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ASSESSING THE EFFECTS OF MISLEADING POST-EVENT INFORMATION USING MULTINOMIAL PROCESSING TREE MODELS

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ASSESSING THE EFFECTS OF MISLEADING POST-EVENT INFORMATION USING MULTINOMIAL PROCESSING TREE MODELS

A DISSERTATION APPROVED FOR THE
DEPARTMENT OF PSYCHOLOGY

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Abstract

Multiple studies have shown that misleading post-event information can alter an individual's memory. Three hypotheses (no-conflict, coexistence, destructive updating) have been proposed to explain the fate of the original memory trace and have subsequently been mathematically formalized to gain a more comprehensive understanding of the predictions regarding false memory formation (Wagenaar & Boer, 1987). We utilized multinomial processing tree (MPT) models to test these hypotheses concurrently. In two experiments, we implement the Loftus (1978) misinformation paradigm to subsequently apply MPT models to the data. In *Experiment 1* and *Experiment 2*, we found support for both the no-conflict and coexistence models, but due to the no-conflict model being the most parsimonious model, we defaulted to the no-conflict model. However, when only the top-performing participants were examined, we found strong evidence for the coexistence model. In *Experiment 2*, we also categorized participants based on their perceptions of what happened to their original memory and used these distinctions to determine if there was a correspondence between participants' intuitions and model fits. We found some correspondence between participants categorized as endorsing No-Conflict and minimal support for Coexistence and the respective models. Surprisingly, we did not replicate the overall misinformation effect that we found in *Experiment 1*. However, we did find a misinformation effect for the participants classified as Coexistence and Destructive Updating, suggesting that participants who acknowledged a conflict were affected by the conflicting information. Future research should continue to apply these models to different sub-sets of participants to examine the extent to which participants are aware of a conflict.

Keywords: multinomial processing tree models, no-conflict, coexistence, destructive updating, misinformation effect, false memory

Assessing the Effects of Misleading Post-Event Information Using Multinomial Processing Tree Models

Memory is malleable and does not function as an exact recording of the past. The malleability of memory has practical relevance in multiple contexts but is frequently examined within an eyewitness memory framework. For example, following a crime, a witness is questioned about the event. However, interviewers (or other witnesses) could inadvertently alter the witness's original memory of the crime. An interviewer could mention details reported by another witness or suggest a piece of evidence that becomes incorporated into the witness's memory. It is the incorporation of inaccurate information into memory that contributes to innocent individuals being falsely convicted.

Numerous studies have shown that misleading post-event information can alter an individual's memory (Ackil & Zaragoza, 1995, 1998; Eisen et al., 2017; Loftus et al., 1978; Loftus, 2005; Zaragoza et al., 2001), and three hypotheses have been proposed to explain the fate of the original memory trace. They are destructive updating, coexistence, and no-conflict. Testing these hypotheses concurrently provides a greater understanding of the mechanism responsible for updating memory. However, these verbal explanations must be mathematically formalized to provide definitive predictions regarding false memory formation. Utilizing mathematical modeling provides an unambiguous understanding of the underlying differences among these explanations and, in doing so, allows for a clearer understanding of the impact of misleading post-event information on the original memory.

Wagenaar and Boer (1987) assessed and modeled the three aforementioned hypotheses using all-or-none probabilistic, multinomial processing tree (MPT) models (Batchelder & Riefer, 1980, 1990, 1999; Riefer & Batchelder, 1988). Their experiment followed the typical Loftus paradigm (1974, 1978), the first to assess the effects of misleading post-event information (i.e., the misinformation effect). The misinformation effect occurs when an individual receives contradictory information following memory formation and later incorporates it into their original memory. In Phase 1 of this paradigm, participants are presented with a story and questioned about it in Phase 2. During Phase 2, some participants are asked about information that contradicts the original memory (inconsistent condition). Of interest is the extent to which these participants endorse the contradictory information during a subsequent memory test (Phase 3). Endorsing the contradictory post-event information presents itself as a reduction in the percentage of correct responses to critical test items. As mentioned, endorsing this post-event information can be explained in one of three ways: destructive updating, coexistence, or no-conflict.

Each of these three hypotheses can be instantiated as a model, and of interest is how these three models predict different performance outcomes in Phase 4 (added to the Loftus paradigm by Wagenaar & Boer, 1987), in which participants are asked to determine the specific source of the contradictory information. The three models can be distinguished based on the participants' performance in Phase 4. More specifically, how participants' answers to the Phase 4 critical source question are impacted by whether they were asked an inconsistent (contradicts the original memory), consistent (exactly reiterates the original memory), or neutral (generically reiterates the original memory) post-event critical question in Phase 2.

Destructive Updating

Loftus et al. (1978) proposed the destructive updating hypothesis, claiming that misleading post-event information destroys the original memory. More specifically, individuals misled following exposure to the original information form a new memory. This is hypothesized to occur by either the original memory being replaced by a new one or by combining the two competing memories into a new memory. In either instance, the original memory trace is rendered inaccessible because it has been obscured or destroyed. This hypothesis predicts that Phase 4 performance for participants who were asked the inconsistent post-event critical question in Phase 2 should be lower compared to those asked the consistent or neutral post-event critical question.

Coexistence

The coexistence hypothesis proposes that the original memory persists; however, it is rendered inaccessible because of inhibition (or suppression). Misleading post-event information inhibits the original memory of the event but does not destroy it (Christiansen & Ochalek, 1983), thereby maintaining the existence of memory traces for the original and the misleading information. Therefore, the impact of the misleading post-event information is attributed to a failure to retrieve information from the original memory trace, not a loss of it. This hypothesis predicts no specific difference in the Phase 4 performance between non-misled (consistent and neutral) and misled (inconsistent) participants when answering the post-event critical question because once the misled participants are told that they saw, for example, a traffic light instead of a stop sign, they should be able to report the color of the traffic light to the same extent that the non-misled participants do.

No-Conflict

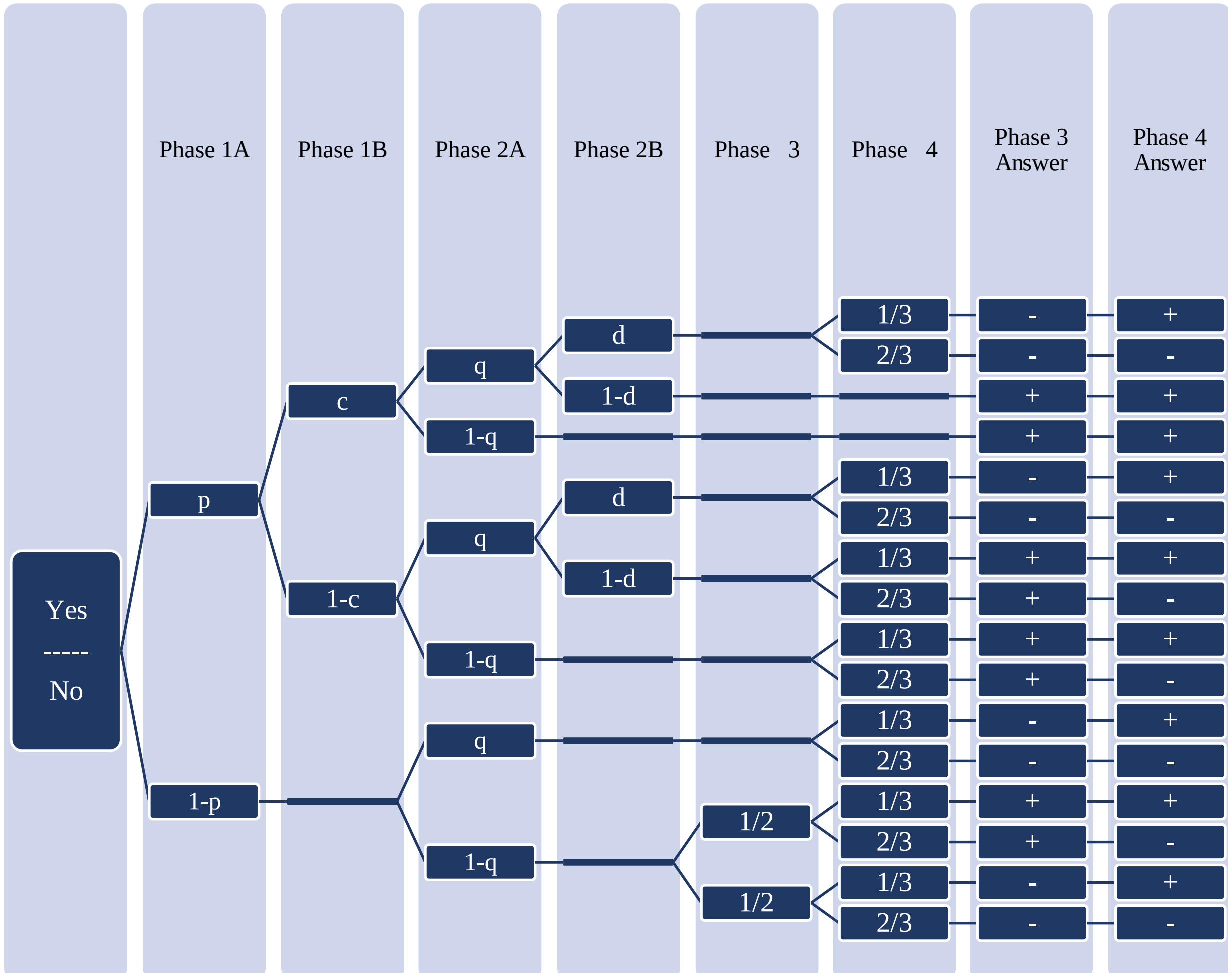
The no-conflict hypothesis proposes that individuals are only misled if they forget the original information or do not encode it (McCloskey & Zaragoza, 1985). More specifically, participants who successfully encode the original event information will not experience a conflict between the original memory trace and the misleading post-event information and can produce a correct response to the post-event critical question. However, individuals who do not encode (or forget) the original information will rely on the post-event information. If this information is misleading, they will produce an incorrect response without experiencing a conflict between the original and misleading memory trace. This hypothesis predicts no difference in Phase 4 performance between the non-misled (consistent and neutral) and misled (consistent) participants when answering the source question because participants either originally encode the relevant information or do not encode it to begin with and, therefore, can only guess the correct answer. Wagenaar and Boer (1987) found that this model accounted best for their obtained results. However, they also argued that destructive updating and coexistence could not be definitively excluded, despite being less parsimonious (they have one additional parameter).

The present set of experiments tests the predictions of the mathematical formulations of these three hypotheses. Utilizing mathematical modeling allows us to conduct a precise test of the underlying differences among these hypotheses, something not achievable if the models are specified verbally. To explain the models and the associated parameters, we do so in the context of one of the main stimulus materials to be used in the experiments (both past experiments and in the current research). In Phase 1, participants are presented with a story that contains written and pictorial depictions of a mother running errands. The critical image depicts a car at an intersection that shows the traffic light as either red, yellow, or green. In Phase 2, participants' memories are assessed for details of the story. Of interest is the critical item question. Here, participants are asked one of three questions: Participants are asked if they remembered a pedestrian crossing the road when the car approached the traffic light (consistent), the stop sign (inconsistent), or the intersection (neutral) (like Loftus et al., 1978). Regardless of the critical item question asked, all participants saw the traffic light in Phase 1. In Phase 3, participants complete a recognition test. The critical image pair on this test depicts one image with the traffic light and another image with a stop sign. Of interest is the extent to which participants in the inconsistent condition endorse the misinformation (the stop sign). In Phase 4, participants are told that they actually saw a traffic light in Phase 1 and are asked to report the color of the traffic light.

To apply MPT models to this paradigm, the models must be specified to the possible Phase 3 and Phase 4 response outcomes in order to detail the equations necessary to match to the data and estimate the parameters. Of particular interest is performance in the inconsistent condition because the three models only differ in how the misleading information is handled. *Figure 1* represents the Destructive Updating MPT model for the inconsistent condition, which requires four parameters. Shown in Phase 1A of *Figure 1*, parameter *p* represents the proportion of participants who encoded the traffic light. The proportion of participants who did not encode the traffic light is 1 – *p*. In Phase 1B (*Figure 1*), for those who did encode the traffic light, parameter *c* reflects the proportion of participants who encoded the color of the traffic light (*c*) versus those who did not (1 – *c*). Especially relevant in the inconsistent condition is parameter *q*, which represents the proportion of participants who encoded the stop sign, or did not (1 – *q*) (Phase 2A). Lastly, if both the traffic light and the stop sign are encoded, *d* reflects the proportion of participants in which destructive updating occurs, or does not occur (1 – *d*) (depicted in Phase 2B, *Figure 1*). Three of these parameters (*p, c, q*) are also required in the coexistence model. However, the *d* parameter is replaced by *s* (*Figure 2* – Phase 2B), which captures the conflict between the traffic light and the stop sign, reflecting the proportion of participants whose memory of the traffic light is suppressed (*s*) or not suppressed (1 – *s*). For the no-conflict model, only parameters *p, c,* and *q* are necessary (*Figure 2 in Appendix*). Note that if parameter *s* equals zero, the coexistence model reduces to the no-conflict model. This is also true for the destructive updating model when parameter *d* equals zero. The process trees for the coexistence and no-conflict models are in the *Appendix (Figures 1 and 2)*.

Even though memory strengths are undoubtedly continuous in real life, simplifications like MPT models, which are simple statistical models that treat memory as all-or-none, have been shown to work surprisingly well at summarizing data, estimating relevant latent parameters, and disentangling and measuring the distinct contributions of different cognitive processes (Batchelder & Riefer, 1990, 1999; Riefer & Batchelder, 1988). Because MPT models can be used to disentangle empirical effects across latent processes, this allows researchers to extrapolate information from data in a way that ad hoc statical techniques cannot. For example, Batchelder and Riefer (1980, 1986) utilized an MPT model with storage and retrieval contributions (components normally confounded). Researchers in the field of memory usually focus on the recall of items as the main dependent variable. However, successful recall requires at least two separate processes (storing the information and retrieving it). So Batchelder and Riefer (1986) presented participants with word lists that contained several pairs of categorically related words (e.g., oxygen and hydrogen, doctor and lawyer) and several singleton words and demonstrated that their model could disentangle these contributions. It is models like these that allow researchers to explore a vast amount of relevant theoretical issues and conduct precise comparisons among related theories.

Figure 1. Destructive Updating Model



To estimate the parameters for each model, we first must obtain the probability of each of the four possible response patterns that fall along each path of the MPT models. The four possible response patterns are 1) Phase 3 – Correct and Phase 4 – Correct, 2) Phase 3 – Incorrect and Phase 4 – Incorrect, 3) Phase 3 – Correct and Phase 4 – Incorrect, and 4) Phase 3 – Incorrect and Phase 4 – Correct. The probability of each tree branch is the product of all the encountered probabilities along each branch. The total probability of a response pattern is then summed across the branches that lead to the same response outcome. For example, the total probability of getting Phase 3 incorrect and Phase 4 correct for the inconsistent condition under the destructive updating model (*Figure 1*) is:

$p \times c \times q \times d \times (^1/_3) + p \times (1 - c) \times q \times d \times (^1/_3) + (1 - p) \times q \times (^1/_3) + (1 - p) \times (1 - q) \times (^1/_2) \times (^1/_3)$.

This process is repeated for each response pattern outcome (four total) for the other two conditions (consistent and neutral) under each of the other two models (coexistence and no-conflict).

Should destructive updating be supported, we would expect a decrement in performance in Phase 4 for those in the inconsistent condition compared to those in the consistent or neutral conditions. More importantly, destructive updating should lead to chance performance in Phase 4: If misinformation destroys the original memory (the memory of the traffic light), someone can only guess the color of the traffic light. The coexistence model predicts that performance in Phase 4 should not differ among the consistent, inconsistent, or neutral conditions. Because this model assumes the existence of two memory trace representations, when there is a conflict between the traffic light and the stop sign, suppression will occur in some participants. However, this does not eliminate the coexistence, and once participants are told that they saw the traffic light, they will have access to that memory trace. The no-conflict model assumes no conflict between the traffic light and the stop sign when both are encoded, so the color of the traffic light can be chosen in Phase 3.

In addition to using stimulus materials similar to those used by Loftus et al. (1978) and Wagenaar and Boer (1987), we expanded the context of examination. Memory can be updated in multiple contexts, not just in an eyewitness situation. For example, in the classroom, students often have preconceived ideas about various topics, but as the course progresses, they are presented with confirming and conflicting information. Unlike previous research, which has only used the traffic light scenario, we will be using three scenarios, because this allows us to examine subsets of participants based on performance level, which was not possible in previous studies as participants could only be right or wrong. It is possible that not all participants update memory in the same way, and being able to break down participants into performance-based subsets may allow a more nuanced understanding of the veracity of these hypotheses (see Batchelder, 1998). The second and third contexts are structurally the same but instead reflect events that do not reference a pedestrian and traffic. We describe them in more detail below.

Experiment 1

Method

Participants

A total of 516 introductory psychology students (444 females, 62 males, and 5 non-binary individuals; M_{Age} = 18.65 years, SD_{Age} = 1.24) from the University of Oklahoma participated in this study in exchange for partial course credit. This sample size is based on the sample collected in the Wagenaar and Boer (1987) study. This is far more participants than are needed to evaluate the empirical misinformation effect, but it is necessary for robust parameter estimation of the models being evaluated. All students were enrolled in an introductory psychology course and were recruited via a university recruitment portal (SONA study flier). Upon signing up, participants were informed that they would view various pictorial and written descriptions of different scenarios before being asked to answer questions about them. Participants received a maximum of one research credit for their psychology course. They received credit following the completion of one Qualtrics survey. To participate, students were at least 18 years of age and able to provide consent. In addition, participants must consider themselves proficient in English and have normal color vision.

All participants' data were kept anonymous and separate from identifying information. No significant risks were encountered by the participants, and they were treated in accordance with APA (American Psychological Association) ethical standards. The study was approved by the University of Oklahoma Institutional Review Board (IRB).

Design

The independent variable in this experiment is the type of post-event critical question asked: consistent, inconsistent, or neutral. This variable is a within-subject factor. We counterbalanced the order in which participants were asked a consistent, inconsistent, and neutral post-event critical question. Participants experienced each scenario only once, as well as each of the post-event critical question conditions (consistent, inconsistent, neutral). For example, based on counterbalancing, if exposed to the consistent condition for the first scenario, upon starting the second scenario, participants were exposed to either the inconsistent or neutral condition, and so on. The presentation order of the three scenarios was also counterbalanced.

Materials

Participants completed a demographic survey that consisted of self-reporting their gender, age, and race/ethnicity. They also viewed three different stimulus sets consisting of a series of ten slides. Each set contained written and pictorial depictions of either a mother running errands (discussed earlier), a woman baking, and two friends studying. These slides served as the learning material. Slides with images were shown for three seconds, and slides containing written depictions were presented for 30 seconds. We first describe the mother running errands scenario.

For the mother running errands, the critical image depicted a car approaching a traffic light. The traffic light appeared red, yellow, or green (counterbalanced across participants). Following exposure to the slides, participants were asked eight questions about the storyline's content, one of which was the critical item question. Participants were asked either a consistent, inconsistent, or neutral critical item question (one per scenario). Participants also completed a 16-item recognition test. Within this 16-item test, a critical image pair depicted one image with the traffic light and the other with a stop sign. The position of each image with the pairs was rotated between left and right across participants. After each recognition decision, a confidence judgment was collected using a Likert scale ranging from 1 (not confident at all) to 5 (extremely confident).

The second stimulus set followed the same general outline as the mother running errands scenario. Here, participants were shown slides that depicted the events involved in prepping and baking a dessert. The critical image depicted a measuring cup of sugar; however, counterbalancing among participants determines if participants see a measuring cup labeled as ½, ¾, or 1 cup. Participants are later asked either a consistent, inconsistent, or neutral critical item question. The question asks whether they remembered a hand towel placed next to the sugar, the coffee mug, or the ingredients, respectively. The critical image pair depicted one image with sugar and the other with a coffee mug. In the third stimulus set, participants were shown slides that depicted the events involving two friends studying together. The critical image depicted a laptop; however, counterbalancing among participants determined if participants saw a laptop with a blue, purple, or orange case. Participants received either a consistent, inconsistent, or neutral critical item question in which they were asked if they remembered a book bag next to the laptop, the iPad, or the electronic device, respectively. The critical image pair depicted one image with a laptop and the other with an iPad.

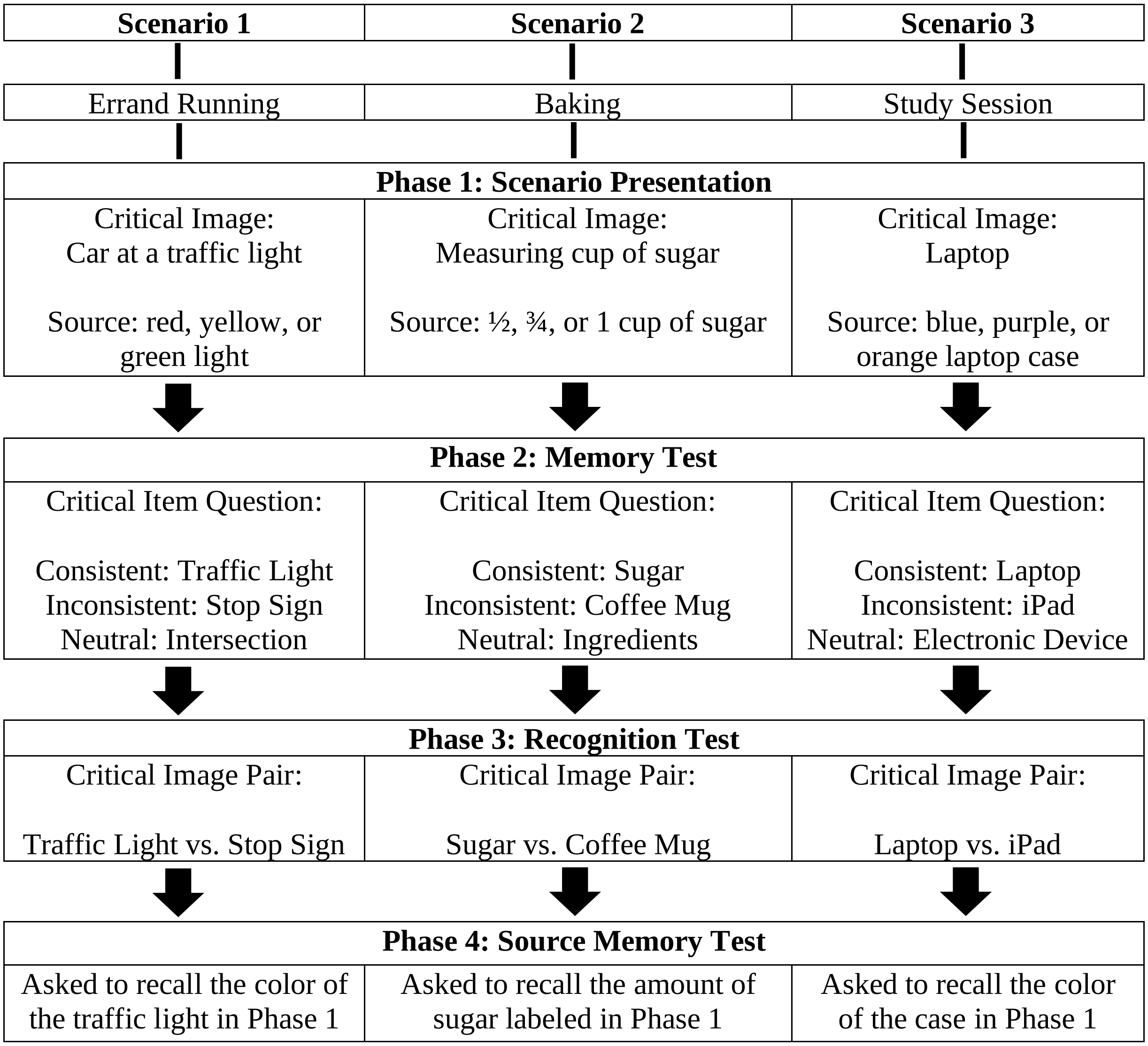
We piloted all stimulus scenarios to ensure that each induced comparable memory performance. In the pilot study, participants (N = 25) viewed all three scenarios but were only exposed to inconsistent information for each scenario (the stop sign, coffee mug, and iPad, respectively). Of interest was the rate at which participants endorsed this inconsistent information. Subsequently, participants were told that they saw the traffic light, sugar, and laptop, respectively, and that they should report the color of the traffic light, the amount of sugar present, and the color of the laptop case. The results of the pilot study were consistent with that of previous research (Wagenaar & Boer, 1987), demonstrating comparable memory performance for participants exposed to inconsistent information in our pilot study compared to participants in the inconsistent condition in Wagenaar and Boer (1987). The results of this pilot study can be seen in *Table 1* in the *Appendix*. All the Phase 2, 3, and 4 questions appear in the *Appendix* (Stimulus Scenario Questions).

Six two-minute distractor tasks (word search puzzles) were also used. Distractor tasks were completed between Phase 1 and Phase 2, and between Phase 2 and Phase 3, for each of the three scenarios.

Procedure

After obtaining informed consent and completing the demographics questionnaire, participants begin Phase 1 (see *Figure 2*). In Phase 1, participants were presented with one of the three scenarios (errand running, baking, or studying). Before Phase 2, participants completed the first distractor task. Next, in Phase 2, participants' memories were assessed for the details of the scenario with eight questions. Of interest is the critical item question. Depending on the counterbalancing of the condition, participants were asked a consistent (traffic light/sugar/laptop), inconsistent (stop sign/coffee mug/iPad), or neutral (intersection/ingredients/electronic device) critical item question. Before starting Phase 3, participants completed the second distractor task. In Phase 3, participants completed the recognition test and provided confidence ratings for each decision. Of particular interest is the extent to which participants in the inconsistent condition endorsed the misinformation (stop sign/coffee mug/iPad). This same procedure was repeated two more times for the scenarios and critical item questions not already experienced. Phase 4 was completed after all three scenarios had been completed. In Phase 4, participants are only asked about the scenario in which they were presented with inconsistent information (stop sign/coffee mug/iPad). Here, regardless of the answer provided by participants to the critical image pair in Phase 3, participants were told that they actually saw a traffic light, a measuring cup of sugar, or a laptop in Phase 1, depending on the counterbalancing of the condition. Next, participants were asked to recall the color of the traffic light (red, yellow, or green), the amount of sugar present (½, ¾, or 1 cup), or the color of the laptop case (blue, purple, or orange). Participants provided a confidence rating for each decision. After completing Phase 4, participants were debriefed and compensated for their time.

Figure 2.



Results

A total of 450 participants' data were included in the subsequent analyses. Of the original 516 students who participated, 66 participants' data were removed. Of these 66 participants, 37 started the experiment but did not finish, five withdrew, 22 started the study but timed out, and two participants did not consent to the researchers keeping their data.

The three models (no-conflict, destructive updating, coexistence) predict different performance outcomes, and therefore, analyzing these parameterized models will allow us to determine which hypothesis provides the best explanation for the effect of post-event misinformation. First, we need to verify that we got a significant misinformation effect.

Misinformation Effect

The effect of the misleading post-event information was present in Phase 3 and can be seen in *Table 1.* The inconsistent condition differed significantly from the consistent condition and the neutral condition, but the consistent condition did not differ significantly from the neutral condition ($\chi^2(2, N = 1350) = 15.859$, $p < 0.001$, $V = 0.108$). These findings are evidence of a misinformation effect because the inconsistent condition led to poorer performance, consistent with findings from Wagenaar and Boer (1987). The three scenarios were designed to be structurally the same, but we still examined performance in Phase 3 and Phase 4 by scenario and found that performance was comparable across scenarios. The proportion of participants who answered correctly across scenarios can be seen in *Table 2* in the *Appendix*.

Table 1

Proportions of Participants that Answered Correctly in Phase 3 and Phase 4

Post-Event Information	Phase 3	Phase 4
Consistent	0.76 (342)	0.41 (185)
Inconsistent	0.66 (297)	0.40 (179)
Neutral	0.76 (344)	0.43 (192)

Note. Frequencies are in parentheses.

General Memory Performance

Though we are primarily interested in the misinformation effect, we did examine general memory performance for the Phase 2 and Phase 3 questions. In general, participants paid close attention to the details of the scenarios and performed well when answering both the Phase 2 questions correctly ($M = 0.81$, $SD = 0.12$) and the Phase 3 questions correctly ($M = 0.81$, $SD =$

0.11). We also assessed participants' confidence in their answers for the Phase 3 critical image pair and the answers to the Phase 4 source question. The average confidence ratings are presented in *Table 2* as a function of the post-event information condition. Across the post-event information condition, participants, on average, were fairly confident when making the critical recognition decision in Phase 3, but only somewhat confident when answering the source question in Phase 4. There was not a significant difference in reported confidence for Phase 3 ($F(2, 1347) = 1.264$, $p = 0.283$, $\eta_p^2 = 0.002$) or Phase 4 ($F(2, 1347) = 0.249$, $p = 0.780$, $\eta_p^2 = 0.000$).

Table 2
Average Confidence Rating for the Phase 3 Critical Question and Phase 4 Source Question

Post-Event Information	Phase 3	Phase 4
Consistent	3.42 (1.37)	2.33 (1.31)
Inconsistent	3.34 (1.37)	2.36 (1.30)
Neutral	3.48 (1.35)	2.40 (1.36)

Note. Confidence ratings range on a scale from 1 (Not at all Confident) to 5 (Extremely Confident). Standard deviations are in parentheses.

Parameter Estimation

We specified each model to detail the equations necessary to apply to the data and subsequently estimate the parameters. We estimated these parameters using the *R* package *R2jags* (Su et al., 2015). *R2jags* was used to run Bayesian estimation using the JAGS software within *R*, which allowed us to sample from the posterior distributions of the parameters via MCMC simulations. After fitting the models to the data, we obtained the parameter point estimates (*Table 3*) for the best fit of each model. Once the best-fit parameters were obtained, we entered these estimates into the equations for each model and computed the overall fits of each model to the data (*Table 4*).

Table 3

Parameter Estimates for the Best Fit of Each Model

	Parameters				
Model	*p*	*c*	*q*	*d*	*s*
No-Conflict	0.454	0.251	0.174	N/A	N/A
Coexistence	0.483	0.245	0.135	N/A	0.607
Destructive Updating	0.479	0.244	0.134	0.587	N/A

Note. *N* = 450 participants.

Table 4 (Data column) reports the proportion of responses for Phase 3 and Phase 4 response outcomes for each of the three post-event information conditions. The Model column reflects the predictions from the best-fitting parameters for the No-Conflict model. The fit of the model is excellent, which is apparent from comparing the values in the Data and Model columns. The corresponding fits for the destructive updating and coexistence models can be seen in *Table 3* and *Table 4* in the Appendix, respectively. The fits of the destructive updating and coexistence models are also excellent. The close correspondence between model and data can also be presented visually and are shown in *Figure 3* for all three models. The combined Phase 3 and Phase 4 performance is depicted along the *y*-axis for each model, and the best-predicted values for each model are represented along the *x*-axis. A perfect prediction would fall along the diagonal line. The corresponding *r* values are very close to the diagonal (0.990, 0.991, and 0.989 for the no conflict, coexistence, and destructive updating models, respectively).

Figure 3

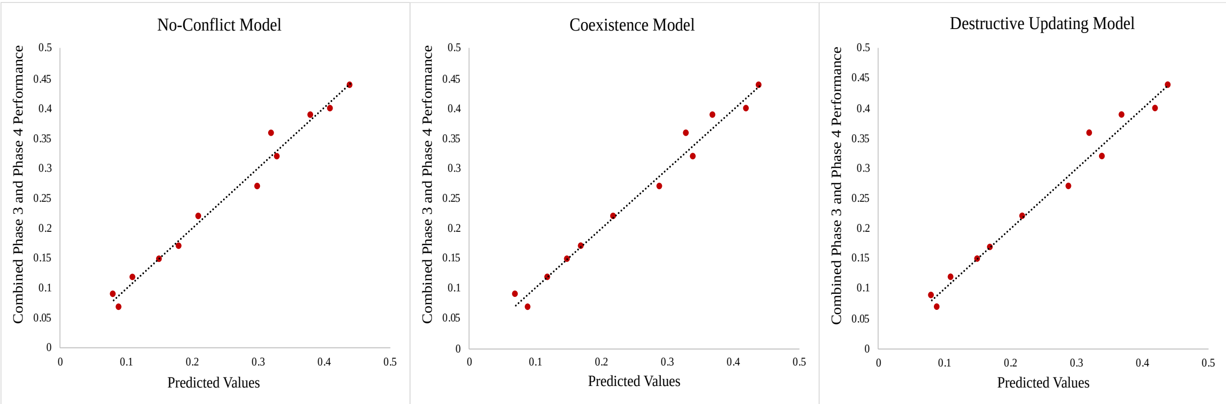


Table 4
Performance of Participants in Phases 3 and 4 for the Best-fitting No-Conflict Model

Post-Event Information	Phase 3	Phase 4	Data	Model
Consistent	+	+	.32	.33
	+	-	.44	.44
	-	+	.09	.08
	-	-	.15	.15
Inconsistent	+	+	.27	.30
	+	-	.39	.38
	-	+	.12	.11
	-	-	.22	.21
Neutral	+	+	.36	.32
	+	-	.40	.41
	-	+	.07	.09
	-	-	.17	.18

Note. The (+) signs represents answering the respective phase question correctly, whereas a (-) signs represents an incorrect answer.

Model Comparisons

All model comparisons were conducted in *R* using the package *MPTinR* (Singmann & Kellen, 2013, 2021). We used the functions *fit.mpt* and *select.mpt* to obtain the model comparison indices, including the Akaike information criteria (AIC) and Bayesian information criterion (BIC), to assess which of the three models best fit the data. *fit.mpt* is used for fitting the MPT models to the data and returns the AIC and BIC values; *select.mpt* aids in the model selection process and takes the results from *fit.mpt* and produces the output comparing the models based on the information criteria AIC and BIC.

In *Table 5*, we present the model selection criteria based on AIC and BIC values for the no-conflict, destructive updating, and coexistence models. AIC is a popular method that is used to compare models and considers both model parsimony and descriptive accuracy. AIC is a technique based on in-sample fit used to estimate the likelihood that a model can estimate future values. However, AIC can be too liberal as it may select overly complex models (Kass &

Raftery, 1995). BIC is another model comparison criterion that weighs the trade-off between model complexity and fit (Stone, 1979). Contrary to AIC, BIC carries a larger penalty term, thereby penalizing models that have more parameters (Wagenmakers & Farrell, 2004). Both AIC and BIC can be derived from a model's likelihood function and maximum likelihood estimates (Vrieze, 2012). According to the AIC and BIC values presented here, the findings are mixed. When interpreting BIC, the no-conflict model (31.584) should be preferred over both the destructive updating and coexistence model, which are indistinguishable from each other. However, when interpreting AIC, there is some evidence for the coexistence model (13.610). *wBIC* and *wAIC* are interpreted as the probability that the respective model is the best-fitting model. Therefore, according to *wBIC*, the probability that the no-conflict model (the more parsimonious model because it has one less parameter) is the best-fitting model is 0.710. whereas according to *wAIC*, the probability that the coexistence model is the best-fitting model is 0.496. The present findings are consistent with the findings of Wagenaar and Boer (1987). They concluded that the parameterization of these models suggests that they generate relatively equivalent predictions, and therefore, the most parsimonious model (no-conflict model) should be accepted.

Table 5

AIC and BIC values for the No-Conflict, Coexistence, and Destructive Updating Models

Model	*df*	Δ*AIC*	*wAIC*	*AIC*	Δ*BIC*	*wBIC*	*BIC*
No-Conflict	6	2.351	0.153	15.961	0.000	**0.710**	**31.584**
Coexistence	5	0.000	**0.496**	**13.610**	2.857	0.170	34.441
Destructive Updating	5	0.691	0.351	14.301	3.548	0.120	35.132

Note. *N* = 450 participants.

However, because we do have some evidence for both the no-conflict and coexistence model, we decided to explore further, as it is possible that not all individuals update memory in the same way. Therefore, we re-fit the data to various subsets of the data. We partitioned the data in multiple ways; however, we dismissed most subsets due to extremely low *Ns (*which makes model fitting unreliable*)*. For example, there were only 18 participants overall who answered all three of the Phase 3 recognition questions, as well as all three of the Phase 4 source questions, correctly.

The following re-fittings of data subsets included the ones that had sufficiently higher *Ns*. We examined both the top-performing and lowest-performing subsets of participants. First, we report on removing the lowest-performing participants. We re-fit the data for those participants who answered at least one (out of three) of the recognition questions correctly from Phase 3 as well as one (out of three) of the source questions from Phase 4 (denoted as $P3_{1+}$ and $P4_{1+}$ performers). Of the 450 participants, 342 fit this classification. We reexamined the presence of the misinformation effect for this subset and again found that the inconsistent condition did significantly worse than the consistent condition and the neutral condition ($\chi^2(2, N = 1026) = 15.949$, $p < 0.001$, $V = 0.125$). The best-fitting parameter point estimates obtained for each of the three models are given in *Table 6.*

Table 6
Parameter Estimates for the Best Fit of Each Model to the $P3_{1+}$ and $P4_{1+}$ Performers

	Parameters				
Model	*p*	*c*	*q*	*d*	*s*
No-Conflict	0.523	0.472	0.211	N/A	N/A
Coexistence	0.567	0.459	0.161	N/A	0.713
Destructive Updating	0.556	0.460	0.157	0.591	N/A

Note. N = 342 participants.

In *Table 7*, we present the model selection criteria based on the AIC and BIC values for these $P3_{1+}$ and $P4_{1+}$ performers. Now we see much stronger evidence in support of the coexistence model. The lower AIC (24.895) and BIC (44.628) values indicate that the coexistence model provides a better fit than the no-conflict and destructive updating models. Moreover, there is strong support for the coexistence model, as it carries 95% (*wAIC)* and 83%

(*wBIC*) of the cumulative model weight. In other words, the coexistence model is 72.5 times more likely to be the best model than the no-conflict model ((Coexistence$_{wAIC}$) ÷ (No-Conflict$_{wAIC}$)) and 25.1 times more likely to be the best model compared to the destructive updating model ((Coexistence$_{wAIC}$) ÷ (Destructive Updating$_{wAIC}$)) (Wagenmakers & Farrell, 2004).

Table 7
AIC and BIC Values for the No-Conflict, Coexistence, and Destructive Updating Models for the P3$_{1+}$ and P4$_{1+}$ Performers

Model	*df*	Δ*AIC*	*wAIC*	*AIC*	Δ*BIC*	*wBIC*	*BIC*
No-Conflict	6	8.556	0.013	33.451	3.623	0.136	48.251
Coexistence	5	0.000	**0.949**	**24.895**	0.000	**0.831**	**44.628**
Destructive Updating	5	6.448	0.038	31.342	6.448	0.033	51.076

Note. N = 342 participants.

We also re-fitted another subset consisting of only the top-performing participants overall. Participants were included here if they answered at least two (out of three) of the recognition questions correctly from Phase 3 and two (out of three) of the source questions from Phase 4 (denoted as P3$_{2+}$ and P4$_{2+}$ performers). Of the 450 participants, 147 fit this classification. Again, we reexamined the presence of the misinformation effect and found that even for the top-performing participants, the inconsistent condition did significantly worse than the neutral condition (χ^2(2, *N* = 441) = 6.099, *p* = 0.047, *V* = 0.118). The best-fitting parameter point estimates obtained for each of the three models are given in *Table 8.*

Table 8
Parameter Estimates for the Best Fit of Each Model to the P3$_{2+}$ and P4$_{2+}$ Performers

	Parameters				
Model	*p*	*c*	*q*	*d*	*s*
No-Conflict	0.702	0.761	0.179	N/A	N/A
Coexistence	0.768	0.740	0.162	N/A	0.747
Destructive Updating	0.724	0.750	0.122	0.473	N/A

Note. N = 147 participants.

In *Table 9*, we present the model selection criteria based on the AIC and BIC values for the $P3_{2+}$ and $P4_{2+}$ performers. Here, we have even stronger support for the coexistence model. The lower AIC (34.076) and BIC (50.432) values indicate that the coexistence model provides a better fit than the no-conflict and destructive updating models. Moreover, the coexistence model now carried better than 99% (*wAIC and wBIC*) of the cumulative model weight!

Table 9

AIC and BIC Values for the No-Conflict, Coexistence, and Destructive Updating Models for the $P3_{2+}$ and $P4_{2+}$ Performers

Model	*df*	Δ*AIC*	*wAIC*	*AIC*	Δ*BIC*	*wBIC*	*BIC*
No-Conflict	6	17.685	0.0001	51.761	13.596	0.001	64.028
Coexistence	5	0.000	**0.999**	**34.076**	0.000	**0.999**	**50.432**
Destructive Updating	5	17.805	0.0001	51.881	17.805	0.000	68.238

Note. N = 147 participants.

Lastly, we decided to re-fit the data for the remaining participants not included in the previous analysis. This includes participants who fell in one of the following three response outcome categories. This includes 1) a participant who answered zero or one (out of three) of the Phase 3 recognition questions correctly and two or three (out of three) of the source questions from Phase 4, 2) a participant who answered two or three (out of three) of the Phase 3 recognition questions correctly and zero or one (out of three) of the source questions from Phase 4, or 3) a participant who answered zero or one (out of three) of the Phase 3 recognition questions correctly and zero or one (out of three) of the source questions from Phase 4 (denoted as $P3_{0\text{-}3}$ or $P4_{0\text{-}3}$). Of the 450 participants, 303 fit this classification. The misinformation effect was present; the inconsistent condition did significantly worse than the consistent condition and the neutral condition ($\chi^2(2, N = 909) = 12.417$, $p = 0.002$, $V = 0.117$). The best-fitting parameter point estimates obtained for each of the three models are given in *Table 10*.

Table 10
Parameter Estimates for the Best Fit of Each Model to the $P3_{0\text{-}3}$ or $P4_{0\text{-}3}$ Performers

	Parameters				
Model	*p*	*c*	*q*	*d*	*s*
No-Conflict	0.333	0.012	0.182	N/A	N/A
Coexistence	0.352	0.010	0.155	N/A	0.519
Destructive Updating	0.352	0.011	0.153	0.524	N/A

Note. N = 303 participants.

In *Table 11*, we present the model selection criteria based on the AIC and BIC values for the $P3_{0\text{-}3}$ or $P4_{0\text{-}3}$ performers. To reiterate, these are the participants who were excluded from the previous assessment; therefore, after removing the top performers (the $P3_{2+}$ and $P4_{2+}$ performers), we see strong evidence for the no-conflict model here. The lower AIC (44.699) and BIC (59.136) values indicate that the no-conflict model provides a better fit than the coexistence and destructive updating models, and that these two models cannot be distinguished from each other when excluding the best-performing participants. Moreover, the no-conflict model now carried 41% of the cumulative model weight according to *wAIC* and 89% according to *wBIC*. Note that, although supportive of the no-conflict model, it is less weight/support than when only looking at the top-performing participants (which strongly supported the coexistence model, see *Table 9*).

Table 11
AIC and BIC Values for the No-Conflict, Coexistence, and Destructive Updating Models for the $P3_{0\text{-}3}$ or $P4_{0\text{-}3}$ Performers

Model	*df*	Δ*AIC*	*wAIC*	*AIC*	Δ*BIC*	*wBIC*	*BIC*
No-Conflict	6	0.000	**0.410**	**44.699**	0.000	**0.885**	**59.136**
Coexistence	5	0.659	0.295	45.359	5.472	0.057	64.609
Destructive Updating	5	0.659	0.295	45.395	5.472	0.057	64.609

Note. N = 303 participants.

The coexistence model assumes that the original memory persists (traffic light/measuring cup of sugar/laptop) but is rendered inaccessible by inhibition or suppression. *Experiment 1* showed compelling evidence that the coexistence model cannot be ruled out when the top-performing participants ($P3_{2+}$ and $P4_{2+}$) are included. However, the remaining participants ($P3_{0-3}$ or $P4_{0-3}$) support the no-conflict model. In sum, *Experiment 1* provided some support for both the coexistence and no-conflict models, for different subsets of participants. This contrasts with previous research that has defaulted to the more parsimonious no-conflict model largely because the models are indistinguishable from each other (Wagenaar & Boer, 1987). However, given that participant performance is relevant to model fits in *Experiment 1*, this could be an indication that the models can, in fact, be distinguished, and that variations amongst participants are masking what is happening and consequently leading researchers to default to the most parsimonious model (Smith & Batchelder, 2008).

Discussion

Experiment 1 assessed the predictions of the three memory-updating hypotheses that have been instantiated as models to account for the effects of misleading post-event information. When assessing all participants, we gained some evidence supporting both the no-conflict and coexistence models, but due to the no-conflict model being the most parsimonious of the three models, and all three models fitting the data exceptionally well, we (like Wagenaar & Boer, 1987) defaulted to the no-conflict model. However, when only the top-performing participants ($P3_{2+}$ and $P4_{2+}$) are included, we found very strong evidence for the coexistence model. This suggests that the coexistence model provides the best explanation for how these individuals account for misinformation and how they subsequently update memory. Moreover, when examining the parameter estimates for the best-fitting values, we see higher values for p and c (see *Tables 6* and *8*) for the top performers compared to all other participant comparisons, providing evidence that the top-performing participants not only are better at identifying the correct image in Phase 3, and correctly answering the subsequent source question in Phase 4, but that the coexistence model best captures this participant ability. This begs the question of the extent to which the no-conflict and destructive updating models can capture other memory-updating abilities or differences as a function of participant capabilities.

In *Experiment 2*, we will apply other performance-based classifications to target specific explanations. In other words, the three hypotheses may function differently depending on participants' performance and/or how participants perceive what is happening to their memories. For example, a participant that experiences destructive updating may result in the misleading stop sign information replacing the traffic light information to the extent that they have no memory of the traffic light. Therefore, clustering participants together based on their perception of what is happening to their memories, and then assessing the model fits for these different clusters, may lend insight into how these models generalize. This is possible because these models include parameters that measure underlying cognitive capacities, which will be used in the model comparisons as a means to reveal possible between-group differences (Batchelder, 1998). To do this, *Experiment 2* included additional multiple-choice questions to try to assess the extent to which participants were aware of what happened to the original memory trace as a function of the memory-updating explanations. Of interest is how well these models match participants' intuition of their own memory abilities.

Experiment 2

The goal of *Experiment 2* is to replicate the findings from *Experiment 1* and examine model comparisons following various performance-based classifications. This will further our understanding of the underlying mechanisms responsible for the misinformation effect and allow for a more nuanced understanding of the specificity of these hypotheses.

It is important to consider the memory strategy of participants, as this could inform us about how participants account for the exposure to misinformation. Previous research has shown that there are individual differences in recall strategy, such that some participants, when presented with a to-be-remembered word list, show greater recency effects (better memory for items at the end of the word list) than primacy effects (better memory for words presented at the beginning of the word list), while others show greater primacy effects than recency effects, and some show both (and tended to exhibit higher memory accuracy overall) (Unsworth et al., 2011). To support the notion that there are strategic differences across participants, Farrell and Lewandowsky (2018) utilized a k-means clustering technique to determine whether this algorithm could identify these three discrete memory performance groups. K-means clustering is a technique that can identify clusters of participants with similar performance characteristics based on their data. Using this technique, Farrell and Lewandowsky (2018) identified three clusters of participants consistent with the aforementioned patterns of memory performance described in Unsworth et al. (2011). Thus, it is important to consider how different participants handle misinformation differently, which could impact their endorsement of it. Given the verbal definitions of the three models (no-conflict, coexistence, destructive updating), our plan was to use these descriptions as a way to group participants based on how they believe the exposure to the misinformation impacted their original memory.

Experiment 2 is identical to *Experiment 1,* with the exception that participants were asked additional follow-up questions at the end of the experiment (in Phase 5) to determine whether they were aware of the misinformation. This information will be used as an additional classification metric to determine if the models match the participants' intuition about their memories, and also to assess if participants' intuitions might impact the misinformation effect.

Research conducted by Bulevich and Thomas (2012) determined that metamemorial processes are relevant to the misinformation effect. Additionally, previous research investigating participants' metacognitive awareness shows that feeling-of-knowing (FOK) judgments were more accurate in predicting future recognition when participants were presented with contextual information (Thomas et al., 2011). This suggests that individuals are, to some extent, aware of how their memory works and what they are able to recall. Therefore, assessing participants' ability to monitor their memories might lend insight into one's susceptibility to misinformation.

In Phase 4 of *Experiment 2*, we inform participants of the misleading information they were presented with in Phase 2, which is why in Phase 5, we ask participants the extent to which they know they were presented with misleading information. We also assess participants' perception of the state of their original memory trace. This information will be used to group participants and assess how the models capture the effect of misleading post-event information and to determine if there is a correspondence between participants' intuitions and the best fitting model.

Method

Participants

A total of 653 participants (373 females, 260 males, and 19 non-binary individuals; M_{Age} = 26.49 years, SD_{Age} = 7.14) from the University of Oklahoma and Prolific.co participated in this study in exchange for partial course credit (maximum of one research credit for their psychology course) or $7 for their time. This is far more participants than needed to evaluate an empirical misinformation effect, but it is necessary for robust parameter estimation of the models being evaluated and to further partition participants based on performance. All students were enrolled in an introductory psychology course and were recruited via a university recruitment portal

(SONA study flier) or online through Prolific.co. Upon signing up, participants were informed that they would view various pictorial and written descriptions of different scenarios before being asked to answer questions about them. To participate, participants were at least 18 years of age and able to provide consent. In addition, participants must consider themselves proficient in English and have normal color vision.

All participants' data were kept anonymous and separate from identifying information. No significant risks were encountered by the participants, and they were treated in accordance with APA (American Psychological Association) ethical standards. The study was approved by the University of Oklahoma Institutional Review Board (IRB).

Materials

The materials used here were identical to those used in *Experiment 1*, with the exception that participants were also asked three additional follow-up questions to determine whether they were aware of the inconsistent information (stop sign/coffee mug/iPad) presented to them during Phase 2 and whether they believed it impacted their original memory trace. Here, participants were only asked about the scenario in which inconsistent information was presented in Phase 2. Of particular interest is participants' response to question number two, which asks, "Which of the following best describes your experience when you saw the side-by-side images of the traffic light/measuring cup of sugar/laptop and the stop sign/coffee mug/iPad and had to determine which image you saw during the presentation of the story?" This is a forced-choice question where each option is consistent with a definition of one of the three memory-updating hypotheses (no-conflict, coexistence, destructive updating). This question required participants to choose a response outcome that best matched what they thought happened to their original memory, although participants also were able to indicate that the response options listed were not consistent with what they felt happened to their original memory (None of the above). The follow-up questions are in the Appendix (*Experiment 2 Follow-Up Questions as a Function of Scenario*).

Procedure

The procedure is identical to *Experiment 1*; however, following the end of Phase 4, participants were asked three follow-up questions based on the scenario in which they were exposed to inconsistent information (Phase 5).

Results

A total of 564 participants' data were included in the subsequent analyses. Of the original 653 students who participated, 89 participants' data were removed, which is comparable to the number of participants removed in *Experiment 1*. Of these 89 participants, 70 started the experiment but did not finish, five withdrew, 12 started the study but timed out, and two participants did not consent to the researchers keeping their data.

Misinformation Effect

We first examined whether we have a misinformation effect in Phase 3. In contrast to *Experiment 1*, the (minor) decrease in the inconsistent condition in *Experiment 2* was not significant ($\chi^2(2, N = 1692) = 0.286, p = 0.867$). The associated proportions can be seen in *Table 12.* Given the results of *Experiment 1*, and much prior literature, the lack of an overall misinformation effect was puzzling. To preview, there are a couple of subsets of the data where we did find the misinformation effect; we will have more to say about this after first reporting the *Experiment 2* analyses that parallel what we did in *Experiment 1*.

Table 12

Proportions of Participants that Answered Correctly in Phase 3 and Phase 4

Post-Event Information	Phase 3	Phase 4
Consistent	0.73 (410)	0.43 (245)
Inconsistent	0.72 (406)	0.46 (257)
Neutral	0.73 (414)	0.44 (246)

Note. Frequencies are in parentheses.

General Memory Performance

We examined general memory performance for the Phase 2 and Phase 3 questions. In general, and consistent with *Experiment 1*, participants paid close attention to the details of the scenarios and performed well when answering both the Phase 2 questions correctly (M = 0.81, SD = 0.13) and the Phase 3 questions correctly (M = 0.81, SD = 0.11). We also assessed participants' confidence in their answers to the Phase 3 critical image pair and the Phase 4 source question. The average confidence ratings are presented in *Table 13* as a function of the post-event information condition. Across the post-event information condition, participants, on average, were fairly confident when making the critical recognition decision in Phase 3, but only somewhat confident when answering the source question in Phase 4. There was a significant difference in reported confidence for Phase 3 ($F(2, 1689) = 3.088$, $p = 0.046$, $\eta_p^2 = 0.004$) such that reported confidence for the Phase 3 critical recognition question was significantly higher in the inconsistent condition (3.41) compared to those in the consistent condition (3.22) ($p = 0.052$). This is not consistent with *Experiment 1,* which found no significant differences in Phase 3 confidence. There was not a significant difference in reported confidence for Phase 4 ($F(2, 1689) = 1.687$, $p = 0.185$, $\eta_p^2 = 0.002$), which is consistent with the findings from *Experiment 1*.

Table 13

Average Confidence Rating for the Phase 3 Critical Question and Phase 4 Source Question

Post-Event Information	Phase 3	Phase 4
Consistent	3.22 (1.41)	2.21 (1.35)
Inconsistent	3.41 (1.39)	2.35 (1.39)
Neutral	3.26 (1.36)	2.23 (1.33)

Note. Confidence ratings range on a scale from 1 (Not at all Confident) to 5 (Extremely Confident). Standard deviations are in parentheses.

Parameter Estimation

After fitting the models to the data, we obtained the parameter point estimates (*Table 14*) for each model's best fit. Once the best-fit parameters were obtained, we entered these estimates into the equations for each model and got the overall fits of each model to the data.

Table 14

Parameter Estimates for the Best Fit of Each Model

	Parameters				
Model	*p*	*c*	*q*	*d*	*s*
No-Conflict	0.453	0.305	0.042	N/A	N/A
Coexistence	0.459	0.304	0.038	N/A	0.506
Destructive Updating	0.457	0.303	0.033	0.451	N/A

Note. N = 564 participants.

Table 15 (Data column) provides the proportion of responses for the Phase 3 and Phase 4 response outcomes for each of the three post-event information conditions. The Model column reflects the predictions from the best-fitting parameters for the No-Conflict model. Like *Experiment 1*, the fit of the model is excellent, which is apparent from comparing the values in the Data and Model columns. The corresponding fits for the destructive updating and coexistence models can be seen in *Table 5* and *Table 6* in the Appendix, respectively. Also, like in *Experiment 1*, the fits of the destructive updating and coexistence models are excellent. The close correspondence between each model and data are presented visually in *Figure 4*. The combined Phase 3 and Phase 4 performance is represented along the y-axis for each model, and the best-predicted values for each model are along the x-axis. The corresponding r values are very close to the diagonal (0.989, 0.991, and 0.991 for the no conflict, coexistence, and destructive updating models, respectively).

Figure 4

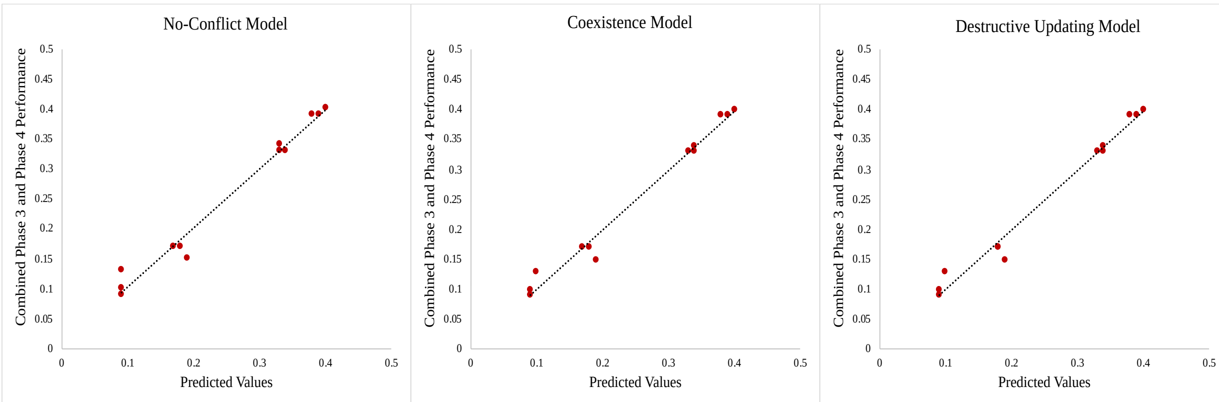


Table 15
Performance of Participants in Phases 3 and 4 for the Best-fitting No-Conflict Model

Post-Event Information	Phase 3	Phase 4	Data	Model
Consistent	+	+	.33	.34
	+	-	.40	.40
	-	+	.10	.09
	-	-	.17	.17
Inconsistent	+	+	.33	.33
	+	-	.39	.38
	-	+	.13	.09
	-	-	.15	.19
Neutral	+	+	.34	.33
	+	-	.39	.39
	-	+	.09	.09
	-	-	.17	.18

Note. The (+) signs represents answering the respective phase question correctly, whereas a (-) signs represents an incorrect answer.

Model Comparisons

In *Table 16*, we present the model selection criteria based on AIC and BIC values for the no-conflict, coexistence, and destructive updating models. According to the AIC and BIC values presented here, the findings are consistent with the findings from *Experiment 1* and Wagenaar and Boer (1987). When interpreting AIC (17.430) and BIC (33.731), the no-conflict model should be preferred over both the destructive updating and coexistence model, which again are indistinguishable from each other. As the obtained *wAIC* and *wBIC* can be interpreted as the probability that one model is the best-fitting model, the probability that the no-conflict model (the more parsimonious model) is the best-fitting model is 0.503 according to *wAIC*, and 0.939 according to *wBIC*. Therefore, the most parsimonious model (no-conflict model) should be preferred.

Table 16

AIC and BIC values for the No-Conflict, Coexistence, and Destructive Updating Models

Model	*df*	Δ*AIC*	*wAIC*	*AIC*	Δ*BIC*	*wBIC*	*BIC*
No-Conflict	6	0.000	**0.503**	**17.430**	0.000	**0.939**	**33.731**
Coexistence	5	0.997	0.305	18.427	6.341	0.038	40.162
Destructive Updating	5	1.929	0.192	19.359	7.363	0.024	41.094

Note. N = 564 participants.

Findings from *Experiment 1* suggest that the coexistence model cannot be ruled out, though, especially when examining the performance of the top-performing participants. Therefore, like in *Experiment 1*, we re-fit the data to the same subsets of top-performing and lower-performing participants. First, we removed the lowest performing participants and re-fit the data for those participants who answered at least one (out of three) of the recognition questions correctly from Phase 3 as well as one (out of three) of the source questions from Phase 4 (denoted as $P3_{1+}$ and $P4_{1+}$ performers). Of the 564 participants, 464 fit this classification. Because we are re-fitting a new subset of the data, we reexamined for the presence of the misinformation effect and still found that the inconsistent condition did not differ significantly from the consistent condition and the neutral condition ($\chi^2(2, N = 1392) = 0.464, p = 0.793$). The best-fitting parameter point estimates obtained for each of the three models are given in *Table 17*.

Table 17

Parameter Estimates for the Best Fit of Each Model to the $P3_{1+}$ and $P4_{1+}$ Performers

	Parameters				
Model	*p*	*c*	*q*	*d*	*s*
No-Conflict	0.493	0.477	0.053	N/A	N/A
Coexistence	0.505	0.475	0.056	N/A	0.585
Destructive Updating	0.497	0.476	0.040	0.458	N/A

Note. *N* = 464 participants.

In *Table 18*, we present the model selection criteria based on the AIC and BIC values for these $P3_{1+}$ and $P4_{1+}$ performers. According to the AIC and BIC values presented here, the findings are mixed. When interpreting AIC, there is evidence for the coexistence model (33.790). However, when interpreting BIC, the no-conflict model (50.924) should be preferred. Like *Experiment 1*, when excluding the low-performing participants, we have some evidence for the coexistence model. According to *wAIC*, the probability that the coexistence model is the best-fitting model is 0.594; according to *wBIC*, the probability that the no-conflict model is the best-fitting model is 0.850. These mixed findings are consistent with the findings of Wagenaar and Boer (1987): the more parsimonious no-conflict model should be preferred, given the mixed support for both the coexistence and no-conflict model. Nevertheless, these findings are partially consistent with what we found in *Experiment 1*; as we remove the lowest-performing participants, we gain support for the coexistence model.

Table 18

AIC and BIC Values for the No-Conflict, Coexistence, and Destructive Updating Models for the $P3_{1+}$ and $P4_{1+}$ Performers

Model	*df*	Δ*AIC*	*wAIC*	*AIC*	Δ*BIC*	*wBIC*	*BIC*
No-Conflict	6	1.419	0.292	35.209	0.000	**0.850**	**50.924**
Coexistence	5	0.000	**0.594**	**33.790**	3.820	0.126	54.744
Destructive Updating	5	3.299	0.114	37.089	7.119	0.024	58.043

Note. *N* = 464 participants.

We also re-fit another subset consisting of only the top-performing participants. Participants were included here if they answered at least two (out of three) of the recognition questions correctly from Phase 3 and two (out of three) of the source questions from Phase 4 (denoted as $P3_{2+}$ and $P4_{2+}$ performers). Of the 564 participants, 185 fit this classification. Again, we reexamined for the presence of the misinformation effect and still found that the inconsistent condition did not differ significantly from the consistent or neutral condition ($\chi^2(2, N = 555) = 1.695$, $p = 0.429$). The best-fitting parameter point estimates obtained for each of the three models are given in *Table 19.*

Table 19

Parameter Estimates for the Best Fit of Each Model to the $P3_{2+}$ and $P4_{2+}$ Performers

	Parameters				
Model	*p*	*c*	*q*	*d*	*s*
No-Conflict	0.693	0.732	0.157	N/A	N/A
Coexistence	0.728	0.721	0.125	N/A	0.635
Destructive Updating	0.707	0.724	0.103	0.410	N/A

Note. *N* = 185 participants.

In *Table 20*, we present the model selection criteria based on the AIC and BIC values for the $P3_{2+}$ and $P4_{2+}$ performers. Here, as in *Experiment 1*, we see strong support for the coexistence model. The lower AIC (47.787) and BIC (65.063) values indicate that the coexistence model provides a better fit than the no-conflict and destructive updating models. Moreover, the coexistence model now carried 97% and 81% (*wAIC and wBIC,* respectively) of the cumulative model weight. In other words, the coexistence model is 38.6 times more likely to be the best model than the no-conflict model and 96.5 times more likely to be the best model compared to the destructive updating model (Wagenmakers & Farrell, 2004).

Table 20

AIC and BIC Values for the No-Conflict, Coexistence, and Destructive Updating Models for the $P3_{2+}$ and $P4_{2+}$ Performers

Model	*df*	Δ*AIC*	*wAIC*	*AIC*	Δ*BIC*	*wBIC*	*BIC*
No-Conflict	6	7.313	0.025	55.099	2.994	0.181	68.056
Coexistence	5	0.000	**0.965**	**47.787**	0.000	**0.810**	**65.063**
Destructive Updating	5	9.115	0.010	56.902	9.115	0.008	74.178

Note. *N* = 185 participants.

Lastly, we re-fit the data for the remaining participants not included in the previous analysis. As in *Experiment 1*, this includes participants who fell in one of the following three response outcome categories: 1) a participant who answered zero or one (out of three) of the Phase 3 recognition questions correctly and two or three (out of three) of the source questions from Phase 4, 2) a participant who answered two or three (out of three) of the Phase 3 recognition questions correctly and zero or one (out of three) of the source questions from Phase 4, or 3) a participant who answered zero or one (out of three) of the Phase 3 recognition questions correctly and zero or one (out of three) of the source questions from Phase 4 (denoted as $P3_{0\text{-}3}$ or $P4_{0\text{-}3}$). 379 participants fit this classification. We reexamined for the presence of the misinformation effect and found that even for the participants who tended to be the lower performers (perhaps with relatively poorer memories), the inconsistent condition did not differ significantly from the consistent condition or the neutral condition ($\chi^2(2, N = 1137) = 0.389$, $p = 0.823$). The best-fitting parameter point estimates obtained for each of the three models are given in *Table 21*.

Table 21

Parameter Estimates for the Best Fit of Each Model to the $P3_{0\text{-}3}$ or $P4_{0\text{-}3}$ Performers

	Parameters				
Model	*p*	*c*	*q*	*d*	*s*
No-Conflict	0.336	0.016	0.035	N/A	N/A
Coexistence	0.337	0.017	0.030	N/A	0.463
Destructive Updating	0.338	0.016	0.029	0.473	N/A

Note. N = 379 participants.

In *Table 22*, we present the model selection criteria based on the AIC and BIC values for the $P3_{0\text{-}3}$ or $P4_{0\text{-}3}$ performers. After removing the top performers, we now see evidence supporting the no-conflict model. The lower AIC (17.515) and BIC (32.623) values indicate that the no-conflict model provides a better fit than the coexistence and destructive updating models. Moreover, the no-conflict model now carried 58% of the cumulative model weight according to *wAIC* and 94% according to *wBIC*. More specifically, the no-conflict model is 2.72 times more likely to be the best model than the coexistence model and the destructive updating model (Wagenmakers & Farrell, 2004).

Table 22
AIC and BIC Values for the No-Conflict, Coexistence, and Destructive Updating Models for the $P3_{0\text{-}3}$ or $P4_{0\text{-}3}$ Performers

Model	*df*	Δ*AIC*	*wAIC*	*AIC*	Δ*BIC*	*wBIC*	*BIC*
No-Conflict	6	0	**0.576**	**17.515**	0.000	**0.944**	**32.623**
Coexistence	5	2	0.212	19.515	7.036	0.028	39.660
Destructive Updating	5	2	0.212	19.515	7.036	0.028	39.660

Note. N = 379 participants.

Overall, the model-fitting results of *Experiment 2* match those of *Experiment 1*. In general, we have evidence for the no-conflict model when assessing all participants, but strong evidence for the coexistence model when assessing the top-performing participants. However, the misinformation effect did not replicate in *Experiment 2*. Given the unexpected lack of a misinformation effect, the following section includes assessing various data divisions to determine if the missing effect is merely being masked. We assess differences between 1) participants who participated from the University of Oklahoma versus Prolific.co, 2) the three stimulus scenarios, 3) just the first scenario presented to participants, and 4) the order of presentation of those scenarios. We conclude our analyses by comparing the differences among the sub-classifications of participants based on the responses to the Phase 5 follow-up questions to assess if there is a correspondence between participants' intuitions and model fits.

We compared the participants who completed the study for partial research credit (University of Oklahoma students) versus those who completed the study in exchange for financial compensation (Prolific.co). There was not a significant misinformation effect for those who participated from the University of Oklahoma ($\chi^2(2, N = 621) = 2.328$, $p = 0.312$) nor Prolific.co ($\chi^2(2, N = 1071) = .444$, $p = 0.801$). Additionally, we compared performance as a function of the different scenarios to determine if one scenario was responsible for the lack of a misinformation effect. However, there was not a significant misinformation effect when solely examining performance for the Errand Running scenario ($\chi^2(2, N = 564) = 1.498$, $p = 0.473$), the Baking scenario ($\chi^2(2, N = 564) = 2.970$, $p = 0.227$), or the Study Session scenario ($\chi^2(2, N = 564) = 1.532$, $p = 0.465$). We also compared performance as a function of the first scenario presented to participants and there was not a significant misinformation effect ($\chi^2(2, N = 564) = 3.074$, $p = 0.215$). We compared performance as a function of the order of presentation of the scenarios. There was not a significant misinformation effect for the participants who received the Errand Running scenario first ($\chi^2(2, N = 201) = 3.211$, $p = 0.201$), the Baking scenario first ($\chi^2(2, N = 199) = .446$, $p = 0.800$), or the Study Session scenario first ($\chi^2(2, N = 164) = 2.421$, $p = 0.298$). We also compared the performance of participants who fell below (and above) the median (0.83) memory performance in Phase 2 and, again, did not find a misinformation effect. Lastly, we examined potential differences between the participants who indicated in Phase 5 whether they were aware of the misinformation they were presented in Phase 2 (yes/no); again, we found no significant misinformation effect.

Phase 5 Participant Classifications

A main goal of *Experiment 2* was to determine if the models would match participants' perceptions about what happened to the original memory trace. Therefore, we divided participants' responses as a function of the response outcome from the Phase 5 questions. To reiterate, this question required participants to choose the response outcome that best described what they thought happened to their original memory (e.g., their memory for the traffic light). Based on the participants' response to this question, participants were categorized as endorsing no-conflict, coexistence, destructive updating, or none of the above. If participants were classified as endorsing no-conflict, they were further classified as remembering (No-Conflict (Remembered)), or not remembering (No-Conflict (Did Not Remember)), the critical information. This subclassification is necessary because the no-conflict hypothesis suggests that individuals are only misled if they forget or do not encode the original information. Those who encode the original information will not experience a conflict and can produce a correct response to the Phase 3 question. Only individuals who do not encode (or forget) the original information will rely on the inconsistent information to answer the Phase 3 question.

Out of 564 participants, 179 participants were categorized as No-Conflict (Remembered), and 126 were categorized as No-Conflict (Did Not Remember) (305 participants combined); 113 and 86 participants were categorized as Coexistence and Destructive Updating, respectively. 60 participants indicated that None of the above depicted how they felt their memories were impacted. We re-fit the models to each of these categorizations; those classified as No-Conflict (Remembered) and No-Conflict (Did Not Remember) were fit separately, as well as those two categories Combined. We also checked for the presence of the misinformation effect for each categorization.

We found that in the No-Conflict (Remembered) group, there was not a misinformation effect; in fact, the inconsistent condition actually did significantly better than the consistent and neutral condition ($\chi^2(2, N = 537) = 27.702$, $p < 0.001$, $V = 0.227$). Additionally, there was no misinformation effect for those in the No-Conflict (Did Not Remember) ($\chi^2(2, N = 378) = 4.531$, $p = 0.104$) and Combined ($\chi^2(2, N = 915) = 4.736$, $p < 0.094$) groups. The best-fitting parameter point estimates obtained for each of the three models for each of these three categorizations are in *Table 7* in the *Appendix.*

In *Table 23*, we present the model selection criteria based on the AIC and BIC values for each of these three categorizations. For each categorization, we have strong support for the no-conflict model, as indicated by lower AIC and BIC values. This suggests that, at least for those categorized as endorsing the no-conflict option, the no-conflict model best fits their data.

Table 23
AIC and BIC Values for the No-Conflict, Coexistence, and Destructive Updating Models for the No-Conflict (Remembered, Did Not Remember) and Combined Categorization Groups

Model by Categorization	*df*	Δ*AIC*	*wAIC*	*AIC*	Δ*BIC*	*wBIC*	*BIC*
No-Conflict (Remembered)							
No-Conflict	6	0	**0.576**	**50.675**	0.000	**0.921**	**63.533**
Coexistence	5	2	0.212	52.675	6.286	0.040	69.819
Destructive Updating	5	2	0.212	52.675	6.286	0.040	69.819
No-Conflict (Did Not Remember)							
No-Conflict	6	0.000	**0.445**	**8.803**	0.000	**0.851**	**20.607**
Coexistence	5	0.896	0.284	9.698	4.831	0.076	25.438
Destructive Updating	5	0.988	0.271	9.791	4.923	0.073	25.530
Combined							
No-Conflict	6	0	**0.576**	**19.408**	0.000	**0.938**	**33.865**
Coexistence	5	2	0.212	21.408	6.819	0.031	40.684
Destructive Updating	5	2	0.212	21.408	6.819	0.031	40.684

Additionally, we re-fit the data of those who were classified as Coexistence, Destructive Updating, and None of the Above, and reexamined for the presence of the misinformation effect. For the first time in *Experiment 2*, we now find a significant misinformation effect for both the Coexistence ($\chi^2(2, N = 339) = 8.303$, $p = 0.016$, $V = 0.156$) and Destructive Updating categorizations ($\chi^2(2, N = 258) = 7.008$, $p = 0.030$, $V = 0.165$). For the Coexistence categorization, the inconsistent group did worse than the consistent group, whereas, for the Destructive Updating categorization, the inconsistent group did worse than the neutral group. There was not a misinformation e`ffect for the None of the Above categorization ($\chi^2(2, N = 180)$

= 1.882, p = 0.390). The best-fitting parameter point estimates obtained for each of the three models for each of these three categorizations are in *Table 8* in the *Appendix.*

In *Table 24*, we present the model selection criteria based on the AIC and BIC values for each of these three categorizations. Of interest for the Coexistence classification and the Destructive Updating classification is the extent to which the coexistence and destructive updating models, respectively, are the best-fitting models. However, this was not the case for either classification. For the Coexistence classification, we have support for the coexistence and the no-conflict models, as indicated by a lower AIC (11.504) for the coexistence model and a lower BIC (23.734) value for the no-conflict model. For the Destructive Updating classification, we again have support for the coexistence and no-conflict models, such that the lowest AIC value (18.675) is associated with the coexistence model, whereas the lowest BIC value (32.095) is associated with the no-conflict model. These findings suggest that there is not a correspondence between participants' intuitions and model fits for the Coexistence and Destructive Updating classifications. For the None of the Above classification, there is strong support for the no-conflict model, though it is important to reiterate that there were only 60 participants who fit this description, which is a small sample size and likely insufficient for robust parameter estimation.

Table 24
AIC and BIC Values for the No-Conflict, Coexistence, and Destructive Updating Models for the Coexistence, Destructive Updating, and None of the Above Categorization Groups

Model by Categorization	*df*	Δ*AIC*	*wAIC*	*AIC*	Δ*BIC*	*wBIC*	*BIC*
Coexistence							
No-Conflict	6	0.752	0.325	12.256	0.000	**0.765**	**23.734**
Coexistence	5	0.000	**0.473**	**11.504**	3.074	0.165	26.808
Destructive Updating	5	1.707	0.202	13.210	4.780	0.070	28.514
Destructive Updating							
No-Conflict	6	2.761	0.166	21.436	0.000	**0.541**	**32.095**
Coexistence	5	0.000	**0.661**	**18.675**	0.792	0.364	32.887
Destructive Updating	5	2.676	0.173	21.351	3.468	0.095	35.563
None of the Above							
No-Conflict	6	0	**0.576**	**9.202**	0.000	**0.870**	**18.781**
Coexistence	5	2	0.212	11.202	5.193	0.065	23.974
Destructive Updating	5	2	0.212	11.202	5.193	0.065	23.974

Discussion

Contrary to our findings from *Experiment 1,* we did not find an overall misinformation effect. However, we do see directional differences in the parameter estimates for the best fit of each model from *Experiment 1* (*Table 3*) to *Experiment 2* (*Table 14*), such that the values of *c* in *Experiment 2*, increased to 0.305, 0.304, and 0.303 for no-conflict, coexistence, and destructive updating, respectively, from 0.251, 0.245, and 0.244 (in *Experiment 1*). Contrarily, the values of *q* in *Experiment 1* of 0.174, 0.135, and 0.134 for no-conflict, coexistence, and destructive updating, respectively, decreased to 0.042, 0.038, and 0.033 in *Experiment 2*. Parameter *c* reflects the proportion of participants who encoded the source of the relevant information (traffic light color/amount of sugar/laptop color), and parameter *q* represents the proportion of participants who encoded the inconsistent information (stop sign/coffee mug/iPad). Therefore, even though we did not empirically induce a misinformation effect, the parameters in the memory-updating models implemented here move in a manner consistent with an expected impact of misinformation. Specifically, these changes in parameter values signal an impact of the misinformation such that higher values of *q* are indicative of a greater endorsement of misleading information, as supported by a misinformation effect in *Experiment* 1. Whereas higher values of *c* are indicative of better source encoding, which would subsequently reduce encoding of the misinformation, thereby decreasing the likelihood of a misinformation effect. Future research should explore a more general relationship between an increase in *c*, a reduction in parameter *q*, and the absence of a misinformation effect. However, interestingly, participants classified as Coexistence and Destructive Updating did show a significant misinformation effect, suggesting that participants who acknowledge a conflict are, in fact, affected by the conflicting information.

Experiment 2 assessed the predictions of the three memory-updating hypotheses and assessed how well these models capture participants' perceptions of their memory. When assessing all participants, we gained some evidence supporting both the no-conflict and coexistence models, which is consistent with our findings from *Experiment 1* when all participants were considered. However, due to the no-conflict model being the most parsimonious, and all three models fitting the data exceptionally well, we (like Wagenaar & Boer, 1987) defaulted to the no-conflict model. However, when only the top-performing participants ($P3_{2+}$ and $P4_{2+}$) are included, we again found very strong evidence for the coexistence model, which suggests that the coexistence model, in some circumstances, provides the best explanation for how individuals account for misinformation and how they update their memory.

Lastly, we found some evidence to support a correspondence between participants' perceptions of what happens to their memories, and subsequent model fits. First, the no-conflict model did provide the best fit to the data of participants who were categorized as endorsing no-conflict. However, that might be because that model is the most parsimonious rather than because it was in close correspondence with what these participants did. There was only some evidence for the coexistence model (lowest AIC value) best fitting the data of participants endorsing coexistence. However, those endorsing destructive updating were best fit by both the no-conflict and coexistence models.

General Discussion

In this section, we begin by presenting our misinformation effect findings and the subsequent exploration of the effect. We include some possible explanations for why we did not replicate the effect in *Experiment 2*. Next, we discuss the modeling results and how participant ability seems to play a contributing factor in endorsing misinformation. We also discuss the extent to which these models correspond with participants' initiations of their memory. We conclude this section with a discussion of the experiments' limitations, followed by the proposal of future research ideas.

We did not find an overall misinformation effect in *Experiment 2,* despite overall memory performance in Phase 3 and Phase 4 being comparable between the two experiments. Previous research has shown that memory can be improved for highly rewarded items compared to low-reward items (cash versus course credit) as a function of increased motivation to perform (Bowen & Kensinger, 2017). So, it is possible that the financial incentive that was provided to the participants who completed the study via Prolific.co could have increased the participants' motivation to perform well and served to limit the typical impairment induced by the presentation of inconsistent information. However, we assessed for the misinformation effect in both the paid and the non-paid participant samples and did not find the effect in either.

We also examined multiple other data breakdowns in an effort to find a misinformation effect that may have been masked. For example, we grouped participants based on the type of post-event information (consistent, inconsistent, or neutral) they received first, the scenario they were presented with first, and the order of presentation of those scenarios, but all breakdowns failed to yield a significant misinformation effect.

We also looked for the misinformation effect as a function of the Phase 5 classifications and found that participants classified as Coexistence and Destructive Updating did show a significant misinformation effect. This suggests that participants who recognized a conflict were, in fact, affected by the conflicting information. Previous research has shown that metamemorial processes are relevant to the misinformation effect (Bulevich & Thomas, 2012). When known details are recollected, participants often acknowledge that the event was actually encountered. However, when a memory search fails, they use alternatives like plausibility, familiarity, or accessibility to establish what they experienced (Reder et al., 1986; Thomas et al., 2010). Consequently, when it comes to the misinformation effect, participants may report the misleading information because it is more easily accessible (Thomas et al., 2010). So, under the coexistence and destructive updating hypothesis, the misleading information obstructs access to the original memory, and therefore, participants are left relying on the misleading information. It is important to replicate this finding, though. And future research should continue to target participants that acknowledge (or do not) the conflict. This type of research could help explain why, or why not, a misinformation effect is found. A possible manipulation that could be used to make participants more (versus less) aware of a conflict would be to increase the retention interval or implement a forced confabulation paradigm (Ackil & Zaragoza, 1998). The forced confabulation paradigm instantiates an event that requires participants to confabulate an answer to a question that they do not know the answer to, subsequently creating an event that will likely stand out to participants and serve as a later reminder of the conflicting information to the original event.

Previous research has shown that there are individual differences in recall strategy (tendency towards primacy or recency effects) (Unsworth et al., 2011). So, it is possible that how individuals handle the presentation of misinformation could vary, which could impact the extent to which these memory-updating hypotheses capture memory differences. Additionally, research investigating individual differences in susceptibility to the misinformation effect found that working memory capacity was negatively correlated with the misinformation effect, such that participants with higher working memory capacity were less likely to show a misinformation effect (Calvillo, 2014). Here, participants were tasked with monitoring the sources of two stimuli (vignette and written text). These findings suggest that the susceptibility to the misinformation effect may be higher in participants who have difficulty monitoring sources of information. More specifically, it is well acknowledged that recognition memory involves both familiarity and recollection (Yonelinas, 2002). Familiarity reflects an overall measure of memory strength (or stimulus recency) and requires little to no memory capacity. In contrast, recollection, which is considered more effortful, suggests the retrieval of qualitative information about a past event (Yonelinas et al., 2010). Therefore, participants more susceptible to misinformation—those with lower working memory capacity—might be more likely to rely on familiarity than recollection, or less likely to call upon recollection when they need it.

Our study requires participants to monitor the source of two externally-generated stimuli: traffic light and stop sign, measuring cup of sugar and coffee mug, or laptop and iPad. And, in *Experiment 2*, we did not find a misinformation effect other than amongst the participants who acknowledged a conflict (Coexistence and Destructive Updating participants). Therefore, participants may have been able to monitor the sources of information to a greater extent by relying more on recollection and less on familiarity, which subsequently improved their ability to answer the critical Phase 3 question. This is a possibility because the misinformation-affected participants acknowledged the conflict but were still negatively impacted by it, so it's possible that we had more participants in *Experiment 2* than in *Experiment 1* who acknowledged the conflict but were subsequently able to handle it. Though the misinformation effect was not present for the participants, whether paid (N = 357) or not (N = 207), it is still possible that motivation to perform played a contributing factor because these participants could have been trying harder to pay attention to all the details of the scenarios, which subsequently led them relying more on recollection processes than familiarity in *Experiment 2*. And because so many more participants were paid, this could have contributed to negating a traditional misinformation effect.

Future research should examine the extent to which individuals report misleading information as a function of being given the choice to withhold a response. The Quantity-Accuracy Profile (QAP) methodology (Koriat & Goldsmith, 1996) assesses the extent to which memory retention disruption, monitoring, and control deficits contribute to the susceptibility of misinformation. The QAP assumes that monitoring will impact control. Therefore, when participants are given the option, they will withhold answers coupled with low confidence (Goldsmith & Koriat, 2008). Examining the confidence-accuracy relationship within this context will continue to elucidate mechanisms responsible for the endorsement of misinformation and, subsequently, how these models can capture these differences. This is especially relevant, considering that within an eyewitness context, under the right circumstances, there is a strong relationship between confidence and accuracy (Gronlund & Benjamin, 2018).

Across both experiments, we have provided the first evidence that both no-conflict and coexistence models of memory updating can account for the endorsement of misinformation. The coexistence (and destructive updating) model assumes a conflict between two memory traces, while the no-conflict model does not. When assessing all participants, we gained some evidence supporting both the no-conflict and coexistence models, but due to model parsimony, and all three models fitting the overall data exceptionally well, we (like Wagenaar & Boer, 1987) default to the no-conflict model when the entirety of our samples are considered. But interestingly, when only the top-performing participants are assessed, we find, in both experiments, very strong evidence for the coexistence model. This suggests that participants update their memories in different ways, possibly as a function of memory ability.

Differences in memory ability could impact the strategy implemented by participants to account for misinformation. For example, someone with lower memory capabilities may display memory outcomes more consistent with destructive updating processes compared to someone with a higher memory ability, such that someone with lower working memory capacity would likely have fewer resources available for utilizing the source information. Future research is needed to evaluate this idea, but future studies could apply these models in the same way but with participants of low- and high-level memory capability. Or researchers could implement a dual-task manipulation to induce a difference. For example, participants could engage in the same paradigm implemented here, while also having to monitor for three odd digits in a row over headphones (or not) (Jones & Jacoby, 2001). This type of manipulation can be used to alter participants' memory capacity for remembering relevant information, which may have subsequent consequences on their memory ability.

One of my most interesting findings involves the first evidence supporting the coexistence model. This model proposes that the original memory persists but is rendered inaccessible because of inhibition (or suppression). According to Radvansky (1999), suppression is the mechanism that reduces the activation of a mental representation, whereas inhibition is the action and result of reducing activation. Suppression is considered an attentional mechanism where the involved cognitive process must identify previously encountered information among interfering distractors. One part of the process is activating a memory representation, whereas another part involves the active inhibition of related sources of inconsistent information. Suppression keeps inconsistent representations from entering a state of active cognitive processing so that errors can be reduced. According to the coexistence hypothesis, misleading information inhibits the original memory of the event but does not destroy it (Christiansen & Ochalek, 1983), thereby maintaining the existence of both memory traces. We especially see coexistence supported for the top-performing participants, suggesting that they are potentially better equipped to inhibit the intrusion of inconsistent information compared to other participants.

We show some correspondence between participant classification and model fit among the participants classified as No-Conflict, but only minimal evidence that the coexistence model corresponds with participants classified as Coexistence. For participants classified as Coexistence, both the no-conflict and coexistence models fit the data well, so we default to the no-conflict model. To reiterate, these models are not very distinguishable from each other, so this might explain why we do not see much correspondence between participant classifications and model fit. We also did not find correspondence among those classified as Destructive Updating. Previous research investigating participants' metacognitive awareness of the consequences of exposure to misinformation shows that participants are generally unaware of their susceptibility to inaccurate information (Salovich & Rapp, 2021: Experiment 1). Therefore, it is possible that participants classified as Coexistence and Destructive Updating were not as attuned to how their memories were impacted by the misleading information. For example, given that the destructive updating hypothesis suggests that the original memory trace is rendered inaccessible because it has been destroyed, full destruction of an original memory trace could be indicative of poorer memory ability in general, such that participants were unable to successfully monitor sources of information and subsequently identify accurate information. To reiterate, though, only 86 participants could be classified as Destructive Updating, so to get a fuller picture, implementing studies that increase the number of participants who acknowledge destructive updating or coexistence is important. This could be done by increasing the retention interval between Phase 2 and Phase 3, which would make it more difficult for a participant to determine which information they were actually presented in Phase 1. This might induce more of a feeling of the original memory being "destroyed." Additionally, more follow-up questions should be added to further tap into participants' metacognitive awareness of misinformation. Perhaps the questions used in Phase 5 were not comprehensive enough to tap into participants' metacognitive awareness of misinformation. Thus, with more fine-tuned questions, the models may show a correspondence between model fit and participant classification.

Limitations

A lack of ecological validity for these experiments is important to acknowledge. Memory can be impacted by multiple external factors, and the present set of experiments occurred in a controlled online setting. Furthermore, though we had a wider range of demographics than most studies of the misinformation effect, our experiments were still highly controlled and artificial in nature, even though a strength of our study is that we included additional (three) scenarios. However, the scenarios were all structured the same and depicted stories that likely were not deemed relevant to participants. This is why it is important to implement these models within a more ecologically-relevant context. For example, a factor that can differentially impact memory, particularly false memory, and is relevant within an eyewitness setting, is stress. Stress can negatively impact memory (Christianson, 1992), and in an eyewitness context, events are likely to be stress-inducing or emotionally charged. Interestingly, a study (Zoladz et al., 2017) investigating pre-learning stress effects found a robust misinformation effect that was not influenced by stress; however, the misinformation effect disappeared completely in participants who were stressed but exhibited a blunted cortisol response (e.g., Non-responders: Significantly more stressed than those who were not in the stress condition but showed a cortisol increase of less than 2.5 nmol/1 in response to the stressor: cold pressor test)). Not only does this study exemplify differences in stress effects on memory, but it also provides support that individual differences and different subsets of participants may or may not exhibit a misinformation effect. Though stress effects were not examined in our study, this finding involving non-responders is consistent with what we found in *Experiment 2*.

Also, there was a relatively short delay between Phase 2 and Phase 3, which can make it difficult to capture potential changes in memory. Given our short delays, this could also explain the small misinformation effect in *Experiment 1* (effect size = 0.108) and no effect in *Experiment 2*. However, this effect size does fall within the range (0.007 to 0.350) of effect sizes found in other misinformation effect studies (Patihis & Loftus, 2016; Riesthuis, 2022). Extending the delays between Phases 2, 3, and 4 would be of great practical relevance, especially when trying to expand on the instantiations of these memory-updating hypotheses.

Future Research

There are various other factors that could impact an individual's susceptibility to endorsing misinformation; therefore, it is important to consider how these models can capture different experimental manipulations. Future research should investigate the extent to which viewer perspective impacts one's susceptibility to endorsing misinformation. Researchers could manipulate the perspective from which participants are directed to focus on different aspects of the scenario. Ecker et al. (2011) found that when participants made inferences about a sequence of events (cause of a fire), they relied on misinformation (initial suspicion of arson that was subsequently corrected), even when they correctly remembered that the misinformation was retracted. Previous research indicates that outdated or retracted information persists in one's memory despite retractions or attempts to update it (Ayers & Reder, 1998). Misinformation is often repeated when it is retracted, which can inadvertently enhance its impact and could serve as an iterative reminder of the misinformation (Hintzman, 2010; Schwarz et al., 2007). Therefore, given that the coexistence model posits that the original memory persists, but misleading information inhibits it (but does not destroy it), and the no-conflict model posits that individuals are only misled if they forget (or do not encode) the original information, a perspective change can be used to induce these types of memory updating to assess the extent that the subsequent modeling analyses can capture these differences.

Additionally, a study conducted by Loftus (1977b), found that after participants witnessed a car accident involving a green car, and were subsequently provided with erroneous information that the car was blue, adjusted their color selections on a color wheel toward the false information during a color recognition test, deviating from the actual color they had seen. In another study by Loftus (1977a), when participants saw a yellow book but were questioned about a blue book, they incorrectly chose the misleading color as their first choice, and then for a second choice, tended to choose the color green, which is the blending of the colors yellow and blue. This result suggested that individuals' memories blend prior knowledge and information acquired after the initial learning scenario. Though we did not find support for destructive updating, a manipulation may be more likely to induce destructive updating. Then we could examine the extent to which the destructive updating model provides the best fit in this circumstance.

It is clear that memory does not operate within a vacuum. Memories can be altered, forgotten until adequately prompted, or completely lost, and it is these nuances that make it crucial to examine how changes in memory can have real-world consequences. The aims of *Experiments 1* and *2* were to evaluate the predictions of three parameterized memory-updating models, and in doing so, these experiments provided us with a more comprehensive understanding of the accuracy of these hypotheses. By utilizing multinomial processing tree models, we have provided evidence that both the no-conflict and coexistence models account for participants' susceptibility to misinformation. We also provide some evidence that the no-conflict model matches participants' perceptions of their memory, but that participants' memory ability is a key factor that cannot be ignored. Additionally, these findings promote the continued use of modeling to assess the mechanisms of memory. False memory formation is crucial to understand within an eyewitness memory framework. It is the incorporation of false information into memory that can contribute to innocent individuals being falsely convicted for crimes.

Therefore, by precisely assessing the effects of misleading post-event information, we can gain a more definitive understanding of the underlying mechanisms responsible for memory updating.

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Appendix

Table 1 Pilot Study Results

Post-Event Information	Phase 3	Phase 4
Inconsistent	0.70	0.63

Note. Proportion answered correctly in Phase 3 and Phase 4.

Table 2
Proportion of participants who answered correctly in Phase 3 and Phase 4 as a function of scenario.

Scenario	Phase 3	Phase 4
Baking	0.82 (369)	0.39 (177)
Traffic	0.71 (321)	0.46 (209)
Study	0.65 (293)	0.38 (170)

Note. Experiment 1. In parentheses is the number of participants who answered correctly (*N* = 450).

Table 3
Performance of participants in Phases 3 and 4, according to the data and best-fitting solution for the destructive updating model.

Post-Event Information	Phase 3	Phase 4	Data	Model
Consistent	+	+	.32	.34
	+	-	.44	.44
	-	+	.09	.08
	-	-	.15	.15
Inconsistent	+	+	.27	.29
	+	-	.39	.37
	-	+	.12	.11
	-	-	.22	.22
Neutral	+	+	.36	.32
	+	-	.40	.42
	-	+	.07	.09
	-	-	.17	.17

Note. Experiment 1

Table 4

Performance of participants in Phases 3 and 4, according to the data and best-fitting solution for the coexistence model.

Post-Event Information	Phase 3	Phase 4	Data	Model
Consistent	+	+	.32	.34
	+	-	.44	.44
	-	+	.09	.07
	-	-	.15	.15
Inconsistent	+	+	.27	.29
	+	-	.39	.37
	-	+	.12	.12
	-	-	.22	.22
Neutral	+	+	.36	.33
	+	-	.40	.42
	-	+	.07	.09
	-	-	.17	.17

Note. Experiment 1

Table 5

Performance of participants in Phases 3 and 4, according to the data and best-fitting solution for the destructive updating model.

Post-Event Information	Phase 3	Phase 4	Data	Model
Consistent	+	+	.33	.34
	+	-	.40	.40
	-	+	.10	.09
	-	-	.17	.18
Inconsistent	+	+	.33	.33
	+	-	.39	.38
	-	+	.13	.10
	-	-	.15	.19
Neutral	+	+	.34	.34
	+	-	.39	.39
	-	+	.09	.09
	-	-	.17	.18

Note. Experiment 2

Table 6

Performance of participants in Phases 3 and 4, according to the data and best-fitting solution for the coexistence model.

Post-Event Information	Phase 3	Phase 4	Data	Model
Consistent	+	+	.33	.34
	+	-	.40	.40
	-	+	.10	.09
	-	-	.17	.17
Inconsistent	+	+	.33	.33
	+	-	.39	.38
	-	+	.13	.10
	-	-	.15	.19
Neutral	+	+	.34	.34
	+	-	.39	.39
	-	+	.09	.09
	-	-	.17	.18

Note. Experiment 2

Table 7

Parameter Estimates for the Best Fit of Each Model to the No-Conflict (Remembered, Did Not Remember) and Combined Categorization Groups

	Parameters				
Model by Categorization	*p*	*c*	*q*	*d*	*s*
No-Conflict (Remembered)					
No-Conflict	0.640	0.266	0.022	N/A	N/A
Coexistence	0.639	0.265	0.014	N/A	0.399
Destructive Updating	0.640	0.265	0.014	0.404	N/A
No-Conflict (Did Not Remember)					
No-Conflict	0.377	0.286	0.163	N/A	N/A
Coexistence	0.393	0.280	0.138	N/A	0.514
Destructive Updating	0.391	0.281	0.136	0.511	N/A
Combined					
No-Conflict	0.532	0.271	0.027	N/A	N/A
Coexistence	0.534	0.271	0.019	N/A	0.432
Destructive Updating	0.534	0.271	0.019	0.427	N/A

Table 8
Parameter Estimates for the Best Fit of Each Model to the Coexistence, Destructive Updating, and None of the Above Categorization Groups

	Parameters				
Model by Categorization	*p*	*c*	*q*	*d*	*s*
Coexistence					
No-Conflict	0.347	0.373	0.233	N/A	N/A
Coexistence	0.384	0.359	0.210	N/A	0.585
Destructive Updating	0.375	0.355	0.206	0.511	N/A
Destructive Updating					
No-Conflict	0.362	0.518	0.151	N/A	N/A
Coexistence	0.394	0.515	0.170	N/A	0.644
Destructive Updating	0.383	0.513	0.152	0.556	N/A
None of the Above					
No-Conflict	0.345	0.185	0.082	N/A	N/A
Coexistence	0.345	0.194	0.066	N/A	0.466
Destructive Updating	0.347	0.187	0.067	0.447	N/A

Figure 1. Coexistence Model

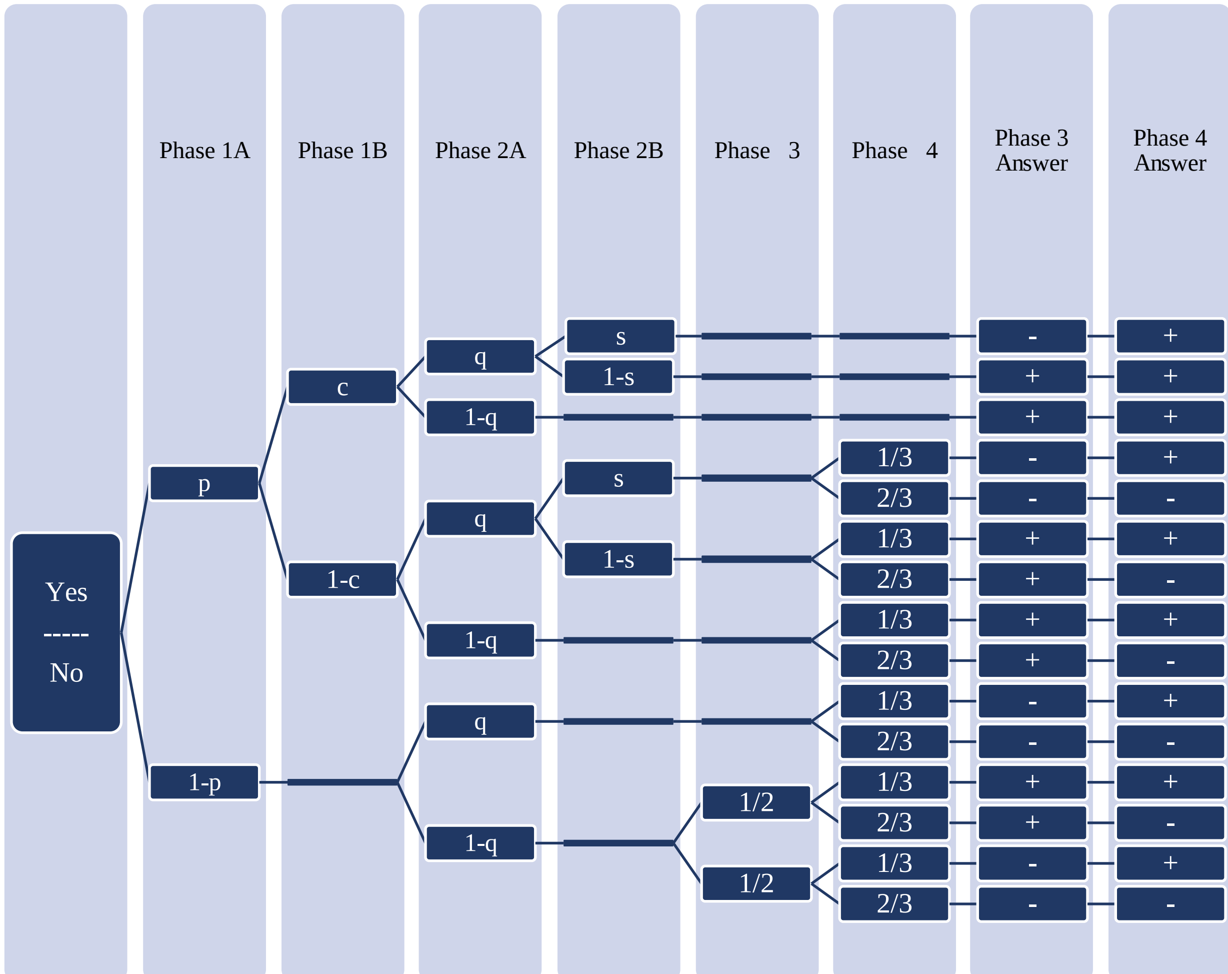
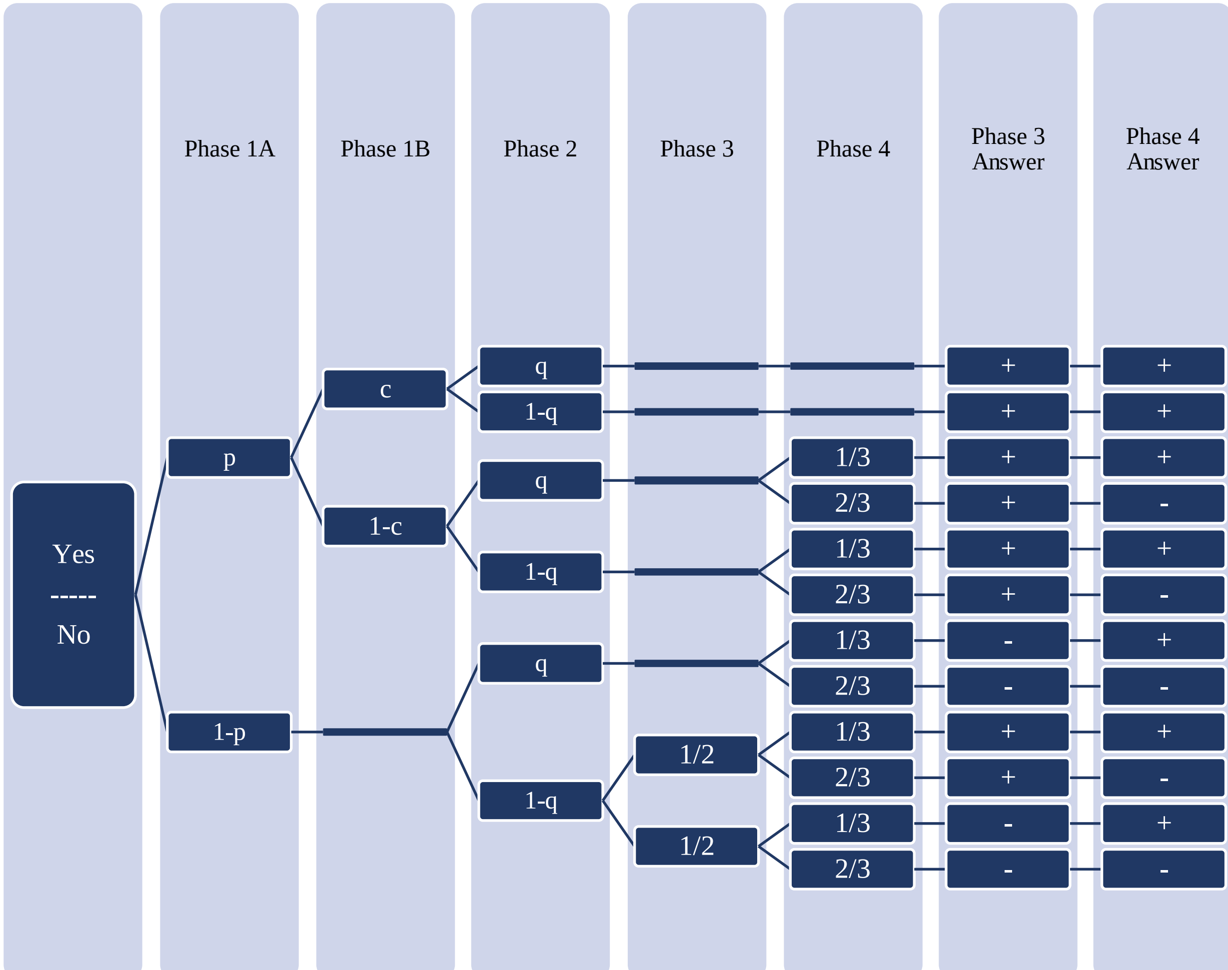


Figure 2. No-Conflict Model



Stimulus Scenario Questions

1. Errand Running Scenario Questions
   a. Phase 2: 8 Questions
      1. No – Did Max have to arrive at his game 2 hours before it started?
      2. Yes – Was Amelia's first stop 11 miles away from the gym?
      3. No – Did Amelia need to buy paper towels from the store?
      4. Yes – Was Amelia's total cost at the store $16.05?
      5. No – Critical question – Did a pedestrian cross the street when the car, after leaving the gas station, arrived at the stop sign, traffic light or intersection?
      6. Yes – Was Amelia 8 miles away from the gym when Max called?
      7. No – Did Amelia walk over to Court B after buying her ticket?
      8. No – Was this Max's third game of the weekend?

   b. Phase 3: 16-item Recognition Test
      1. Amelia decided to stop at the store closest to the gym first / Amelia decided to stop at the store farthest from the gym first
      2. Max had to be at the gym 2 hours before his game started / Max had to be at the gym 1.5 hours before the game started
      3. Amelia's first stop was 16 miles away from the gym / Amelia's first stop was 11 miles away from the gym
      4. Amelia did drive five miles farther to go to a grocery store / Amelia did not drive five miles farther to go to a grocery store
      5. Picture
      6. Amelia spent 15 minutes shopping / Amelia spent 20 minutes shopping
      7. Amelia did buy paper towels / Amelia did not buy paper towels
      8. Amelia had to wait in the checkout line behind 3 people / Amelia had to wait in the checkout line behind 4 people
      9. Picture
      10. Amelia had to make a U-turn to get to the gas station / Amelia did not have to make a U-turn to get to the gas station
      11. Max calls her mom while she is pumping gas / Max calls his mom after she finishes pumping gas
      12. Max calls his mom, saying he forgot one of his ankle braces / Max calls his mom, saying he forgot one of his shoes
      13. Picture Critical Image Pair
      14. Amelia had to pay to park / Amelia did not have to pay to park
      15. Amelia arrived at the gym about 45 minutes before the game should start / Amelia arrived at the gym about 30 minutes before the game should start
      16. Picture

   c. Phase 4: 1. What was the light color of the traffic light?

2. Baking Scenario Questions
   a. Phase 2: 8 Questions
      1. No - Was Jackie told how many cupcakes she should make?
      2. Yes - Did Jackie preheat the oven to 350 degrees?
      3. No - Did Jackie play music on her phone?
      4. Yes - Did Jackie mix the dry ingredients before the wet ingredients?
      5. No - Critical Question - Did you see the hand towel next to the measuring cup of sugar, the coffee mug or the ingredients?
      6. Yes - Did it take Jackie 4 minutes to mix all of the cupcake batter together?
      7. No - Did the cupcakes bake for a total of 15 minutes?
      8. No - Did Jackie use the red sprinkles?

   b. Phase 3: 16-item Recognition Test
      1. Jackie made cupcakes for a birthday party / Jackie made cupcakes for a work luncheon
      2. Jackie was told how many cupcakes to make / Jackie was not told how many cupcakes to make
      3. Jackie decided to set out the butter at room temperature / Jackie decided to not set out the butter at room temperature
      4. Jackie played classical music while baking / Jackie played country music while baking
      5. Picture 1
      6. Jackie decided to use an old baking recipe book / Jackie decided to use a new baking book recipe book
      7. Jackie preheated the oven to 350 degrees / Jackie preheated the oven to 450 degrees
      8. Jackie used the hand whisk for the dry ingredients / Jackie did not use the hand whisk for the dry ingredients
      9. Picture 2
      10. Jackie used 3 cups of flour / Jackie used 2 cups of flour
      11. Jackie sifted the flour / Jackie did not sift the flour
      12. Jackie used 3 tablespoons of butter / Jackie used 2 tablespoons of butter
      13. Picture 3 Critical Test Item
      14. Jackie did not spray the cupcake pan with oil / Jackie did spray the cupcake can with oil
      15. Jackie used vanilla icing / Jackie used chocolate icing
      16. Picture 4

   c. Phase 4: 1. How much sugar was in the measuring cup?

3. Study Session Scenario Questions
    a. Phase 2: 8 Questions
        1. Yes – Does Alex need to write a 12-page research paper for her class?
        2. No – Did Alex's professor tell the class what the topic of their research paper should be?
        3. No – Did Jordan and Alex go on their 6-mile hike?
        4. Yes – Does Jordan and Alex discuss when they plan to take communications?
        5. No - Critical question – Did you see the bookbag next to the iPad, laptop, or device on the living room table?
        6. Yes – Do they have to solve four problems by hand during the exam?
        7. No – Does Alex order a muffin before they leave the café?
        8. No – Is their exam worth 50% of their final grade?

    b. Phase 3: 16-item Recognition Test
        1. Alex's research paper is for her economy class / Alex's research paper is for her history class
        2. Alex decided to write her paper on the economies of different countries / Alex decided to write her paper on the predicted status of the economy six months from now
        3. Alex works at her desk most of the morning / Alex works on her couch most of the morning
        4. Alex plans to write 2 pages before Jordan arrives / Alex plans to write 3 pages before Jordan arrives
        5. Picture
        6. Jordan calls Alex to discuss lunch plans / Jordan texts Alex to discuss lunch plans
        7. The pizza is delivered to the apartment / The pizza is picked up by Jordan
        8. Jordan and her boyfriend went to a festival over the weekend / Jordan and her boyfriend went to the movies over the weekend
        9. Picture
        10. Alex plays an episode of Friends on her TV / Alex plays an episode of The Office on her TV
        11. Jordan has to prioritize scheduling when to take biology / Jordan has to prioritize scheduling when to take accounting
        12. Alex and Jordan study in the living room / Alex and Jordan study in Alex's home office
        13. Picture 3 Critical Test Item
        14. Jordan misses a few classes because of traveling for volleyball matches / Jordan misses a few classes because of traveling for soccer matches
        15. They must familiarize themselves with 42 different definitions / They must familiarize themselves with 32 different definitions
        16. Picture

    c. Phase 4: 1. What color was the laptop case?

Experiment 2 Follow-Up Questions as a Function of Scenario

A. Baking Scenario
   1. When viewing this story, you actually saw a measuring cup of sugar. However, later, you were misleadingly asked about a coffee mug. Did you notice this? (Yes/No)
   2. Which of the following best describes your experience when you saw the side-by-side images of the measuring cup of sugar and the coffee mug and had to determine which image you saw during the presentation of the story?
      a. Your memory of the measuring cup of sugar seemed replaced by the misleading coffee mug information.
      b. Your memory of the measuring cup of sugar seemed replaced by the misleading coffee mug information until you were asked about the amount of sugar in the measuring cup later on in the study.
      c. You remembered seeing the measuring cup of sugar during the presentation of the story, and you were able to correctly choose the measuring cup of sugar later on in the study.
      d. You did not remember, or you forgot that you saw the measuring cup of sugar, and because you were questioned about a coffee mug, you answered coffee mug.
      e. None of the above
   3. When answering the question about the amount of sugar in the measuring cup, did you still think that you saw a coffee mug? (Yes/No)
      a. Please explain in as much detail as possible____________________________

B. Errand Running Scenario
   1. When viewing this story, you actually saw a traffic light. However, later, you were misleadingly asked about a stop sign. Did you notice this? (Yes/No)
   2. Which of the following best describes your experience when you saw the side-by-side images of the traffic light and the stop sign and had to determine which image you saw during the presentation of the story?
      a. Your memory of the traffic light seemed replaced by the misleading stop sign information.
      b. Your memory of the traffic light seemed replaced by the misleading stop sign information until you were asked about the color of the traffic light later on in the study.
      c. You remembered seeing the traffic light during the presentation of the story, and you were able to correctly choose the traffic light later on in the study.
      d. You did not remember, or you forgot that you saw the traffic light, and because you were questioned about a stop sign, you answered stop sign.
      e. None of the above
   3. When answering the question about the color of the traffic light, did you still think that you saw a stop sign? (Yes/No)
      a. Please explain in as much detail as possible______________________________

C. Study Session Scenario

1. When viewing this story, you actually saw a laptop. However, later, you were misleadingly asked about an iPad. Did you notice this? (Yes/No)
2. Which of the following best describes your experience when you saw the side-by-side images of the laptop and the iPad and had to determine which image you saw during the presentation of the story?
    a. Your memory of the laptop seemed replaced by the misleading iPad information.
    b. Your memory of the laptop seemed replaced by the misleading iPad information until you were asked about the color of the laptop later on in the study.
    c. You remembered seeing the laptop during the presentation of the story, and you were able to correctly choose the laptop later on in the study.
    d. You did not remember, or you forgot that you saw the laptop, and because you were questioned about an iPad, you answered iPad.
    e. None of the above
3. When answering the question about the color of the laptop, did you still think that you saw an iPad? (Yes/No)
    a. Please explain in as much detail as possible______________________________