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MISLEADING POSTEVENT INFORMATION: TESTING PARAMETERIZED MODELS OF INTEGRATION IN MEMORY *

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A classic series of experiments by Loftus, Miller and Burns (1978) showed that a person's recollection of an event can be changed by misleading postevent information. Several hypotheses accounting for this effect have been proposed. Loftus' hypothesis of destructive updating claims that the original memory is destroyed by the postevent information. The coexistence hypothesis asserts that the older memory survives but is rendered inaccessible through a mechanism of inhibition or suppression. The non-conflict hypothesis simply accounts for the affect by claiming that subjects can only be misled if they did not encode or if they forgot the original event. These three hypotheses were modelled with the help of all-or-none probabilistic event trees. An experiment was conducted in order to test the three models and to assess parameter values. The experiment followed the classic Loftus paradigm. We suggested to some subjects that they had seen a stopsign, whereas in fact they had seen a traffic light. The misleading postevent information resulted in poorer reproduction of traffic light. Later, all subjects were asked whether they could remember the color of the traffic light, even if they believed they had seen a stopsign. The results showed that subjects who received the misleading post-event information were at least as good at recalling the color of the traffic light as subjects who did not receive misleading information. The no-conflict model accounts well for the obtained results, although the two other, less parsimonious, models cannot be entirely rejected.

A large number of experiments in different settings have shown that information presented after an event, and conflicting with the event, may change a person's recollection of this event. Much of this work has been done by Elizabeth Loftus and her coworkers (Loftus et al. 1978), and has been amply confirmed by others (e.g., Pezdek 1977; Dooling

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and Christiaansen 1977; Weinberg et al. 1983). The normal procedure in these experiments consist of the presentation of a story, either by pictures or by written text (phase 1). In a subsequent stage some questions about the story are asked; in the experimental group one of the questions refers to a detail that contradicts the original story (phase 2). Finally, a recognition test for elements of the story is given (phase 3). The critical test item relates to the detail on which misleading information was presented. The effect of impaired memory reveals itself as a lowering of the percentage of correct responses to the critical test item.

Recent discussions on the misleading information effect have centered around two issues: whether the effect could be a product of the testing procedures, and what sort of theory could account for the effect. The first issue was directly addressed by Bekerian and Bowers (1983) and Bowers and Bekerian (1984) who argued that the recognition test in phase 3 should follow the chronological order of the story that constituted phase 1. They claimed that only the usual random testing procedure, in which this order is disrupted, produces the effect of impaired recall. Yet, some other studies do show that misleading postevent information can impair subsequent recall even when the final testing follows the order of the original event (McCloskey and Zaragoza 1985).

The second issue regarding the misinformation effect is more intriguing: what mechanism produces this effect? Originally, Loftus and her coworkers coined the notion of *destructive updating*. They argued that subjects who were misled formed a new memory in phase 2, either through replacing the old memory by a new one, or by blending the two rival memories into a new one. In both cases the old memory trace would be rendered inaccessible because it was obscured or obliterated. This hypothesis was supported by experiments in which a 'second guess' technique was employed (Loftus 1979). After phase 3, subjects were informed that some misleading information may have been presented. Then they were asked to specify what, according to their best recollection, had been presented in phase 1 and phase 2. The results showed no improvement.

An alternative explanation of misinformation effects rests upon the notion of simultaneous existence of two memory representations (cf. Hasher et al. 1981; Christiaansen and Ochalek 1983; Bekerian and Bowers 1983). According to this *coexistence* hypothesis the effect of misleading information is the result of inhibition: the most recent trace inhibits the older one, however without destroying it. Thus, the effect of misleading postevent information is attributed to a failure of retrieving information from memory, not to a loss of information from memory. Another version of the coexistence principle was proposed by McCloskey and Zaragoza (1985). When the information from both phases is recalled, subjects could reason that the experimenter would not deceive them about what was in the slides. As a consequence they would presume that their recall of the phase-1 information is incorrect. Although this version of the coexistence principle does not imply any impairment of memory proper, it makes the same predictions as the more familiar version. Data in accordance with the predictions of the coexistence model can therefore never prove that misleading postevent information affects memory.

The third explanation, originally refuted by experiments of Loftus et al. (1978) but strongly defended by McCloskey and Zaragoza (1985) might be labelled *no-conflict*. This explanation claims that subjects who encode the relevant information in phase 1 will never experience a conflict between rival memories; those subjects will always make the correct choice in phase 3. However, subjects who did *not* encode or who forgot the relevant information of phase 1 will rely on the postevent information presented in phase 2. If this information was misleading, subjects will produce an incorrect response in phase 3, but without ever having experienced a conflict between two memory traces. The first aim of the present study is to test some predictions of mathematical formulations of the three hypotheses: destructive updating, coexistence and no-conflict. The vague and sketchy formulations of the hypotheses thus far have confused the discussion and prevented advancement in this area, as will be demonstrated. It is only by more precise modelling that differences between models can be made explicit. We will test predictions of the models in a situation in which the negative effect of misleading postevent information is first established, after which it is attempted to retrieve an aspect of the original information through further questioning. The prediction of the destructive updating theory is that misled subjects will be less successful than control subjects. The two other theories predict no difference.

The models are cast within the framework of all-or-none probabilistic event trees, grouping subjects into classes with identical process histories. The choice probabilities at the nodes of the trees are parameters representing proportions of subjects following one history or the other. The predictions of the proportion of correctly responding subjects in each condition are then expressed in terms of the parameters of the model. When these predictions are set equal to the actual data, the best fitting parameter values can be obtained, for instance by a least squares solution.

The choice of event trees with their all-or-none character is inspired by McCloskey and Zaragoza's analysis of what happens in experiments on misleading postevent information. They describe the recall process as all-or-none, and perform all computations on the relative sizes of groups of subjects who did or did not recall the relevant information. The all-or-none representation of memory processes is not unusual (cf. Loftus et al. 1978: exp. 4; Loftus et al. 1985) and is more elaborately defended by Jones (1976). This is not the place to discuss the merits of all-or-none models of memory. At this point we only want to argue that event trees are the appropriate formalizations of the theories proposed thus far by other authors.

All-or-none probabilistic event-tree models

Before presenting the models it is helpful to briefly describe the stimulus situation that was used in the actual experiment. In phase 1 a pictorial story was presented, describing a pedestrian–car collision. Picture 11 showed a car at an intersection, and a traffic light that was either red, yellow or green. In phase 2 question 17 asked whether the subject could remember a pedestrian traversing the road when the car approached the *traffic light* (consistent group), the *stopsign* (inconsistent group) or the *intersection* (neutral group). In phase 3 monochrome picture pairs were presented for a recognition test. Each pair contained one picture that was actually presented in phase 1; the other member of the pair differed slightly. The tenth pair, shown in fig. 1 represented the intersection with either a traffic light or a stopsign. In phase 4 subjects were told that *traffic light* was the correct response in phase 3. Then they were asked to recall the color of the traffic light.

When the theory of destructive updating is applied to the whole sequence of experimental manipulations in the inconsistent group, six critical events can be distinguished. These events are modelled in fig. 2. First, in phase 1 we divide the subjects into two groups: those who encoded the traffic light *in such a way that it can be reproduced in*

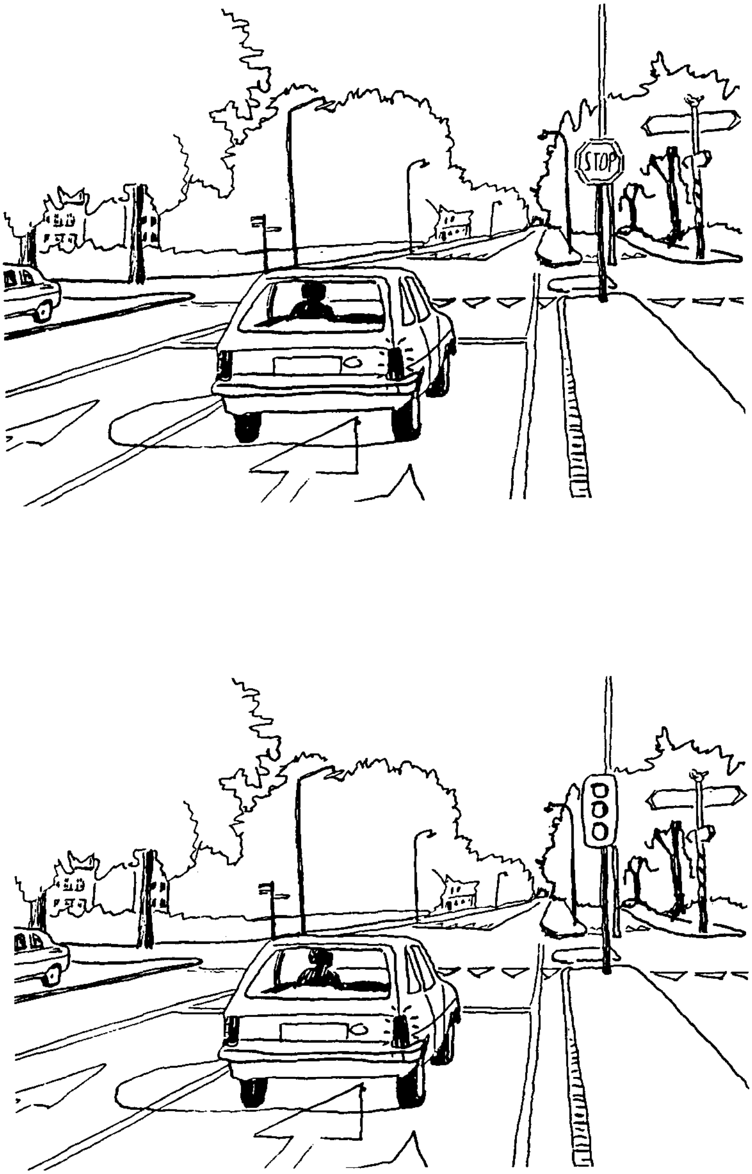

Fig. 1. Pair number 10 of the third phase test pictures, containing the critical episode at the intersection.

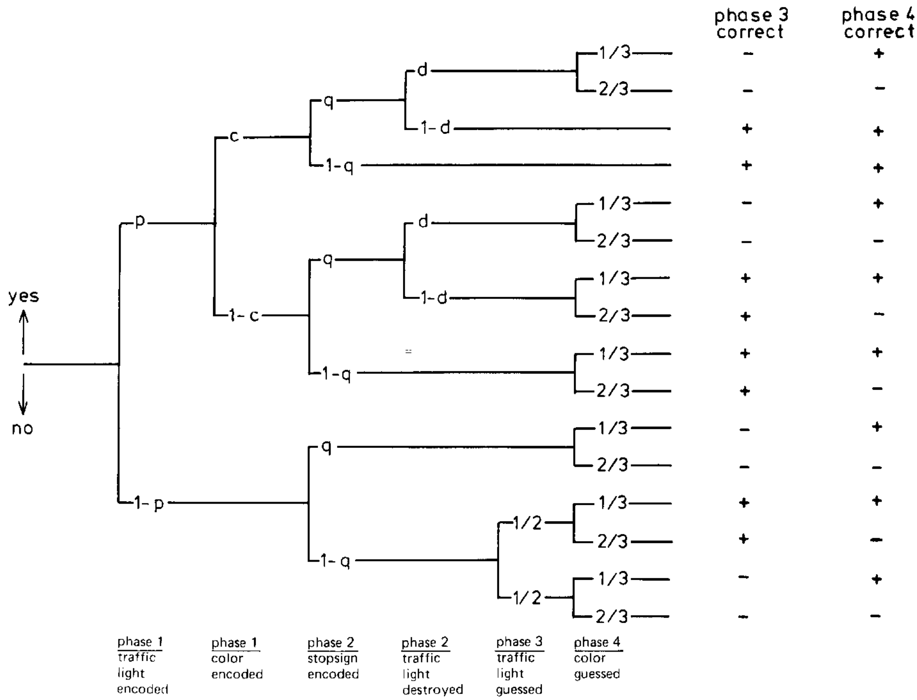

Fig. 2. Tree diagram for the inconsistent condition, according to the theory of destructive updating.

phase 3 (proportion p) and those who did not (proportion $1-p$). The second critical event is only relevant for those who encoded traffic light. They are divided again: those who encoded the color of the light *such that it can be reproduced in phase 4* (proportion c) and those who did not (proportion $1-c$). The third critical event is encoding the misleading information about the stopsign in phase 2. The parameter q describes the proportion of subjects who coded this information well enough to create a conflict (when they encoded traffic light) or to produce an incorrect recognition in phase 3. [1] The fourth critical event occurs again in phase 2: destruction of the memory of the traffic light

[1] In fact two parameters might be employed here. The results will reveal, however, that such a refinement is unnecessary.

in those cases in which both traffic light and stopsign are encoded. The proportion of subjects in which destruction takes place is labeled d. In phase 3 guessing can take place in those subjects who encoded neither traffic light nor stopsign. Finally, in phase 4, those subjects who did not encode the color of the traffic light and those in whose memory this encoding was subsequently destroyed, will have to guess at the color.

The proportion of all subjects who follow a particular branch of the tree, and thus produce the responses listed in the two last columns, are computed by simple multiplication of the proportions encountered along the path. For example: the uppermost branch will contain a proportion of $p \times c \times q \times d \times 1/3$ subjects. The proportion of subjects giving the correct response in phase 3 is obtained by adding across all branches having a plus-sign in the column labelled 'phase 3 correct'.

The advantage of this strict formulation of the model is that it makes all assumptions explicit. Thus it is assumed that destruction of the original information may take place only in case of a conflict between the two representations in memory. The effect of destruction is not only that the recollection of traffic light is lost completely, but also that the color of the traffic light cannot be reproduced above chance level. If destruction does not occur, the correct response in phase 3 will always be given. The probabilities of success in the subsequent stages are independent of each other: the probability of encoding stopsign is independent of the encoding of the traffic light, or the color of the traffic light.

The computation of predicted percentages of correct responses is almost impossible without the formal representation in an event tree. The contribution to the percentage correct consisted of three groups in McCloskey and Zaragoza's discussion of the misled condition. The addition of phase 4 increased the number of groups in the misled condition to 16, eight of which produce the correct answer in phase 3.

Event trees for the coexistence model and the no-conflict model are presented in figs. 3 and 4. The tree representing the inconsistent condition according to coexistence theory is constructed such that in case of a conflict between traffic light and stopsign, there is a proportion of subjects s, in whose memories the encoded traffic light will be *suppressed.* A further specification of this suppression mechanism is not needed, but note that suppression does not eliminate the coexistence. As soon as, between phase 3 and 4, the subjects are told the correct answer, they have access to the still existing memory of traffic light and

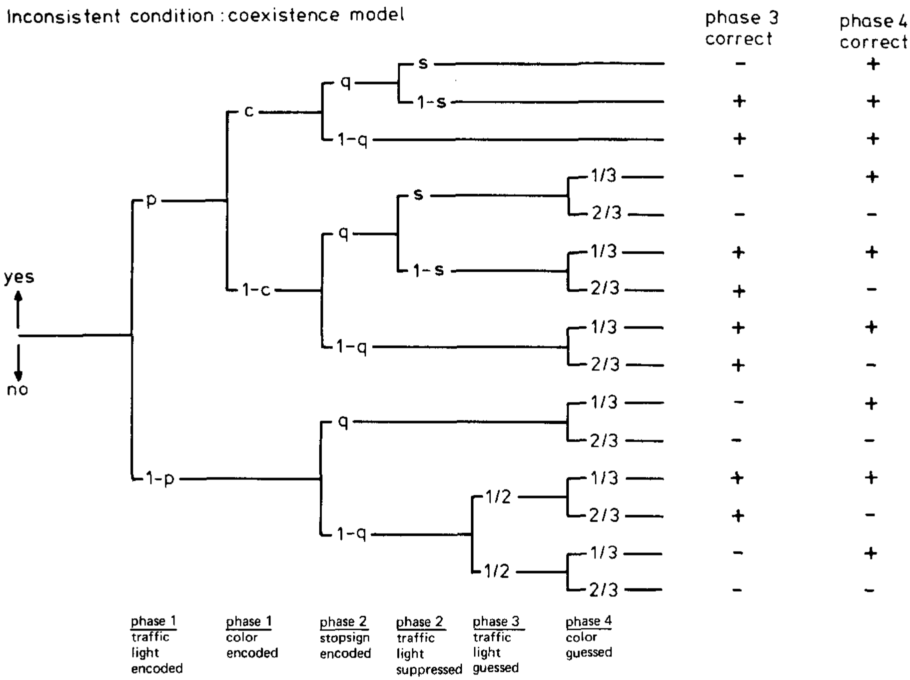

Fig. 3. Tree diagram for the inconsistent condition, according to the coexistence theory.

eventually its color. This model is, for instance, fully compatible with McCloskey and Zaragoza's account of how reasoning ('the experimenter will not deceive me') could cause a performance decrement. If it should be assumed that release from suppression is less than complete, we are in fact accepting a mixture of destruction and coexistence. We propose to adopt such a complicated model only if the data make it necessary.

The tree representing the no-conflict interpretation of the inconsistent condition contains only five events. In case traffic light and stopsign are both present in memory, it is assumed that traffic light is always chosen as a response in phase 3: the hypothesis states that subjects are only misled when they fail to encode traffic light.

The event trees for consistent and neutral conditions are fairly easy to construct. The models produce identical predictions for all theories, because the theories differ only in the way conflict is handled.

Although the event trees are not meant as models of the processes

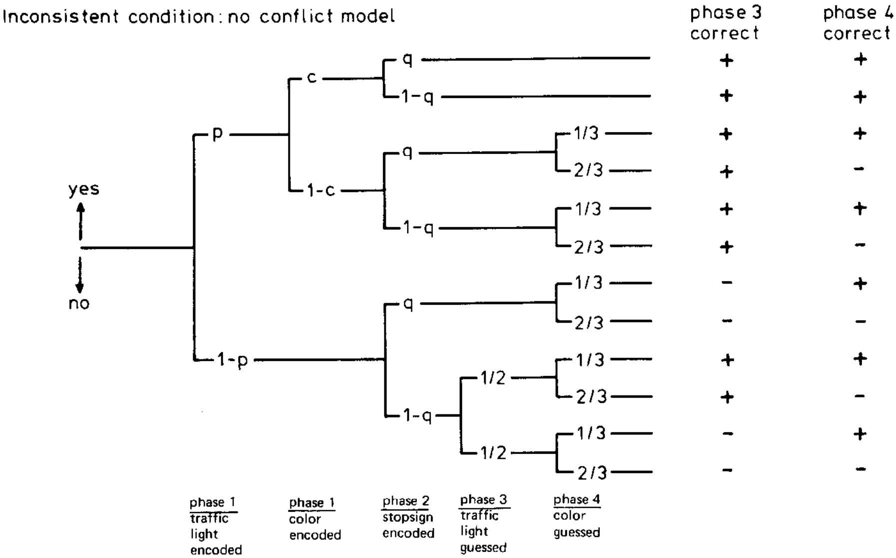

Fig. 4. Tree diagram for the inconsistent condition, according to the no-conflict theory.

occurring in *individual* subjects, they are nevertheless based on some simplifying assumptions about these processes. One such assumption is that the successive events are independent of one another. Dropping this assumption would lead to an enormous increase of parameters, through the introduction of transition probabilities. As mentioned before, the outcome of the encoding of events is presented in an all-or-none fashion. In a process model one could represent depth of encoding by a continuous variable corresponding to a continuously

Table 1
Expected proportions correct in the third phase according to the three models.

Models	Conditions		
	Consistent	Inconsistent	Neutral
No-conflict	$\frac{p+q-pq+1}{2}$	$\frac{p-q+pq+1}{2}$	$\frac{p+1}{2}$
Destructive updating	$\frac{p+q-pq+1}{2}$	$\frac{p-q+pq+1}{2}-pqd$	$\frac{p+1}{2}$
Coexistence	$\frac{p+q-pq+1}{2}$	$\frac{p-q+pq+1}{2}-pqs$	$\frac{p+1}{2}$

Table 2
Expected proportions correct in the fourth phase according to the three models.

Models	Conditions		
	Consistent	Inconsistent	Neutral
No-conflict	$\frac{2pc+1}{3}$	$\frac{2pc+1}{3}$	$\frac{2pc+1}{3}$
Destructive updating	$\frac{2pc+1}{3}$	$\frac{2pc+1-2pqcd}{3}$	$\frac{2pc+1}{3}$
Coexistence	$\frac{2pc+1}{3}$	$\frac{2pc+1}{3}$	$\frac{2pc+1}{3}$

varying probability of reproduction in phases 3 and 4. Again this would force us to introduce too many parameters (cf. the discussion on explanatory yield by Tuggle and Barron (1980)). At the moment we propose to introduce further complications in the event-tree models only if the data force us to do so.

The predicted proportions of subjects giving correct responses in the three conditions of the experiment are summarized in tables 1 and 2. Here are some relevant features of these predictions:

- The *destructive updating model* uses four parameters; in phase 4 the inconsistent question should lead to a lower performance level than the consistent or neutral questions.
- The *coexistence model* also uses four parameters, but in phase 4 consistent, inconsistent and neutral questions should not lead to performance differences.
- The *no-conflict model* makes almost the same predictions as the coexistence model, but uses only three parameters. If adding an extra parameter does not lead to a significant improvement of the fit, the more parsimonious model will be preferred.

One of the purposes of analysis through parameterized models is establishing to what degree the three families of models do in actual practice predict different results. Tables 1 and 2 demonstrate that the differences are to be expected only in the inconsistent groups. The differences are expressed by the multiplication of three proportions (table 1) or four proportions (table 2). The differences can reach an appreciable and statistically significant value only when the proportions involved are not too small. This is an issue that can be settled through experimentation only.

The results of phase 3 and phase 4, if considered separately, provide only six data points. It is felt that fitting three or four parameters to six datapoints is verging on triviality. Therefore, we will not attempt to fit the models to the overall results of phases 3 and 4. Instead we doubled the number of datapoints by looking in each condition at the groups who responded correctly in both phases of the experiment, incorrectly in both phases, correctly only in phase 3, correctly only in phase 4. These predictions are for the no-conflict model presented in table 4.

Method

Stimulus materials and procedure

The paradigm was essentially the same as the one used by Loftus et al. (1978: exp. 1). The major exception is the inclusion of a fourth phase. In phase 1 subjects observed during 66 seconds a series of 22 colored drawings, projected by a slide projector, and depicting a car–pedestrian collision. The critical picture was number 11, showing the car at an intersection with a traffic light. [2] The color of the light was either red, yellow or green. Before reaching the intersection the car was seen at a gas station. In phase 2, which occurred immediately after viewing the drawings, 20 questions were asked. The critical question, number 17, was phrased in three different ways:

Consistent : Did a pedestrian cross the street when the car, after leaving the gas station, arrived at the traffic light?
Inconsistent: Did a pedestrian cross the street when the car, after leaving the gas station, arrived at the stopsign?
Neutral : Did a pedestrian cross the street when the car, after leaving the gas station, arrived at the intersection?

After completion of the questionnaire subjects participated in various other paper and pencil experiments for about 20 minutes. In phase 3 subjects were requested to compare 16 pairs of black and white versions of the drawings. Each pair contained one exact replica of a drawing presented in phase 1. The other member of the pair showed some small alteration (e.g., an extra person, a missing streetlight). The order in which the pairs were presented matched the order of presentation in phase 1. Subjects were requested to indicate for each pair which of the two pictures they had seen before. The correct drawing occurred equally often on the left and the right. The critical pair was

[2] The design of the experiment did not allow for a counterbalancing of traffic light and stopsign as stimuli. However, in a previous experiment with the same stimuli it was established that he effect of misleading postevent information is equal in both conditions.

number 10 (see fig. 1). It contained one picture with a traffic light and one with a stopsign. Since only black and white representations were shown, no information about which light was on was provided. After completion of phase 3 another five-minute period of paper and pencil filler activities was interpolated. Then subjects received the phase-4 questionnaire, informing them that in phase 1 they had actually seen a traffic light. They were then asked to indicate the color of the traffic light, irrespective of whether their answer in the third phase had been correct.

Subjects

A total of 562 paid subjects participated in groups of 50 to 70. The subjects were students at the Catholic University of Nijmegen, at the Free University of Amsterdam and at the University of Leiden. The consistent question was presented to 170 subjects; 250 subjects received the inconsistent (misleading) question; 142 subjects received the neutral question.

Results

The effect of misleading postevent information was clearly present in phase 3, which is shown in table 3.

The inconsistent group differed significantly from the neutral group: $\chi^2(1, N = 392) = 5.69$, $p < 0.01$. The difference between neutral and consistent groups was also highly significant: $\chi^2(1, N = 312) = 6.31$, $p < 0.01$. We may conclude that the original effect of misleading postevent information has been replicated, even with the phase-3 test items in their chronological order. This is a further disconfirmation of the results of Bekerian and Bowers (1983) who claimed that the effect can only be found with a random testing order.

The no-conflict theory predicts that the neutral condition should end up exactly halfway the consistent and inconsistent condition (cf. table 1). This did not happen: the distance between inconsistent and neutral was somewhat larger, but the difference is too small to be significant: the 95% confidence interval of the result in the neutral condition lies, with $N = 142$, between 69 and 83%. Even though the phase-3 results do not refute the no-conflict theory, we may notice that the direction of the difference is in accordance with the predictions of the destruction and coexistence theories.

Table 3
Proportions of subjects that answered correct in phase 3 and phase 4.

Postevent information	Phase 3	Phase 4
Consistent	0.86	0.50
Inconsistent	0.64	0.57
Neutral	0.76	0.53

Table 4
Performance of subjects in phase 3 and phase 4, according to the data and the best fitting solution of the no-conflict model.

Phase 3	Phase 4	Predicted proportion of correct responses	Data	Model
		Consistent condition (N = 170)		
+	+	$(1+p+q-pq+4pc)/6$	46%	48%
+	−	$(1+p+q-pq-2pc)/3$	41%	40%
−	+	$(1-p-q+pq)/6$	4%	4%
−	−	$(1-p-q+pq)/3$	9%	8%
		Inconsistent condition (N = 250)		
+	+	$(1+p-q+pq+4pc)/6$	41%	40%
+	−	$(1+p-q+pq-2pc)/3$	22%	23%
−	+	$(1-p+q-pq)/6$	16%	12%
−	−	$(1-p+q-pq)/3$	21%	25%
		Neutral condition (N = 142)		
+	+	$(1+p+4pc)/6$	44%	44%
+	−	$(1+p-2pc)/3$	32%	31%
−	+	$(1-p)/6$	9%	8%
−	−	$(1-p)/3$	15%	17%

Recall of the color of the traffic light in phase 4 was approximately equally good in the three conditions, as is shown in table 3.

There was a tendency for the subjects in the inconsistent condition to perform somewhat better than the other subjects, but this difference was not significant ($\chi^2(2, N=362)=1.95$, $p>0.20$).

In table 4 the no-conflict model is fitted to the combined data of phases 3 and 4. The fitting algorithm minimized chi-square between the observed proportions and the proportions in the parameterized model. [3]

The solution yielded $p=0.50$, $c=0.57$, $q=0.50$. The fit of the model is excellent, as demonstrated in the last two columns of table 4. The difference between observed data and the model solution was by no means significant ($\chi^2(6, N=562)=4.92$, $p>0.50$). Fitting the destructive updating model, with the restriction that all parameters should have values between 0 and 1, yielded $d=0.0$. The formulae presented in tables 1 and 2 reveal that for $d=0$ there is no difference between no-conflict and destructive updating. A fitting of the coexistence model yielded the solution: $p=0.55$, $c=0.55$, $q=0.43$, and $s=0.25$. The introduction of the extra parameter s increased the goodness of fit: $\chi^2(5, N=562)=2.68$. However, the difference with the more parsimonious model of no-conflict was insignificant: $\chi^2(1, N=1124)=2.24$, $p>0.10$.

[3] We acknowledge the kind assistance of Jeroen Raaijmakers, TNO Institute for Perception, Soesterberg, The Netherlands.

Table 5
Errors in the color of traffic light reported by subjects to whom a yellow or green light was presented.

Postevent information	Wrong color	
	Red	Not red
Consistent	55	14
Inconsistent	62	22
Neutral	42	13

The responses to the phase-4 question are presented again in table 5, in order to shed some light on the question of whether the conflict between traffic light and stopsign could produce a blend. The occurrence of blends between original and misleading information was demonstrated by Loftus (1979). A yellow book may turn green when the misleading information states that it was blue. A pickup may change into a stationwagon, after it is suggested that it was a car. In a similar way it should be possible that a yellow or green traffic light blend with the red stopsign to form a red traffic light. Such a blend would reveal itself by a bias toward recalling a red traffic light when a yellow or green light was presented.

It is evident from table 5 that there was a strong bias toward reporting a red traffic light, but this bias was equally present in all conditions ($\chi^2(2,\ n = 208) = 0.74$, $p > 0.50$). Hence the origin of this bias is probably not the red color of the stopsign.

Discussion

This experiment was designed to test the predictions of three models that have been proposed to account for the effect of misleading postevent information. Two models, destructive updating and coexistence, assume a conflict between the two types of information in memory; the third model, no conflict, does not. The results show an almost perfect fit of the no-conflict model. The parameter values of p, q, c, d and s were such that a distinction among the three model families appeared to be impossible in actual practice. No reasonable amount of subjects would be sufficient for the establishment of statistical differences among the fits of the models. For this reason it is proposed to accept the most parsimonious model, which is the no-conflict model. A further indication that the two conflict models are not applicable is that the phase-4 data show a tendency toward enhanced recall of the color of the traffic light. This occurred in the very condition in which people first seem not to remember the light. This result can only be described by the destruction or coexistence models if negative values of d or s are assumed. Independent of our specific formulation of models by event trees, the results in phase 4 of the inconsistent condition are in conflict with the general idea of destruction and suppression. This phenomenon, if substantiated by further experiments, would create an interesting fourth theory: facilitation by conflict rehearsal. According to such a theory the conflict would cause subjects to rehearse the two representations in memory. While they may finally accept the misleading information as correct, the effect will still be an improved representation of the rejected information.

The parameterization of the three models revealed that in practice the models generate similar predictions, which makes the distinction among them very difficult. This means that the models as such are not easily rejected. But it is possible to reject certain parameterizations of the models. As an example we attempt to specify the limits of d in the destructive updating model. We accept the values of p, c, and q obtained in the solution of the no-conflict model. Then, setting d equal to 1.0, we expect 9.5% fewer correct responses in the fourth phase of the inconsistent condition. This would result in an expected 42.5% correct responses. The difference between this value and the observed 57% correct responses is significant ($\chi^2(1, N = 183) = 15.11$, $p < 0.001$). The lowest value of d that can be rejected in this manner is $d = 0.24$. Hence a drastic version of the theory, stating that the original information will always be destroyed by misleading postevent information, can be rejected. A toned-down version, which states that in case of a conflict between the two types of information there is something like a 20% chance for the original information to be destroyed cannot be rejected. In a way this conclusion could be helpful: if the originators of the destructive updating concept intended the drastic version of the theory, it must now be admitted that this version is disproved by our results.

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