memory test of the word's ink color, and this error rate was dramatically larger than that of the first control trial (50% vs. 2.5%), $\chi^2(1, N = 80) = 23.309$, $p < .001$, $\varphi = .54$. Also, 15 of 20 (75%) of these incorrect-report participants mistakenly reported the identity of the word when asked about the ink color, which is a significantly higher percentage than guessing could produce (75% vs. 33%, $p < .001$ in a binomial test).

Experiment 5b. The results essentially replicated those of Experiment 4. The error rate on the surprise test of the word's ink color was 22.5% (9/40), which was very close to that of Experiment 4 (4/20 = 20%). This error rate was significantly larger than that in first control trial (22.5% vs. 5%), $\chi^2(1, N = 80) = 5.165$, $p = .023$, $\varphi = .25$. More importantly, this error rate was significantly smaller than that in Experiment 5a (22.5% vs. 50%), $\chi^2(1, N = 80) = 6.545$, $p = .01$, $\varphi = .29$, providing stronger evidence that source amnesia was reduced when removing the possible source confusion.

The results of Experiment 5a not only replicated source memory failure on the surprise test, but also replicated the source misattribution effect in Experiment 1, indicating that the observed source amnesia was reliable. The results of Experiment 5b further demonstrated that source amnesia would be largely reduced or eliminated after removing the possibility of source confusion.

General Discussion

These experiments showed that participants often failed to remember the source format of a stimulus they had just attended while performing a congruence judgment in which they did not expect to be asked to report that source. These findings, to the best of our knowledge, provide the first demonstration of source amnesia for information represented in WM with young healthy participants. These results suggest that source information can be poorly represented even immediately after encountering an attended stimulus (i.e., a color word). What participants seem to retain in these experiments

Table 5. Mean Error Rate in Experiment 5 (n = 40 for Each Group)

	Trial type					
Experiment and task	Presurprise	Surprise	Control 1	Control 2	Control 3	Control 4
Experiment 5a						
Congruency	3%	40%	2.5%	5%	0%	0%
Color		50%	2.5%	2.5%	2.5%	5%
Experiment 5b						
Congruency	3%	17.5%	2.5%	2.5%	0%	0%
Color		22.5%	5%	2.5%	0%	0%

Table 6. Long-Term and Short-Term Source Amnesia in Different Task Demands

Task demands	Long-term source amnesia	Short-term source amnesia
Intentional/expected	Yes (e.g., Mitchell, Johnson, Raye, & Greene, 2004; Schacter, Harbluk, & McLachlan, 1984)	No (e.g., Mitchell, Johnson, Raye, & Greene, 2004; Mitchell, Raye, Johnson, & Greene, 2006)
Incidental/unexpected	Yes (e.g., Jacoby, 1991; Naveh-Benjamin, 2000)	Yes (Current study)

are memories of the colors that are untethered to their original source. This leads to a variety of errors, such as source misattribution in Experiment 1, and errors driven by familiarity or temporal precedence in Experiment 2.

Is source information automatically stored?

Mitchell et al.'s (2004, 2006) studies used a short-term source memory task and found that young participants could accurately report the source (i.e., stimulus format or location) of a probed stimulus. However, those participants were instructed in advance to remember the source information of stimuli, while our participants did not expect to report the source format of the colors used in the congruency judgment. Our findings suggest that participants' expectation of the need to report source information plays a critical role in determining whether it will be remembered. It is possible that participants initially automatically encode source information and then stop doing so after a couple dozen repetitions of the event. Future studies with earlier surprise tests (e.g., on the first trial) are needed to test this possibility.[1]

Previous studies demonstrated that long-term source amnesia occurred regardless of whether participants expected to report the source information (see Table 6; e.g., Jacoby, 1991; Mitchell et al., 2004; Naveh-Benjamin, 2000; Schacter, Harbluk, & McLachlan, 1984), while short-term source amnesia was not present when participants expected to report source information (e.g., Mitchell et al., 2004, 2006). The source amnesia observed here thus provides an important complement to the existing literature by showing that it occurs in the short-term for an unexpected probe.

The locus of source amnesia: encoding or retrieval?

It is difficult to determine the locus of long-term source amnesia that occurs in the context of incidental and unexpected memory tasks, since a failure to report in these tasks could be attributed to failures of encoding or retrieval. The current study showed that source amnesia could occur even in short-term-memory paradigms, suggesting that some demonstrations of source amnesia, at least those occurring in the context of incidental memory tasks, reflected a lack of initial memory encoding of source information.

One might argue that the source amnesia was caused by forgetting because of the surprise test. This is unlikely because participants had an intact memory of color representation. Furthermore, previous studies demonstrated that information that has been deliberately encoded into WM could survive a similar surprise test (Chen & Wyble, 2016; Swan, Wyble, & Chen, 2017).

Another interesting finding is that there is a positive correlation between participants' surprise-test performance and the congruency report after the surprise test. Future studies are needed to clarify whether this is due to forgetting induced by performing the surprise question or shared individual variability.

Comparison with attribute amnesia

The present results can be contrasted with attribute amnesia, a failure of participants to report attributes (e.g., color or identity) of a target that had just been attended when they did not expect to report them (Chen & Wyble, 2015a). In contrast, we found here that participants could remember individual features of an attended stimulus, even though they had no expectation to report them. This difference might reflect the fact that attribute amnesia occurs when selecting one item from an array of multiple items, while in the current study, there was only a single stimulus presented on the screen at any given time. Other studies also showed better performance of a surprise test of attributes when there were only two (Chen et al., 2016) or one stimulus presented at a time (Eitam, Yeshurun, & Hassan, 2013; Swan, Collins, & Wyble 2016).

Conclusion

These results suggest a cognitive-economy view of memory function, in which source information is stored only when it is expected to be useful. In the absence of such expectation, information is stored at a conceptual level, without its accompanying source format. In such a case, the source format may be stored at a schema level for the entire task (e.g., I remember that in this study, colors are presented as words or ink colors).

Our findings challenge the common intuition that if we have just experienced and made use of information, we will know its source. Together with previous work on attribute amnesia (e.g., Chen & Wyble, 2015a), these results demonstrate that attention and awareness do not automatically result in memory traces durable enough even for short-term retrieval. They go beyond those previous results by demonstrating that even using information to make inferences is not sufficient for encoding of the information's source.

Action Editor

Edward S. Awh served as action editor for this article.

Author Contributions

The study concept was developed by all authors. H. Chen performed the programming, data collection and analysis, and most of the writing. B. Wyble and R. A. Carlson contributed writing and editing. All authors approved the manuscript for submission.

Declaration of Conflicting Interests

The author(s) declared that there were no conflicts of interest with respect to the authorship or the publication of this article.

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Open Practices

All data and materials have been made publicly available via the Open Science Framework and can be accessed at https://osf.io/4x8tn/. The complete Open Practices Disclosure for this article can be found at http://journals.sagepub.com/doi/suppl/10.1177/0956797617742158. This article has received badges for Open Data and Open Materials. More information about the Open Practices badges can be found at http://www.psychologicalscience.org/publications/badges.

Note

1. We thank an anonymous reviewer for proposing this possibility.

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