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# It Took Me by Surprise:

# Examining the Retroactive Enhancement Effect for Memory of Naturally-Unfolding Events

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Abstract

In two experiments, we examined how accurately participants remembered details from a naturalistic, first-person perspective film, which ended with the protagonist either encountering or not encountering an unexpected detail. Participants who watched the film with the unexpected detail at the end displayed superior accuracy for preceding event details compared to those who watched a film without such a detail. This retroactive enhancement effect generalized across both visual and auditory details, but it appeared contingent upon the unexpected detail being relevant to the event's story. The effect occurred whether participants' memory was tested immediately or after a two-day delay. The present findings can be seen as consistent with prior work on synaptic tagging and long-term potentiation, but the phenomenon of retroactive enhancement has not been demonstrated previously for naturally-unfolding events. Implications of the findings are discussed in relation to eyewitness memory and intrusive memories in post-traumatic stress disorder.

Keywords: autobiographical memory, event memory, attention magnets, memory enhancement effect, emotion and memory

## General Audience Summary

In our daily lives, we sometimes encounter unexpected situations, such as looking up while driving and seeing a car swerve into our lane. In this study, we examined how experiencing such a surprising moment during an event may affect people's memory for what happened up until that point in time. Specifically, we had participants watch films depicting a naturally-unfolding event from a first-person perspective and asked them to imagine themselves as the films' protagonists. Some of the films included something unexpected happening at the end, while all other aspects of the films were the same up until that point in time. We found that when people experienced something unexpected (such as running into a person as they were leaving a house), they were more accurate when their memory was tested for details that had occurred during the event prior to that unexpected moment. We also found this effect was present only if people encountered something unexpected that was related to the narrative or story of the event. These findings support the idea that experiencing something surprising during events in our daily lives may have a retroactive effect upon our memory for what came before, including improving our memory for details we may not have otherwise remembered. As such, there are potential implications for these results in terms of understanding how intrusive memories of traumatic or stressful events may be triggered by neutral features that preceded these events but which took on significance following the unexpected occurrence (such as how the approaching head lights of a car seen right before a crash may subsequently become a cue for remembering that crash). There are also potential implications for understanding how the surprising moments that occur during a crime may inadvertently affect eyewitnesses' memory for the event.

# It Took Me by Surprise:

## Examining the Retroactive Enhancement Effect for Memory of Naturally-Unfolding Events

Imagine you're driving home from work one day, taking the same route you always travel. Suddenly, you notice a car swerve into your lane, and, for a moment, you think you might be in a head-on collision. Thankfully, the car swings back into its own lane before tragedy ensues. During this unexpected situation, you were likely afraid. Given the role of emotion in shaping our memory for events (e.g., Reisberg & Heuer, 2004), it makes sense your memory for the moments during that surprising encounter might be affected by your reaction. However, what about your memory for the moments *prior to* the presence of the car, such as the drive up until then? In this study, we addressed this question by examining whether participants' memory for an event is retroactively enhanced by encountering a final, unexpected detail.

Despite the intriguing implications of this question, no study has yet examined how memory for naturally-unfolding events may be influenced by a surprising/unexpected encounter by the event's end (although see Ballarini et al., 2013, for findings on how school children's memory for material is improved when a lesson is followed by something novel). In an initial examination of this question, we (Congleton & Berntsen, 2019) had participants watch first-person perspective films of walking through a house while imagining themselves as a thief looking for a safe (a method we call the Simulated Event Paradigm). In one version, participants experience the protagonist taking the money, and then, unexpectedly, running into a man as they attempted to escape (presumably the homeowner, indicating they had been caught), while in another version this scene did not occur. Across three experiments, the results indicated encountering this unexpected detail at the film's end led to enhanced accuracy for preceding details, suggesting the possibility of a retroactive enhancement effect compared to conditions where the unexpected stimulus was absent.

Previous research has extensively demonstrated how the presence of surprising stimuli may influence attention and information-processing strategies (e.g., Schwarz & Clore, 1983; Levine & Bluck, 2004; Kensinger, Garoff-Eaton, & Schacter, 2006; Mather, 2007; Gable & Harmon-Jones, 2010, 2011; Chipchase & Chapman, 2013). However, the fact participants' memory for preceding details was improved only after encountering the unexpected stimulus at the video's end speaks to something happening beyond attentional allocation during the event, especially since all participants were provided with the same goal instructions and first-person perspective. Specifically, the final stimulus should not have been able to influence the accuracy and content of earlier details if this effect was solely due to attention, as the details themselves were no longer present (and, thus, could only be remembered).

Such retroactive enhancement of details preceding a surprising and/or emotional encounter would seem consistent with research on synaptic tagging (e.g., Frey & Morris, 1997; Dunsmoor, Murty, Davachi, & Phelps, 2015). In a study examining how memories for pictures of objects and animals may be strengthened if they are later determined to be conceptually related to an emotional event, Dunsmoor et al. (2015) had participants first classify a set of basic-level objects as either tools or animals. Afterwards, they engaged in a fear conditioning task, experiencing electric shocks when seeing novel items from one category, while seeing additional items from the other category without shocks. Participants showed enhanced memory for earlier (previously neutral) pictures that were conceptually related to the materials accompanied by shock during fear conditioning. The effect of such "shocking/unexpected" stimuli has been observed in additional research on memory consolidation. Specifically, administering epinephrine to participants after they view emotionally-arousing stimuli leads to memory enhancement for this previously presented material (Cahill & Alkire, 2003), while having participants engage in a cold pressor stress task produces similar enhancement effects for preceding emotionally-arousing materials (Cahill, Gorski, & Le, 2003).

However, Dunsmoor et al., (2019) failed to find an enhancement effect when paring pictures of objects with electric shocks, concluding that emotion-enhanced memory for neutral information reflects a complex relationship among arousal, attention, and anticipation.

The aim of the present study was to both replicate and extend Congleton and Berntsen (2019), who demonstrated a retroactive enhancement effect associated with a surprising, but not emotionally disturbing, visually-presented detail after short delays. However, it is presently unclear whether Congleton and Berntsen's (2019) findings would generalize to other types of encounters, such as auditory details and details unrelated to the plot. If the surprising detail needs to be meaningfully related to the overall event in order for the effect to occur, it would suggest it is not only the unexpected or disturbing nature of the detail that matters, but also its relevance to the unfolding of the event's plot (cf. thematic elicitation of emotion; e.g., Laney, Campbell, Heuer, & Reisberg, 2004). This seems especially relevant, given that Dunsmoor et al. (2019) claimed the enhancement effect may have occurred in their study by participants forming a meaningful association between the neutral stimuli and the impending outcome. Also unexamined is whether such an effect (if present) persists across an extended delay, an important boundary condition to examine given research on synaptic tagging has included delays of 6 and 24 hours (e.g., Dunsmoor et al., 2015; Dunsmoor et al., 2019).

## Experiment 1

The aim of this experiment was to replicate and extend findings from a previous study using the Simulated Event Paradigm described above (Congleton & Berntsen, 2019). Participants watched a first-person perspective film depicting a house, with only the ending varying across conditions. Specifically, participants encountered an unexpected visual detail of a man, an auditory detail of an air raid siren, a combination of these details, or they encountered nothing unexpected. Following a distracter task, half the participants answered questions assessing their memory

accuracy immediately (Immediate Test conditions), while the other half answered these questions after two days (Delayed Test conditions). Based on previous findings, we predicted participants in the "unexpected" conditions would display superior accuracy for film details preceding the encounter, compared to those who experienced nothing unexpected. Further, we predicted participants exposed to the combination of unexpected visual and auditory details would be most accurate, reasoning that if a single stimulus had a beneficial effect upon memory then encountering multiple stimuli would result in a greater effect. We also expected this advantage to be maintained across time.

## Method

**Participants and design**. Participants were recruited from the Amazon Mechanical Turk online subject pool from English-speaking countries through the service of Turk Prime (now known as CloudResearch). They were informed the purpose of the study was to gain a better understanding of how people comprehend the details of an experience if they are asked to adopt a specific perspective during that experience. The approximate sample size for this study was determined by conducting a post-hoc power analysis using GPower 3 (Faul et al., 2007) on the results of the third experiment of Congleton & Berntsen (2019), where we investigated the role of stimulus saliency/surprise on the accuracy of participants' memory. The results of an analysis examining the main effect of stimulus saliency/surprise, with an effect size of f =.25, indicated that with a sample size of approximately 100 participants per condition, and an alpha of 0.05 (2-tailed), power was estimated at 99% for that experiment, indicating a high chance to detect an existing effect. When determining the power level for even 80 or 90 participants based on those same criteria, the power level was always over 90%. As online participants were plentiful, we subsequently adopted the criterion of at least 80 participants per condition in determining the sample size for the present study.

There were 793 participants (428 Females, 365 Males; age ranging from 18 to 72, *M_Age* = 37.20) altogether who were randomly assigned to one of eight conditions as part of a between-subjects design, with Encounter Type (No Encounter vs. Visual Encounter vs. Auditory Encounter vs. Combined Encounter) and Time of Test (Immediate Test vs. Delayed Test) acting as the factors. The number of participants ranged from 100-101 in the Immediate Test conditions and 90-107 in the Delayed Test conditions. In order for participants in the Delayed conditions to return to the study after a period of two days, we used the Turk Prime program to invite only those workers who actually completed Part 1 of the survey based on their WorkerIDs. The Turk Prime program then sent out invitations to the email addresses of those invited workers that included the metalink for Part 2 of the study.

**Materials.**

***Online survey***. The surveys were created using Qualtics, an online survey generation database. The study was advertised on the Amazon Mechanical Turk online subject pool website.

***First-person perspective film***. We used a novel film clip to assess the influence of encountering a surprising/unexpected detail on the accuracy of participants' memory. This clip had been constructed for use in a prior study to examine the influence of emotional variables on event memory (Congleton & Berntsen, 2019). The film was constructed using Garrys Mod programming software and Hammer Editor to build the virtual layout map. A recording was then made of a first-person perspective walkthrough of the house, with the video lasting approximately 2 minutes.

Participants were provided with an overarching story to keep in mind while watching the video, and they were asked to imagine themselves in the role of the film's protagonist. Specifically, they were given the following instructions: "You are about to see a video that shows a first-person perspective view of walking through a house. ***While watching this video, imagine that you are a thief who is going through this house.*** You know that there is a safe with rare currency located

somewhere inside the house and you are searching for it in the various rooms. You know that once you find the safe and take the currency, you will immediately leave the house." The choice of this story as part of our materials did not reflect any sympathy with burglars or thieves, or any other illegal activity. Rather, the story was chosen to create an emotional event that was not offensive (e.g., through the use of highly upsetting scenes or images). We followed the example of Anderson and Pichert (1978), who likewise asked participants to view a story from the point of view of a potential burglar.

The participants then watched the film, in which the protagonist began in the garden outside of the house and proceeded into the living room. After exploring the living room and the bathroom, the protagonist entered the kitchen and heard the telephone ringing. The protagonist then moved through a hallway and up the stairs to the second floor, entering an office and a child's bedroom before moving into the master bedroom where the safe was discovered. After opening the safe and removing the currency, the protagonist proceeded downstairs to the back door of the house. The video ended with the protagonist either opening the door and leaving (No Encounter), running into a man at the door (Visual Encounter), hearing an air raid siren as the door was opened (Auditory Encounter), or running into a man and hearing the siren simultaneously (Combined Encounter).

***Distracter task – Shipley Institute of Living Scale 2 – Vocabulary Test***. After watching the film, participants then completed the vocabulary portion of the Shipley Institute of Living Scale 2. This task involves participants seeing a word and then being required to select a synonym for that word from among four alternatives (e.g., if the target word was "fortify," they should select the synonym "strengthen"). This task was included to reduce the possibility of the rehearsal of details of the event prior to the accuracy test. It was selected for use in this study because it likely engages both visuospatial and auditory components of working memory (e.g., Baddeley, 2000).

***Central and peripheral details***. In order to better understand how encountering the presence of a surprising/unexpected detail affects the accuracy of participants' memory, we wanted to include several different measures of memory accuracy. To that end, we included the same categorical distinctions used in Congleton and Berntsen (2019), which involved the same video used in the present study. In that earlier study, we had first classified all the details included in the film into those that were related to the plot of/central to the event itself and those that were not related to the plot/peripheral or contextual in nature. To accomplish this task, we adopted a definition that has been used in prior studies of autobiographical memory and memory and emotion (e.g., Heuer & Reisberg, 1990; Berntsen, 2002). Specifically, a detail was defined as "Central" if it was related to the key emotional experience of the event and if it could not be excluded or replaced without fundamentally altering the content/story of the event. Otherwise, the detail was classified as "Peripheral." This enabled us to include two different measures of memory accuracy directly motivated by previous research on autobiographical event memory (i.e., accuracy regarding plot-related elements and accuracy regarding non-plot related or neutral elements), as well as a third measure of accuracy based on asking participants about critical lures that had not occurred during the video.

As mentioned above, the details of the film had been classified according to this "central vs. peripheral" scheme in an earlier study (Congleton & Berntsen, 2019). Three independent raters coded all possible details included in the films and classified them as either central or peripheral according to the above definition. Based on this coding, it appears there were 20 central details and 120 peripheral details. We selected only those details on which all raters were in 100% agreement as being central to use for coding participants' recall and in designing the recognition questions assessing Central Detail accuracy. Similarly, we selected only those details on which the raters were in 100% agreement as being peripheral to use in designing the questions assessing Peripheral

Detail accuracy. Based on this analysis, seven details were conclusively identified as Central to the goals of the study. Of those seven details, one detail occurred within the first 30 seconds of the movie, two details occurred between 30 and 60 seconds, two occurred around 90 seconds, and the final two details occurred within the last few seconds of the movie (at approximately the 120 second mark). Examples of central details included the act of entering the house, the sound of the telephone, and the safe, while examples of peripheral details included a white hamper basket, chairs around the dining room table, and soda pop bottles in the kitchen.

**Procedure**. After providing informed consent, participants were first asked to listen to an audio file and to name the animal sound they heard in this file (as a manipulation check and a way of ensuring that participants were completing the survey with their audio turned on). They were then informed that they would be watching a first-person perspective film and were provided with the instructions described above. Afterwards, the participants were asked to answer a few questions about their emotional response to the film, including their level of arousal, their emotional valence regarding the event, and their level of startle responses experienced during the film. They then completed the Shipley Vocabulary Task as a distracter. Afterwards, the participants in the Immediate Test conditions completed an accuracy test, where they answered four-alternative, forced-choice questions regarding specific central and peripheral details selected from the film, as well as questions regarding critical lures (i.e., questions about events that did not occur in the film). We included four-alternative, forced-choice accuracy questions as a more fine-grained measure of accuracy than free recall (which had also used in the previous study; Congleton & Berntsen, 2019). These types of questions force participants to think about certain aspects or moments of the event they may otherwise not have recalled, enabling a more detailed assessment of their memory availability. There were 21 questions altogether, with seven questions assessing central details (e.g., "How many times did the alarm beep?"), seven assessing peripheral details (e.g., "In what

room was the white hamper basket?"), and seven assessing critical lures (e.g., "What object did you knock over in the kitchen?"). For participants in the Delayed Test conditions, they completed the forced-choice accuracy test after a two-day delay. See Figure 1 for an illustration of the procedure.

**Manipulation Checks**. In order to ensure that participants were actively following the instructions, we included a number of manipulation checks throughout the survey. For example, we asked participants questions about the manipulation instructions, as well as having them name the audio sound they heard at the start of the experiment (as described above). As in previous studies using the Simulated Event Paradigm (e.g., Congleton & Berntsen, 2019), if participants failed to answer any of the manipulation check questions correctly, or if they did not complete the survey in its entirety, they were excluded from any further analysis.

**Results**

To examine differences in participants' memory (accuracy) for each type of accuracy measure, we began by conducting a repeated-measures analysis of variance (ANOVA), with Accuracy Type (Central vs. Peripheral vs. Lure) acting as the variable. The results revealed a significant effect, $F(2, 791) = 422.38$, $p < .001$, $\eta^2_p = .52$. Follow-up paired samples *t*-tests indicated that participants were significantly more accurate regarding Critical Lure questions ($M = 5.12$, $SD = 1.92$, 95% CI = 4.98, 5.25) compared to questions about Central Details ($M = 4.29$, $SD = 1.58$, 95% CI = 4.18, 4.40, $t[792] = 11.27$, $p < .001$, Cohen's $d = .40$) or Peripheral Details ($M = 2.73$, $SD = 1.47$, 95% CI = 2.63, 2.83, $t[792] = 27.44$, $p < .001$, Cohen's $d = .97$). Participants were also significantly more accurate regarding questions about Central Details compared to Peripheral Details ($t[792] = 23.55$, $p < .001$, Cohen's $d = .83$).

Next, we conducted a 4 x 2 between-subjects ANOVA, with Encounter Type (No Encounter vs. Visual Encounter vs. Auditory Encounter vs. Combined Encounter) and Time of Test (Immediate Test vs. Delayed Test) acting as the variables. We collapsed the accuracy score across

the three accuracy measures, yielding a total accuracy score that could range between 0 and 21. The results revealed significant main effects of Encounter Type, $F(3, 785) = 13.22$, $p < .001$, $\eta^2_p = .05$, and Time of Test, $F(1, 785) = 100.05$, $p < .001$, $\eta^2_p = .11$. The results also revealed a significant interaction between Encounter Type and Time of Test, $F(3, 785) = 8.68$, $p < .001$, $\eta^2_p = .03$. See Table 1 for descriptive statistics and Figure 2 for illustration.

When unpacking the main effect of Encounter Type, the results of follow-up independent samples *t*-tests indicated that participants in the Visual Encounter conditions ($M = 13.07$, $SD = 3.21$, 95% CI = 12.69, 13.52) were significantly more accurate than those in the No Encounter ($M = 12.18$, $SD = 3.52$, 95% CI = 11.75, 12.60, $t[407] = 2.67$, $p = .01$, Cohen's $d = .26$), Auditory Encounter ($M = 11.99$, $SD = 3.14$, 95% CI = 11.47, 12.34, $t[397] = 3.40$, $p = .001$, Cohen's $d = .34$), or Combined Encounter conditions ($M = 11.21$, $SD = 3.28$, 95% CI = 10.77, 11.64, $t[399] = 5.74$, $p < .001$, Cohen's $d = .57$). Participants in the Combined Encounter conditions were also significantly less accurate than those in the No Encounter conditions ($t[392] = 2.83$, $p = .01$, Cohen's $d = .29$). There were no other significant differences observed.

With regard to the Time of Test effect, the results indicated that participants in the Immediate Test conditions ($M = 13.19$, $SD = 3.09$, 95% CI = 12.89, 13.49) were significantly more accurate than those in the Delayed Test conditions ($M = 11.04$, $SD = 3.26$, 95% CI = 10.70, 11.31, $t[791] = 9.53$, $p < .001$, Cohen's $d = .68$).

Finally, when unpacking the interaction between Encounter Type and Time of Test, it appears that while participants in the Combined Encounter condition did not display a significant decrease in their accuracy from the Immediate Test ($M = 11.37$, $SD = 3.20$) to the Delayed Test conditions ($M = 11.04$, $SD = 3.38$; $t[191] = .69$, $p = .49$), the participants in the remaining three conditions did display significant decreases in their accuracy across delay (all $t$s > 5.38, all $p$s < .001). See Figure 2 for details.

In order to determine whether the effect of the unexpected visual encounter replicated across the three types of accuracy measures, we next conducted analyses on the Central, Peripheral, and Critical Lure details separately. The results revealed an advantage of the Visual Encounter condition compared to the No Encounter condition for the measures of Central and Peripheral Detail accuracy (*t*-values were 2.81 and 4.06, both *p*s < .01), while no such advantage was observed with regard to the measure of Critical Lure accuracy ($t = .73$, $p = .47$). Please see supplementary materials for the full analyses and see Table 1 for descriptive statistics.

**Discussion**

Here, we examined whether we would replicate the retroactive enhancement effect – that is, whether encountering an unexpected detail at the end of an event (i.e., a man) leads to enhanced memory for earlier details (Congleton & Berntsen, 2019). We also examined whether the effect would be enhanced if this visual detail was combined with an additional surprising detail, and whether the effect might persist over time. To that end, we combined an unexpected auditory detail of an air raid siren with the visual detail of the man. We then compared this intensified condition to a one where the auditory detail occurred alone.

We predicted participants encountering the combined details would demonstrate the best accuracy across conditions and maintain their memory over time. While the results confirmed that those who experienced the combination of details did preserve their accuracy across delay, they also revealed that, contrary to our prediction, encountering the visual detail alone enhanced participants' memory to a significantly greater degree than experiencing the combined details. One potential explanation is the presence of the siren may have overridden the effects of the visual encounter to some degree in the Combined Encounter condition, having a more distracting effect upon accuracy. Another explanation for this effect is the special nature of the visual detail of the man; namely, his presence was connected to the story of being a thief. In contrast, the siren was not directly related

to the story, and, thus, would be consistent with the idea the auditory stimulus may have had a distracting effect upon accuracy. If true, this would suggest the detail's relevance to the unfolding of the plot is of prime importance. It can also be seen as consistent with Dunsmoor et al. (2019), who found no effect of shock intensity on participants' memory for attended objects, regardless of whether the shock was unexpected or signaled ahead of object presentation. Furthermore, they found warning participants about the presence of upcoming, high intensity shocks interfered with the encoding of neutral information, while having them first attend to neutral information and then receive the warning benefitted their memory to a degree. The authors argued such enhancement may have occurred because of a meaningful association formed between the neutral stimuli and the impending outcome.

Experiment 2 was undertaken to pursue the question of whether a meaningful association between the surprising/unexpected detail and the event is required for enhancement to occur.

## Experiment 2

Findings from Experiment 1 suggested the story relevance associated with the unexpected visual encounter might be the mechanism behind the retroactive enhancement of participants' accuracy (a factor the auditory detail lacked). To examine this possibility, and to possibly extend the effect from visually- to auditorily-presented encounters, in Experiment 2 participants encountered auditory details either relevant or irrelevant to the film's story. We manipulated auditory rather than visual details here to make it more difficult to obtain the effect, as it had already been observed and replicated using visually-presented material in Experiment 1 and in Congleton and Berntsen (2019).

### Method

**Participants and design.** As in Experiment 1, participants were recruited from the Amazon Mechanical Turk online subject pool from English speaking countries. There were 640 participants

(329 Females, 311 Males; age ranging from 18 to 80, *M_Age* = 37.78) altogether who were randomly assigned to one of six conditions as part of a between-subjects design, with Encounter Type (No Encounter vs. Story Irrelevant Detail: Siren vs. Story Relevant Detail: Scream) and Time of Test (Immediate Test vs. Delayed Test) acting as the variables. There were 128 participants in the No Encounter-Immediate Test condition, 77 in the No Encounter-Delayed Test condition, 125 in the Siren-Immediate Test condition, 91 in the Siren-Delayed Test condition, 125 in the Scream-Immediate Test condition, and 94 in the Scream-Delayed Test condition.

**Materials.**

***Online survey***. See Experiment 1.

***First-person perspective film***. The first-person perspective film was identical to that used in Experiment 1, with the exception of the instructions provided to the participants and the ending of the film itself. In addition to the overarching story of being a thief, participants were also told: **"You also know that the owner of the house is away on business, but his wife could be home any moment."** The participants then watched a video in which only the ending differed. In the No Encounter conditions, participants saw a film in which the first-person perspective protagonist was about to open the door to exit the house when the screen went black. In the Siren conditions, participants heard a loud air raid siren as they were about to open the door (the same sound used in Experiment 1). Finally, in the Scream conditions, participants heard the sound of a women screaming as they approached the door (presumably the homeowner's wife). These sounds were presented for an equivalent length of time.

***Distracter task – Shipley Institute of Living Scale 2 – Vocabulary Test***. See Experiment 1.

***Central and peripheral details***. See Experiment 1.

**Procedure**. The procedure was identical to Experiment 1, with the exception of the additional instructions provided to participants (see above for details).

**Manipulation Checks**. See Experiment 1.

## Results

To examine differences in participants' memory (accuracy) for each type of accuracy question, we again began by conducting a repeated-measures ANOVA, with Accuracy Type (Central vs. Peripheral vs. Lure) acting as the independent variable. The results revealed a significant effect, $F(2, 638) = 234.97$, $p < .001$, $\eta^2_p = .52$. Replicating Experiment 1, follow-up paired-samples *t*-tests indicated that participants were significantly more accurate regarding Critical Lure questions ($M = 5.02$, $SD = 2.31$, 95% CI = 4.84, 5.20) compared to questions about Central Details ($M = 4.24$, $SD = 1.78$, 95% CI = 4.10, 4.38, $t[639] = 10.15$, $p < .001$, Cohen's $d = .40$) or Peripheral Details ($M = 2.80$, $SD = 1.42$, 95% CI = 2.69, 2.91, $t[639] = 21.20$, $p < .001$, Cohen's $d = .84$). Participants were also significantly more accurate regarding questions about Central Details compared to Peripheral Details ($t[639] = 17.96$, $p < .001$, Cohen's $d = .71$).

As in Experiment 1, we then conducted a 3 x 2 between-subjects ANOVA, with Encounter Type (No Encounter vs. Siren vs. Scream) and Time of Test (Immediate Test vs. Delayed Test) acting as the factors, and a sum score for total accuracy as the dependent measure. The results revealed main effects of Encounter Type, $F(2, 634) = 6.95$, $p = .001$, $\eta^2_p = .02$, and Time of Test, $F(1, 634) = 131.70$, $p < .001$, $\eta^2_p = .17$. There was no significant interaction between Encounter Type and Time of Test ($F = 1.37$, $p = .26$). See Figure 2 for illustration.

When unpacking the main effect of Encounter Type, the results of follow-up independent samples *t*-tests revealed that participants in the Scream conditions ($M = 12.72$, $SD = 3.64$, 95% CI = 12.00, 12.99) were significantly more accurate than those in the No Encounter (M = 11.79, $SD = 4.32$, 95% CI = 10.75, 11.80, $t[422] = 2.41$, $p = .02$, Cohen's $d = .23$) or Siren condition ($M = 11.63$, $SD = 4.20$, 95% CI = 10.90, 11.90, $t[433] = 2.87$, $p = .004$, Cohen's $d = .28$), while there was no difference between those in the No Encounter and Siren condition ($t[419] = .36$, $p = .72$). In terms

of the main effect of Time of Test, we found that participants in the Immediate Test conditions ($M$ = 13.43, $SD$ = 3.81, 95% CI = 13.06, 13.81) were significantly more accurate than those in the Delayed Test conditions ($M$ = 10.06, $SD$ = 3.62, 95% CI = 9.56, 10.46, $t$[638] = 11.22, $p < .001$, Cohen's $d$ = .90). See Figure 2.

As in Experiment 1, in order to determine whether the effect of the story relevance of the unexpected encounter replicated across the three types of accuracy measures, we next conducted analyses on the Central, Peripheral, and Critical Lure details separately. The results revealed an advantage of the Scream condition compared to the No Encounter condition for the measure of Critical Lure accuracy ($t$[422] = 3.33, $p$ = .001), a marginally significant advantage for the measure of Central Detail accuracy ($t$[422] = 1.71, $p$ = .09), while no such advantage was observed with regard to the measure of Peripheral Detail accuracy ($t$[422] = .62, $p$ = .54). Please see supplementary materials for the full analyses and see Table 2 for descriptive statistics.

**Discussion**

We examined whether the story relevance of the unexpected detail encountered at the film's end had an impact on participants' accuracy for prior details. Participants who heard the story-relevant sound (Scream condition) were significantly more accurate than those who heard the story-irrelevant sound (Siren condition), and they were significantly more accurate than those in the No Encounter condition, replicating Experiment 1. As such, the results are consistent with the idea the story relevance or meaning associated with the unexpected detail has a beneficial effect upon participants' accuracy for preceding event details.

## General Discussion

In two experiments, we examined the retroactive enhancement effect – that is, how encountering a surprising/unexpected detail at the end of an event affects participants' memory accuracy for details occurring prior. We wanted to both replicate and extend the results of

Congleton and Berntsen (2019) by testing the effect's persistence over a two-day delay, whether it varied with the modality of the unexpected detail, and the detail's relevance for the plot of the event.

We initially predicted encountering an unexpected sound together with an unexpected visual detail would result in the greatest enhancement. However, the results of Experiment 1 indicated participants who encountered the visual detail alone showed the greatest retroactive enhancement – displaying superior accuracy for details occurring prior to that encounter. Experiment 2 examined one possible explanation; namely, the visual detail in Experiment 1 was associated with the event's story while the auditory detail was not. We demonstrated that when encountering an unexpected auditory detail relevant to the ongoing story, the enhancement effect was present (relative to the neutral condition), whereas no effect was observed when the detail was irrelevant to the story. Overall, the enhancement effect seems quite robust, replicating across several measures of accuracy and across a two-day delay, suggesting a reliable phenomenon affecting participants' memory.

The advantage of the unexpected and plot-relevant details could reflect their ability to provide a resolution of the event's narrative. Narratives have variously been conceptualized as being structured around a series of high points (e.g., Labov, 1972), or composed of episodes that provide a setting and some problem to be solved and eventually end with a resolution (e.g., Glenn, 1978; Rumelhart, 1977). In this study, we provided a setting for the film's narratives via the story instructions. We then manipulated the films in such a way the unexpected detail either provided a narrative ending or left that narrative unresolved. Running into a man, indicating the thief had been caught, provided a clear ending to the narrative (Peterson & McCabe, 1983). Hearing the sound of a woman screaming provided a similar narrative conclusion, while the sound of an air raid siren did not (as it was unconnected with the story, and, thus, could not provide a clear resolution). Although this interpretation was post hoc in Experiment 1, it was replicated with different materials in

Experiment 2. The results help to clarify when retroactive memory enhancement for an event is likely to occur; when the unexpected detail resolves the narrative, the effect is present, but it is absent or reduced otherwise. Obviously, given their exploratory nature, future research needs to replicate these findings before firm conclusions can be drawn.

The present findings are consistent with Congleton and Berntsen (2019), and with some previous studies of retroactive enhancement following exposure to emotional arousal (Cahill & Alkire, 2003; Dunsmoor et al. 2015). However, they appear to contradict an earlier study by Loftus and Burns (1982). In that study, investigating the notion of retrograde amnesia, participants watched a film depicting a bank robbery. At the end of one version of the film, participants saw a young boy shot in the face (violent version), while in the other version the scene shifted inside the bank before this moment occurred (non-violent version). Their results indicated participants who saw the violent version had poorer memory for details occurring before the violent eruption. They also found showing participants an unexpected, but non-violent, version of the film did not result in such memory deficits.

One potential explanation for the difference in results across these studies might be the severity of the stimuli. While the details used in the present experiments and in Congleton and Berntsen (2019) can be considered unexpected, they were not deeply shocking or offensive. Seeing a boy shot in the face (Loftus and Burns, 1982) is likely considered more emotionally disturbing than simply running into a man, hearing a siren, or even hearing a scream (although all outcomes are negative). As such, it is possible that encountering an unexpected, but not disturbing, detail will lead to retroactive enhancement, while experiencing an emotionally-disturbing detail may lead to detriments. One relevant finding from the present study is while we observed retroactive enhancement when participants encountered the stimulus of the man, we did not observe the effect when they encountered a combination of unexpected stimuli in Experiment 1. While only

tangential to Loftus and Burns (1982), it does speak to the fact that under less-than-optimal (or more disturbing) circumstances, the effect may be absent (Dunsmoor et al., 2019).

Most importantly, the results of the present study suggest the memory effects of encountering an unexpected detail depend on more than just the arousing effect of the detail itself (ranging from being startling to emotionally disturbing). They also depend on the detail's relevance to the unfolding of the story. This would seem to indicate perceptual details considered to be "attention magnets," in the most extreme sense (e.g., in Loftus and Burns, 1982), may primarily distract from the unfolding of the narrative (and, thus, the gradual elicitation of normal emotional reactions; e.g., Reisberg & Heuer, 2004; Laney, Campbell, Heuer, & Reisberg, 2004), while details considered story-relevant and surprising (but not disturbing) may enhance one's memory for that narrative (perhaps even leading to greater narrative cohesion). This may be due to the role of these details as "emotion-defining." For example, seeing "final notice" in bold letters on an unpaid bill, or having someone point a gun at you, may ultimately be responsible for you interpreting such events as emotionally negative, although more research is needed to address this possibility.

The present findings can be seen as congruent with clinical observations, where some patients suffering from PTSD report that peripheral details preceding traumatic moments (or occurring when the event became meaningfully traumatic for them) tend to act as more powerful elicitors of intrusive memories compared to seemingly more "meaningful" details of the trauma (e.g., Ehlers & Clark, 2000; Ehlers, Hackmann, & Michael, 2004). These details also tend to be relatively neutral in content, such as remembering turning your head to one side prior to seeing the oncoming headlights that preceded a car crash (Ehlers et al., 2004). Though tangential to the phenomenon in question, these reports suggest the possibility of a retroactive association between the traumatic moments (and the subsequent emotional reactions the patients experienced) and the earlier, peripheral details preceding that trauma.

The present study has limitations that should be considered when evaluating the results. First, we manipulated a limited number of sensory modalities; vision and audition in Experiment 1 and audition only in Experiment 2. It remains to be seen whether the present findings replicate across a greater variety of surprising details. Also, the effects obtained were relatively small. Thus, replication is needed before firm conclusions can be made; this is especially important given the mixed findings of previous work pursuing related effects (Ballarini et al., 2013; Dunsmoor, 2015, 2019). Second, the use of online experiments with participants recruited through Amazon Mechanical Turk may be seen as a limitation. However, a considerable body of evidence demonstrates conducting studies online is just as effective and reliable as those conducted in laboratories (e.g., Grysman, 2014; Grysman, Prabhakar, Anglin, & Hudson, 2014; Berntsen, Rubin, & Salgado, 2015; see Mason & Suri, 2011 and Buhrmester, Talaifar, & Gosling, 2018 for reviews). Here, we ensured good data quality by incorporating attention checks the participants had to pass to complete the study.

In conclusion, this study provides experimental evidence supporting the notion of retroactive enhancement occurring in naturally-unfolding events. Our results indicate encountering a surprising/unexpected visual detail, or an auditory detail relevant to the unfolding story/narrative, by the end of an event may enhance the accuracy of people's memory for details occurring prior to that moment, relative to a situation where such a detail is absent.

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Table 1

Experiment 1 means and (standard deviations) of accuracy details for each encounter condition

| | Central Detail Accuracy | | Peripheral Detail Accuracy | | Critical Lure Accuracy | |
|---|---|---|---|---|---|---|
| Encounter Type | Immediate | Delayed | Immediate | Delayed | Immediate | Delayed |
| No Encounter | 5.05 (1.30) | 3.43 (1.64) | 2.71 (1.40) | 2.24 (1.65) | 5.99 (1.51) | 4.93 (2.09) |
| Auditory Encounter | 4.30 (1.23) | 3.09 (1.32) | 2.83 (1.39) | 2.22 (1.46) | 6.27 (1.14) | 5.10 (2.09) |
| Visual Encounter | 5.19 (1.37) | 4.20 (1.33) | 3.18 (1.47) | 2.95 (1.26) | 5.86 (1.44) | 4.83 (1.87) |
| Combined Encounter | 5.11 (1.32) | 3.78 (1.62) | 2.98 (1.39) | 2.63 (1.47) | 3.28 (1.23) | 4.62 (2.03) |

Table 2

Experiment 2 means and (standard deviations) of accuracy details for each encounter condition

| | Central Detail Accuracy | | Peripheral Detail Accuracy | | Critical Lure Accuracy | |
|---|---|---|---|---|---|---|
| Encounter Type | Immediate | Delayed | Immediate | Delayed | Immediate | Delayed |
| No Encounter | 4.80 (1.59) | 3.04 (1.27) | 3.03 (1.24) | 2.62 (1.48) | 5.50 (2.01) | 3.55 (2.82) |
| Siren (Story Irrelevant) | 4.91 (1.75) | 3.10 (1.42) | 2.81 (1.38) | 2.59 (1.61) | 5.19 (2.15) | 4.19 (2.52) |
| Scream (Story Relevant) | 5.31 (1.51) | 3.26 (1.34) | 2.97 (1.43) | 2.56 (1.43) | 5.77 (1.98) | 5.13 (1.87) |

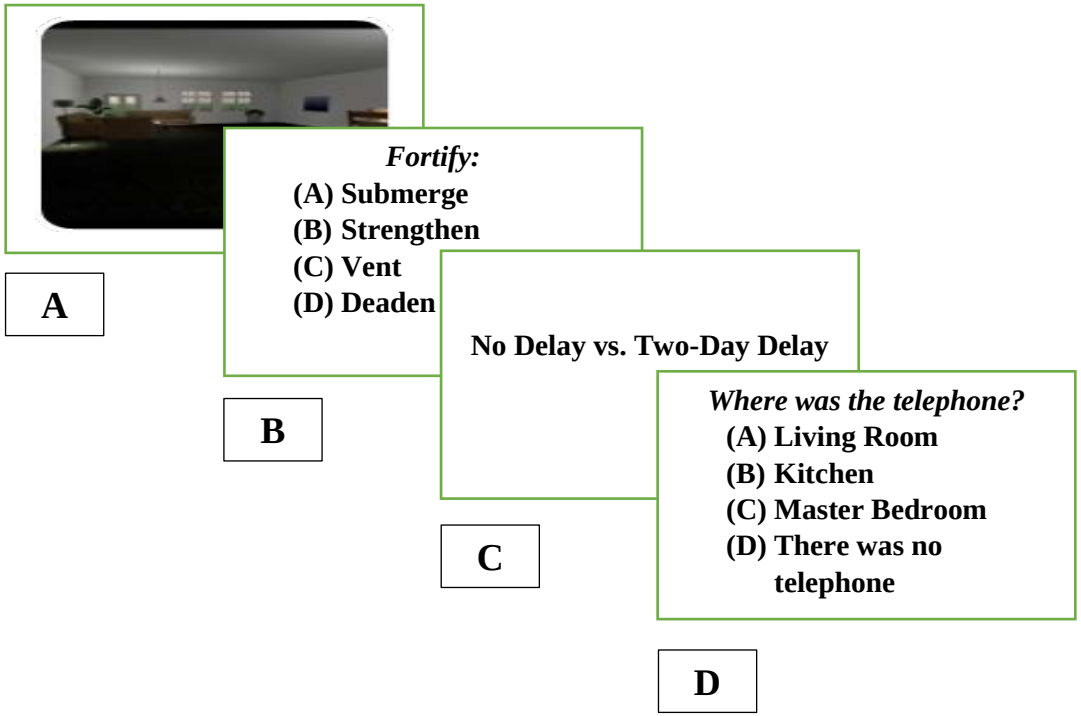


Figure 1. Visual illustration of the procedure: A = First-person perspective film, B = Shipley Vocabulary Test, C = Delay, D = Forced-choice accuracy test.

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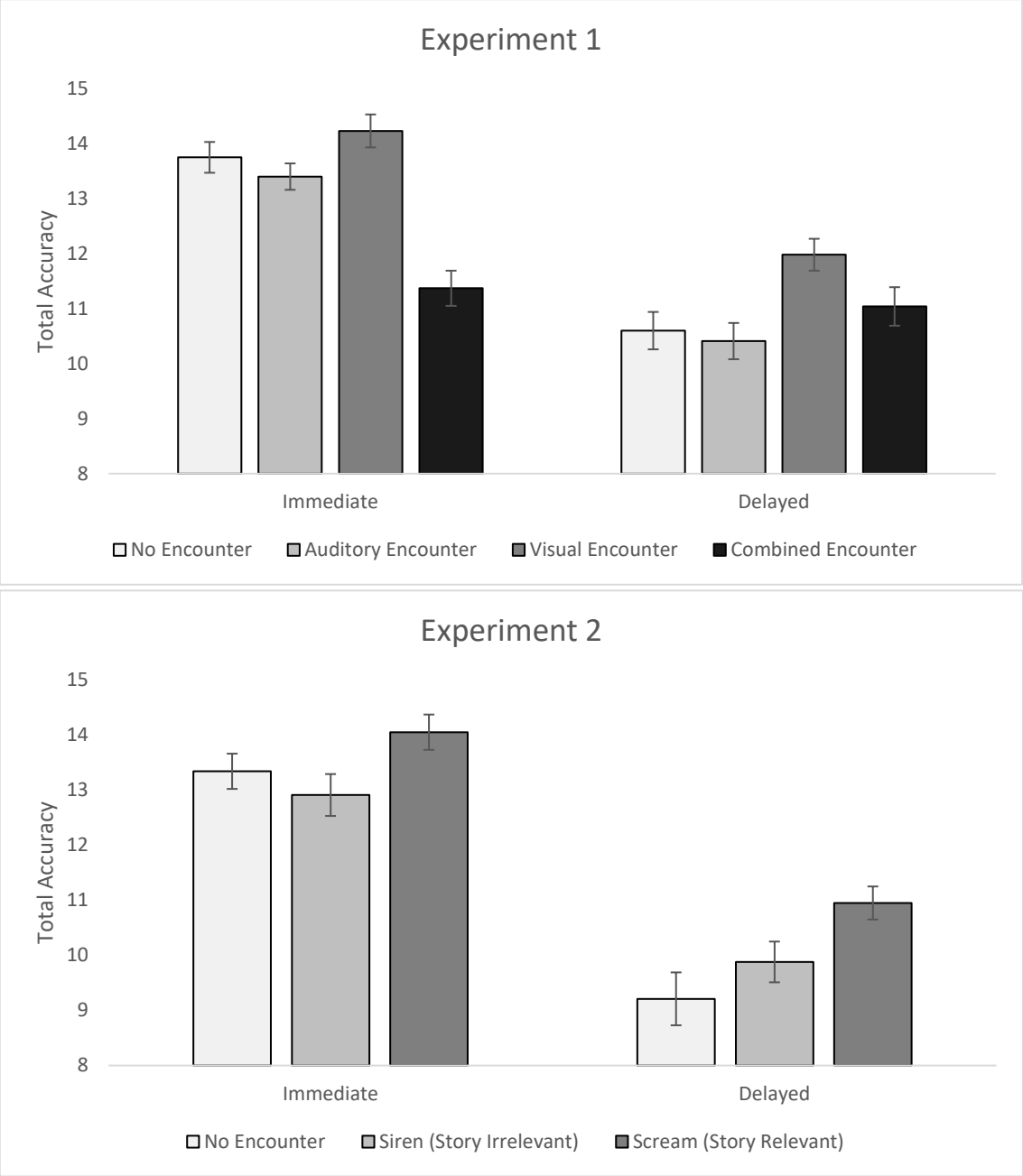


Figure 2.

*Top panel*: Experiment 1 total accuracy scores across the four encounter conditions. *Bottom panel*: Experiment 2 total accuracy scores across the three encounter conditions. Total accuracy refers to the sum of participants' accuracy for Central and Peripheral Details as well as Critical Lures (ranging from 0 to 21). Error bars reflect standard error.