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BRIEF REPORT

Attribute amnesia as a product of experience-dependent encoding

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Abstract
Attribute amnesia, a phenomenon in which participants fail to report a just-attended attribute in a surprise test, reflects the importance of expectation in determining memory for attended information. To investigate how expectations arise in the context of attribute amnesia, the present study examined whether and how different response histories, independently of task instruction, can shape expectation, thereby driving or eliminating attribute amnesia. Participants were assigned to three groups and completed variations of the attribute amnesia task, where they were initially instructed to encode both target location and identity. Two groups of participants were probed four times on target identity before a critical identity probe, in one case intermittently while in the other case repeatedly during the first few trials. Another group of participants was never probed on identity until the critical trial, which occurred on the 370th trial (after many location probes). The results showed that, in spite of common task instruction, performance on the critical trial depended strongly on response history, with initial identity probes providing some protection against attribute amnesia and intermittent probes completely eliminating it. The findings suggest that the encoding of information into working memory is determined by task experience, independently of task instruction.

Keywords Response history · Working memory · Encoding · Expectation

Introduction

It is commonly believed that attended information is mandatorily encoded into memory and thereby available for report in an immediate memory test (e.g., Lamme, 2004; Simons & Chabris, 2011). However, this common-sense belief has been challenged by attribute amnesia (Chen & Wyble, 2015a, b), a recently observed counterintuitive phenomenon in which participants fail to report a just-attended attribute in a surprise test.

In a typical attribute amnesia experiment, participants experience several trials of reporting one attribute of a target stimulus among non-target stimuli and then in one surprise trial are asked to report a different, unexpected attribute of the target. For example, in Chen and Wyble's (2015a) Experiment 1a, participants completed 155 trials (pre-surprise trials) in which four colored items were simultaneously presented for 150 ms and their task was to report the location of the target letter among three distractor digits. Then on the 156th trial (the surprise trial), participants were unexpectedly asked to report the identity and color of the target before reporting its location. Results showed that, even though participants attended to and used identity information to locate the target letter, their reporting accuracy for target identity on the surprise trial was strikingly low and increased drastically on subsequent control trials (trials which have the same procedure as the surprise trial and follow immediately after the surprise trial). Since the only difference between the surprise trial and control trials is participants' expectation regarding whether identity and color would be probed, and the time interval between the stimulus array and test display is very short (e.g., 500 ms in Chen & Wyble, 2015a), Chen and Wyble (2016) proposed that this attribute amnesia effect reflects the importance of expectation in determining memory for attended information. To be more precise, it indicates that memory encoding is a highly selective process: not all attended information is compulsorily encoded, and what is encoded seems to be related to expectations concerning what information is needed for later report.

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Even though attribute amnesia has been replicated extensively (Born et al., 2019, 2020; Chen & Wyble, 2015a, b, 2016; Chen & Howe, 2017; Chen et al., 2016, 2019a, b; Howe & Lee, 2021; Jiang et al., 2016; McCormick-Huhn et al., 2018; Harrison et al., 2021; Swan et al., 2017; Tam et al., 2021; Wang et al., 2021), one essential question revealed by attribute amnesia has been overlooked by most researchers, which reflects the mechanisms by which the expectations that determine the selectivity of encoding are built. On the surface, it seems obvious that expectation is shaped by explicit verbal instruction and may reflect highly-selective goal-contingent encoding, since the surprise trial traditionally probes an attribute that participants were not asked to encode and report; specifically, participants do not receive any instruction concerning the possibility that they will be asked about features other than the one mentioned in the task instruction.

However, an important observation within the context of the classical attribute amnesia paradigm is that during the trials preceding the surprise trial, participants' response history (i.e., their past experience of reporting a particular attribute of a target stimulus) consistently corresponds with their task instruction. In other words, participants are not only unaware of the upcoming surprise trial, but they also have no prior experience reporting the target's identity. This renders response history a plausible alternative factor contributing to how participants encode information about stimuli. The aim of the present study was to tease those two factors apart and uncover whether and how response history can shape the selective encoding of information into memory even when there is explicit instruction regarding the information that should be encoded. Addressing this research question is important, since people's experience in their work and study sometimes does not strictly follow a rule they have been given, and there may be divergence between what people are instructed to do and what their experience demands of them. Uncovering how the selective encoding of visual information is shaped by prior experience or response history is therefore beneficial for the understanding of people's fundamental cognitive processes.

We developed variations of the attribute amnesia paradigm in the present study to isolate and explore the potential role for response history in determining what information is encoded into memory. Participants were divided into three groups, and based on the conditions of the identity test before a critical identity test trial, the groups were named as follows: the *no prior identity probe group*, the *early identity probe group*, and the *intermittent identity probe group*. Participants in all groups were explicitly informed in the task instruction that they might either be asked to report the location or the identity of the target letter. For participants in the *early identity probe group*, the location probe and the identity probe were presented in alternating fashion for the first eight trials, followed by 360 consecutive location trials before another four location and four identity trials were presented in an alternating fashion. With the inserted 360 location trials, a divergence between task instruction and more recent response history was introduced. If response history plays a prominent role in shaping the selective encoding of information, reduced performance would be observed on the next trial probing identity (the 370th trial, which will also be referred to as the critical trial in the remaining text) even though participants have been instructed to encode this attribute and have some experience successfully reporting it when probed (and so are familiar with all of the possible probe displays and how they should respond to them). If, on the other hand, expectations resulting in selective encoding are shaped principally by task instruction, accuracy on the critical trial should be similar to other trials probing target identity. The task procedure in the *no prior identity probe group* and *intermittent identity probe group* was identical to that in the *early identity probe group*, except that the identity test in the first eight trials was removed in the case of the former, and the four identity probes before the critical trial occurred every 74 trials in the case of the latter. While the no prior identity probe group closely resembles classical attribute amnesia experiments, with the critical trial reflecting the first identity probe, the early and intermittent identity probe groups are probed on target identity the same number of times prior to the critical trial, but differ with respect to how the probes are distributed over trials. Comparisons in critical trial performance among these three groups can reveal whether and how different response histories influence the encoding of targets, independently of task instruction.

Besides the main research question mentioned above, the present study may also resolve a concern that has complicated the interpretation of findings obtained using the attribute amnesia paradigm more generally. In the classical attribute amnesia task, it is possible that participants' poor performance on the surprise trial does not indicate a failure of memorizing the unexpectedly probed attributes; rather, it might be caused by forgetting, since reading and comprehending the surprise question could interfere with participants' memory. This alternative explanation concerning forgetting weakens Chen and Wyble's core inference for the phenomenon of attribute amnesia and might impede researchers' interest in using the attribute amnesia paradigm for the study of working memory encoding.

Swan et al. (2017) attempted to resolve this potential concern by unexpectedly altering the reporting requirements for target identity halfway through an attribute amnesia task from recognition to recall and found that attribute amnesia is not driven by the unexpected switch in reporting requirement. While their findings suggested that memory for information participants expected to report can survive an encounter with a surprise question, these findings do not address the issue of whether

memory for unexpectedly probed information is robust against the interference from reading a surprise question. A more compelling scenario would involve positive evidence for attribute amnesia when the probe question is both familiar and expected to appear in the task. In the early identity probe group of the present study, participants had already become familiar with the identity probe during the first eight trials. If any performance decrement in reporting identity occurs during the critical trial in this group, it cannot be explained by memory interference from reading and understanding an unfamiliar identity probe question. In this way, the present study has the potential to strengthen Chen and Wyble's inference concerning the phenomenon of attribute amnesia.

Method

Participants

Ninety-seven participants were recruited from the Texas A&M University community. Thirty-five participants (M_{age} = 19.43 years, SD = 2.39 years; 18 female, 15 male, two no response) were assigned to the *no prior identity probe group*, 30 participants (M_{age} = 20.30 years, SD = 3.26 years; 14 female, 13 male, demographic information not available from three participants) were assigned to the *early identity probe group*, and 32 participants (M_{age} = 18.90 years, SD = 1.19 years; 21 female, ten male, demographic information was not available from one participant) were assigned to the *intermittent identity probe group* (a minimal sample size of 30 was targeted for each group and could be slightly higher based on scheduling considerations). For the *early identity probe group*, due to practice effects, we expected performance on comparison identity probe trials to be near-ceiling (≥ 90%), which would allow for detection of a significant performance decrement on the critical trial with accuracy as low as 60%, well above prior studies of attribute amnesia (e.g., Chen & Wyble, 2015a, 2016; Harrison et al., 2021; Born et al., 2019). All participants reported normal or corrected to normal visual acuity and normal color vision. Participants were compensated with course credit. All procedures were approved by the Texas A&M University Institutional Review Board and conformed with the principles outlined in the Declaration of Helsinki.

Apparatus

A Dell OptiPlex equipped with MATLAB software and Psychophysics Toolbox extensions (Brainard, 1997) was used to present the stimuli on a Dell P2717H monitor. The participants viewed the monitor from a distance of approximately 70 cm in a dimly lit room.

Stimuli

At the beginning of each trial, a white fixation cross (0.98° visual angle) was centered among four white placeholder circles (radius = 0.82°) presented on the four corners of an invisible square. The stimulus array contained one white English letter target (A, B, C, D, E, H, J, K, L, N, P, R, T, V or X; 1.19° × 1.23°) and three white Arabic numeral distractors (2–9; 0.94° × 1.39°), which were presented at the same location as the four placeholders. All stimuli were displayed on a black background.

Procedure and design

This experiment is based on the attribute amnesia task shown in Fig. 1. Participants' task was to search for the target letter among three distractor digits and report either the location (location trials, see Fig. 2A) or identity (identity trials, see Fig. 2B) of the target letter. That is, unlike typical attribute amnesia studies, participants were instructed to encode both the location and the identity of the target. There were in total 376 trials. The identity of the target letters was counterbalanced throughout the whole experiment so that each letter was presented 25 times except that one randomly chosen letter was presented 26 times.

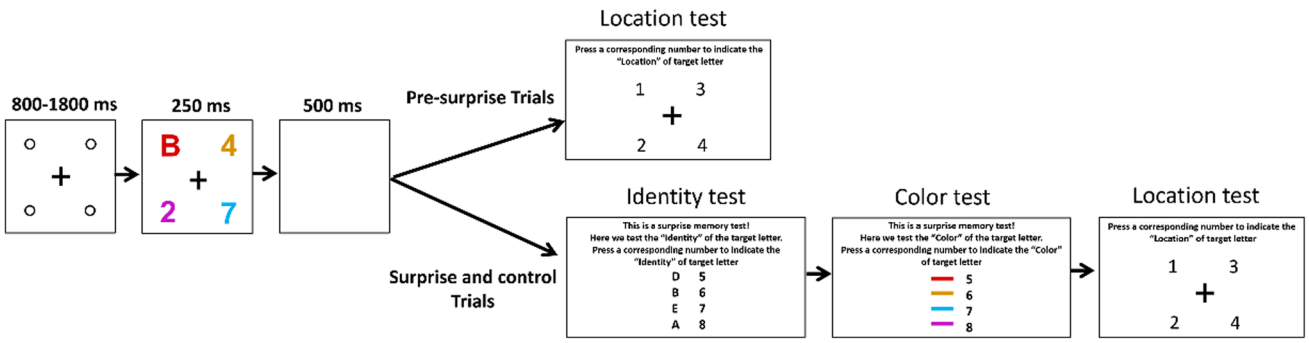

Fig. 1 Procedure of the classic attribute amnesia task (Chen & Wyble, 2015a)

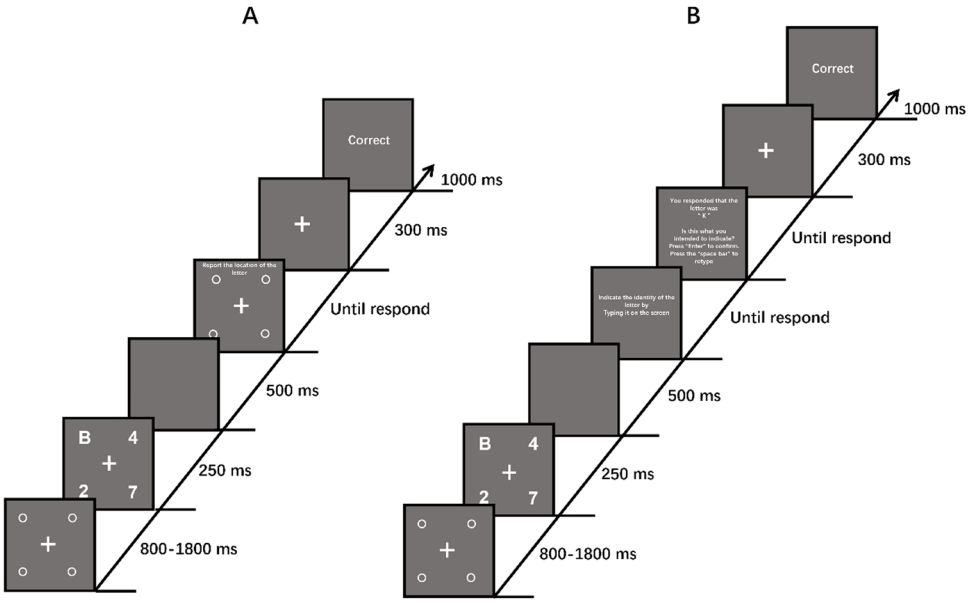

Fig. 2 Sequence of trial events in which **A** target location is probed and **B** target identity is probed

Each trial started with the fixation display for a duration that varied randomly and uniformly between 800 ms and 1,800 ms. Then, the stimulus display appeared for 250 ms, which was followed by a 500-ms blank screen. For location trials, participants were presented with a probe display that was identical to the fixation display and were asked to report the location where the target letter had previously appeared by pressing a corresponding button on the button box. For identity trials, participants were asked to type in the identity of the target letter with the keyboard. There was no time limit on the probe display, which was followed by a 300-ms display with a fixation cross presented at the center of the screen. Then a 1,000-ms feedback display was presented to indicate whether participants made a correct or incorrect response. Finally, a 500-ms inter-trial interval with a fixation cross was presented.

In the *no prior identity probe group* (see Fig. 3A), participants completed 368 location trials, after which they completed four location trials and four identity trials in alternating fashion. The 370th trial, which was the first identity trial of the experiment, served as the critical trial.

In the *early identity probe group* (see Fig. 3B), for the first eight trials, participants completed four location trials and four identity trials in alternating fashion. Then participants completed 360 location trials, after which they completed another four location trials and four identity trials in alternating fashion. The 370th trial, which was the first identity trial at the late stage of the experiment, served as the critical trial.

In the *intermittent identity probe group* (see Fig. 3C), the procedure was identical to that in the early identity probe group except that identity trials preceding the critical trial were presented at trial 74, 148, 222, and 296.

Participants in all groups completed an eight-trial practice session before starting the formal experiment. While participants in the *no prior identity probe group* only practiced the location task to avoid any influence from identity response history prior to the 370th trial, participants in the *early and intermittent identity probe groups* practiced both the location task and identity task.

Results

The results are shown in Tables 1 and 2 and Figs. 4, 5, and 6. For trials before the critical trial, participants' reporting accuracy for location was high in all three groups (see Table 2; 99% for the intermittent identity probe group, 98% for the early identity and the no prior identity probe group), which indicates that participants could accurately locate the target letter among distracting digits.

The no prior identity probe group

Using a McNemar's chi-square test to compare participants' reporting accuracy in identity between the critical trial and the first identity trial after the critical trial (372nd trial), we observed a drastic increase from the critical trial (23%) to the 372nd trial (77%), $\chi 2(1, N = 35) = 19.00$, $p < .001$ $\varphi = .74$), which showed that the attribute amnesia effect was replicated (see Fig. 4).

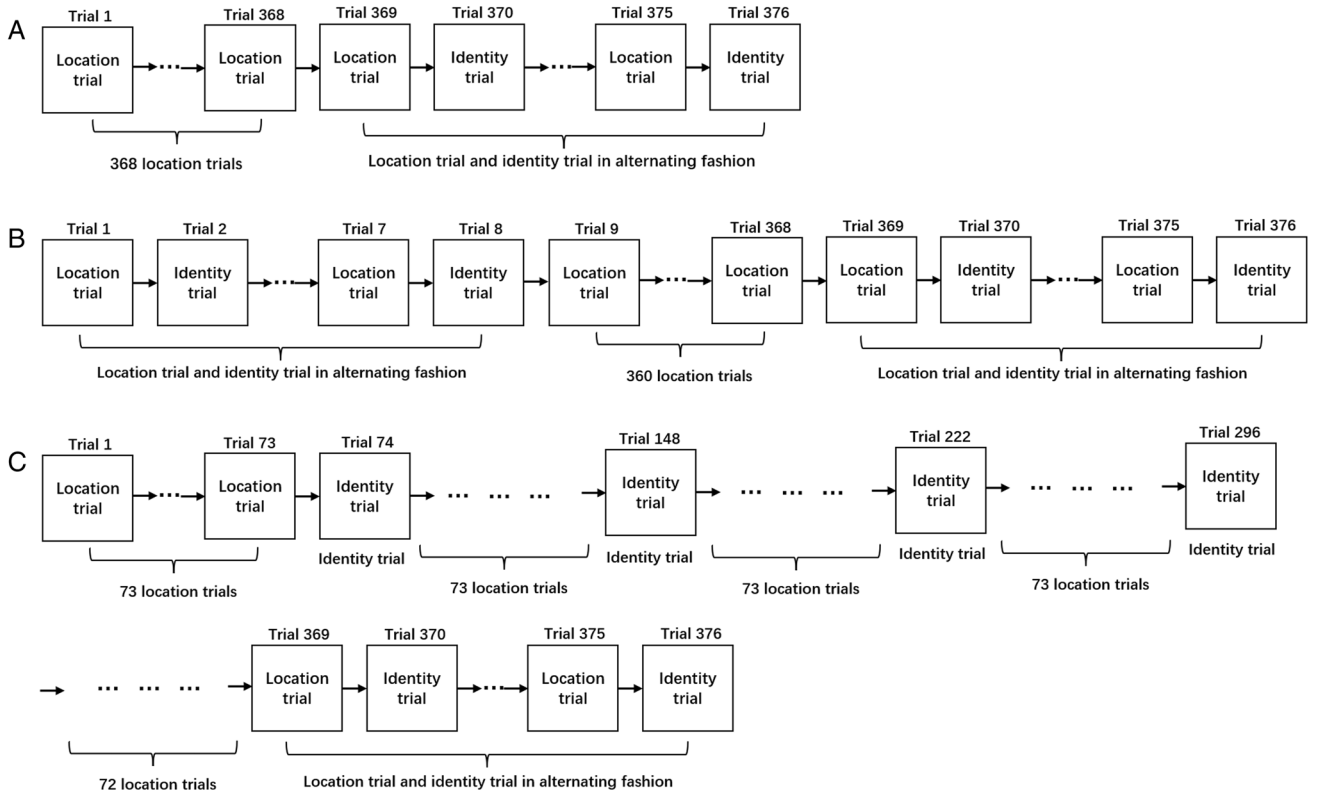

Fig. 3 Experimental procedures. **A** Design of no prior identity probe group. **B** Design of early identity probe group. **C** Design of intermittent identity probe group

Table 1 Identity report accuracy

	No prior identity probe group ($N = 35$)	Early identity probe group ($N = 30$)	Intermittent identity probe group ($N = 32$)
Critical trial-4	N/A	100%	53%
Critical trial-3	N/A	93%	84%
Critical trial-2	N/A	93%	91%
Critical trial-1	N/A	97%	88%
370th (critical) trial	23%	47%	94%
372nd trial	77%	97%	94%
374th trial	83%	100%	100%
376th trial	89%	97%	100%

Critical trial-n (the number of the n refers to the ordinal position of the identity probe trial relative to the critical trial)

N/A Not available

The early identity probe group

See Fig. 5. For the four identity trials before the critical trial, participants' reporting accuracy was high (96%), indicating that they could accurately identify the target letter. Critically, using a McNemar's chi-square test to compare participants' reporting accuracy in identity between the critical trial and the first identity trial after the critical trial (372nd trial), we observed a drastic increase from the critical trial (47%) to the 372nd trial (97%), $\chi 2(1, N = 30) = 15.00$, $p < .001$ $\varphi = .71$), which showed that the attribute amnesia effect was replicated in this group. A significant difference in identity reporting accuracy was also found between the critical trial (47%) and the last identity-probe trial before the critical trial (eighth trial, 97%), $\chi 2(1, N = 30) = 15.00$, $p < .001$ $\varphi = .71$).

Table 2 Location report accuracy

	No prior identity probe group ($N = 35$)	Early identity probe group ($N = 30$)	Intermittent identity probe group ($N = 32$)
Pre-critical location trials	98%	98%	99%
369th trial	94%	93%	100%
371st trial	94%	97%	100%
373rd trial	100%	100%	100%
375th trial	100%	100%	100%

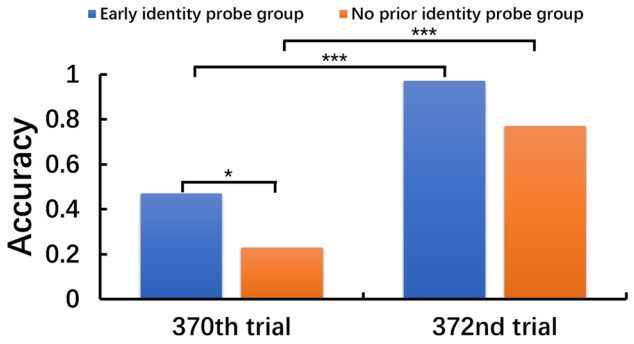

Fig. 4 Reporting accuracy of identity in the critical trial and the first identity trial after the critical trial, comparing participants in the early identity probe group and participants in the no prior identity probe group. *$p < .05$. **$p < .01$. ***$p < .001$. *ns* = not significant

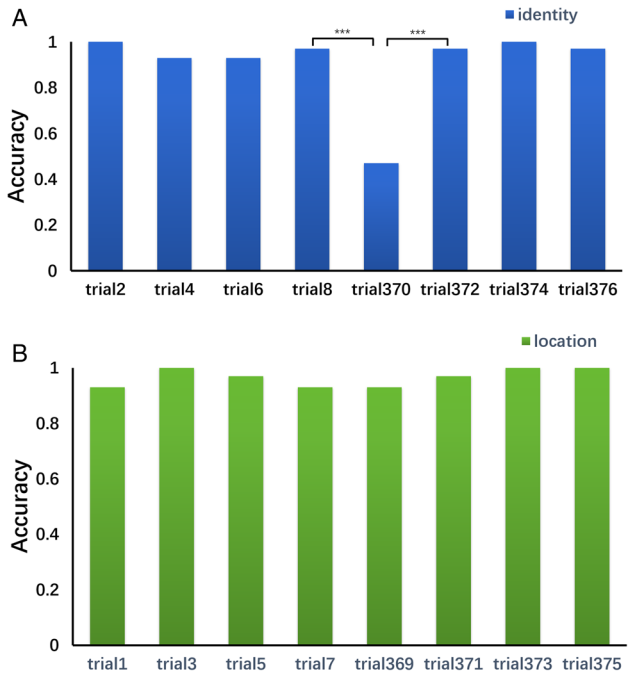

Fig. 5 Reporting accuracy of **A** identity and **B** location in the first and last eight trials of the early identity probe group. *$p < .05$. **$p < .01$. ***$p < .001$. *ns* = not significant

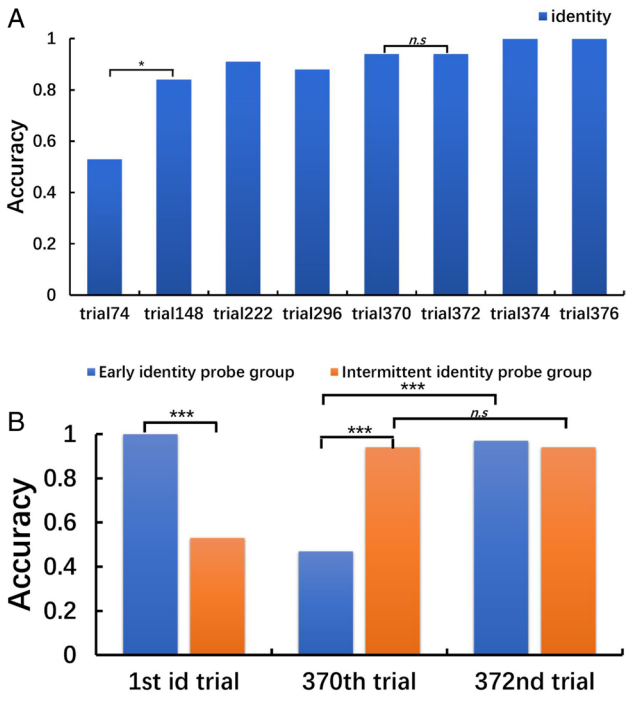

Fig. 6 **A** Reporting accuracy of identity in all the identity probe trials. **B** Reporting accuracy of identity in the first identity trial, critical trial, and the first identity trial after the critical trial, comparing participants in the early identity probe group and participants in the intermittent identity probe group. *$p < .05$. **$p < .01$. ***$p < .001$. *ns* = not significant

The intermittent identity probe group

In the four identity trials (trials 74, 148, 222, and 296) before the critical trial, while reporting accuracy on the first identity trial (trial 74) is 53%, average reporting accuracy for the remaining three trials is 88% (see Fig. 6A). The McNemar's chi-square test used to compare participants' identity reporting accuracy between the first identity trial (trial 74) and the second identity trial (trial 148) showed a significant increase in performance from the first identity trial (53%) to the second identity trial (84%), $\chi 2(1, N = 32) = 6.25$, $p < .05$ $\varphi = .44$), replicating the attribute amnesia effect. A McNemar's

chi-square test was also used to compare identity reporting accuracy between the critical trial (94%) and the first identity trial after the critical trial (372nd trial, 94%) and showed no significant difference between these two trials, $\chi 2(1, N = 32) = 0$, $p = 1.00$ $\varphi = 0$, indicating an elimination of the reoccurrence of attribute amnesia in this group.

Between-groups comparisons

We conducted a traditional chi-square test between the no prior identity probe group and the early identity probe group on critical trial identity reporting accuracy (see Fig. 4). The comparison showed that performance was significantly better for participants in the early identity probe group (47%) than that in the no prior identity probe group (23%), $\chi 2(1, N = 65) = 4.09$, $p < .05$ $\varphi = .25$). Next, between-group comparison was conducted for the intermittent identity probe group and the early identity probe group (see Fig. 6). A Fisher exact test comparing reporting accuracy on the first identity trial for each group showed that performance in the intermittent identity probe group (trial 74: 53%) was significantly worse than that in the early identity probe group (trial 2: 100%), $p < .00001$ (the Fisher exact test, instead of the traditional chi-square test, was conducted because the value for incorrect response in the early identity test group is zero, which violates an assumption of the traditional chi-square test). A traditional chi-square test was then conducted to compare critical trial reporting accuracy between these two groups and showed that reporting accuracy in the intermittent identity probe group (94%) was significantly higher than that in the early identity probe group (47%), $\chi 2(1, N = 62) = 16.66$, $p < .0001$ $\varphi = .52$.

Discussion

There are several findings of note in the present study. First, from the *early identity probe group*, we see that robust attribute amnesia can be observed even when participants know they will sometimes be probed on target identity and indeed have experience successfully reporting target identity. That is, even though participants were instructed to report target identity and had previously responded to multiple identity probes, after experiencing a series of trials in which they were not probed on target identity, many participants failed to report this critical target attribute when it was subsequently probed again, replicating the attribute amnesia effect. At the same time, this initial experience reporting target identity did influence encoding considerably later, on the critical 370th trial, conferring a benefit compared to participants who had never been probed on identity in the *no prior identity probe group* (although participants in this group received the same instructions concerning the task-relevance of target identity). For participants in the *intermittent identity probe group*, we see evidence that it is possible to sustain robust encoding of target identity over many consecutive trials of not being probed on identity, provided that participants' experience tells them to expect periodic identity probes. Consistent with both of the prior two conditions, a lack of being probed on target identity over consecutive trials resulted in poor identity encoding on the first identity probe trial (in spite of having previously experienced the probe during practice). However, a single unexpected probe resulted in a dramatic improvement on the second intermittent probe that was sustained through the remainder of the intermittent probes and on to the critical trial.

The totality of our findings can be well explained by an experience-dependent encoding framework. Participants selectively encode what their experience tells them they will need to later report or otherwise draw reference to. Although encoding may initially reflect goal-directed processes shaped by task instruction, prior response history will quickly overshadow the influence of such instruction, with participants discarding information as a function of their evolving task-specific expectation concerning its probability of being probed. Across conditions, we see that encoding of target identity is initially very high following task instruction, but falls precipitously by the 74th trial if it has not yet been probed. However, experiencing identity probes in the task does confer a sustained benefit for identity encoding that is not completely dissipated even after many consecutive trials of not being probed on identity. At the same time, participants are clearly capable of consistently and robustly encoding identity even if it is very seldom probed, provided that their experience tells them to expect such intermittent "surprise" probes.

If participants' encoding process was predominantly shaped by goal-directed information processing in accordance with task instruction, what they encoded into working memory should closely reflect what they were instructed to and had practiced encoding. Were this the case, reporting accuracy for target identity should have remained consistently high throughout the experiment. In all three participant groups, despite the fact that participants were explicitly informed about the identity test trials through task instructions, impaired identity memory performance was still observed on certain trials. This suggests that verbal instruction does not play a crucial role in establishing the expectations responsible for attribute amnesia; rather, people's prior experience or response history plays a more important role in this process, which becomes a critical driver for the attribute amnesia effect.

Our results also suggest that the process of reading and comprehending a surprise question is not the primary reason for an inability to report information in attribute

amnesia experiments. This is consistent with findings from O'Donnell and Wyble (2023), who investigated the influence of encountering a surprise reading passage on memorized information. They found that, although the surprise passage interfered with memory report generally, such interference could not account for observed attribute amnesia. In the present study, participants in the intermittent and early identity probe groups had the experience of reporting the critical target attribute and were familiar with the process. While interference from reading the questions on participants' memory should be minimal under this condition and comparable to previously experienced identity probes, an impairment in memory performance was still observed on the critical trial for the early identity probe group and on the first identity probe following practice for the intermittent identity probe group. This provides strong evidence supporting the idea that attribute amnesia indicates a failure of working memory encoding, rather than forgetting caused by the probe. In this way, it reinforces the conclusion that working memory encoding is a selective process, and that not all attended objects are necessarily encoded into working memory.

The early identity probe group in the present study can be compared with previous studies that also included an unexpected task switch. For instance, Zivony and Eimer (2022) presented target stimuli in rapid serial visual presentation (RSVP) streams to examine whether focally attended information would fail to be noticed and reported when unexpected. Their findings showed a decrement in identity reporting accuracy when focally attended target stimuli unexpectedly switch from a repeated category (e.g., letter) to a different category (e.g., digit) on the critical trial, indicating the effect of predictions about target category on visual awareness. While the present study is similar to Zivony and Eimer (2022) in demonstrating the importance of expectation on visual cognition, in our experiment the target category remained constant and only the probed attribute of the target varied, such that the manner in which a predictable target was encoded varied with response history. Participants in our study also had prior experience reporting the critical attribute, whereas the critical task switch in Zivony and Eimer (2022) was novel at the time of its presentation. Another related study was conducted by Swan et al. (2017), who adopted the attribute amnesia paradigm and unexpectedly alternated the identity reporting requirement from recognition to recall on the surprise trial. In contrast to the present study, only minimal impairment was observed when participants encountered this unexpected task switch. This discrepancy is understandable since participants' expectation concerning the content to be reported was not violated in Swan et al. (2017), whereas in present study it was violated on the critical trial, which led to greater impairment in participants' ability in reporting the information. Moreover, as mentioned in the Introduction, Swan et al. (2017) and the present study are consistent in showing that the performance decrement in the attribute amnesia paradigm is not attributable to reading and comprehending the surprise question. Another comparable study is Experiment 3 by Chen et al. (2019a), in which a surprise identity test was placed on the very first trial and attribute amnesia was observed on that trial. Unlike the first identity probe trial (the second trial) of our early identity probe group, instructions preparing participants for a potential identity probe was not given in their experiment. A comparison between these two studies indicates that task instructions are still an important factor in shaping how people encode information.

It might be argued that the impaired performance on the critical trial is caused by participants' switching from one reporting task to another, reflecting a switch cost (Monsell, 2003). Our experiment accounted for this by switching between location and identity probes in both the early and intermittent identity probe groups, in addition to the trials following the critical trial for all three groups of participants. To the degree that switching from reporting the location of the target to reporting the identity of the target results in a decrement to memory performance, this decrement should have similarly influenced all trials on which identity was probed in the present study.

Similar to most previous studies on attribute amnesia, in the present study, target location was frequently probed throughout the experiment and a feature of the target served as the infrequently probed attribute. However, much evidence has shown that location may be encoded differently from other attributes. In particular, multiple findings regarding the uniqueness of target location memory within a surprise trial paradigm have been observed (Chen & Wyble, 2015b, 2016, 2018; Tam & Wyble, 2023). For instance, using the classic attribute amnesia task, Chen and Wyble (2016) found that most participants were able to report the target's location in a surprise question. These studies indicate that encoding of location may be automatic and may even occur when the attribute is task-irrelevant. Therefore, it would be interesting to investigate whether similar experience-dependent effects would be observed if the probing of identity and location were switched in the present study.

In conclusion, the present study demonstrates that attribute amnesia can result from experience-dependent encoding. As a phenomenon, attribute amnesia reflects a genuine failure to encode an attribute of an attended target, rather than interference or forgetting attributable to the use of an unfamiliar probe display. Both top-down information induced by task instruction and prior experience can contribute to the expectations that drive encoding, and attribute amnesia is not reducible to a lack of expectation attributable to task instruction. Another implication of this study is that when conflict exists between task instruction and participants' experience of being probed in the task, we show that

response history can to some degree override task instruction in determining what information is encoded. This implication may have the potential to lend insight into people's real-world behaviors; it may indicate that in daily life, when what people have experienced diverges from what they are instructed to do, their behaviors might be more likely to be influenced by experience.

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