Reconstruction Reduces Fixation on Surface Details of Explanations

Abstract

Misunderstandings of science affect many lives. Novices commonly misunderstand explanations by overly relying on surface details instead of evaluating underlying logic. Prior work has found adding a patina of neuroscience leads readers towards positively assessing explanations. How might we help people better understand science explanations? We hypothesized that asking readers to reconstruct experiments leads them to focus more on underlying logic. In a between-subjects experiment, participants relied less on irrelevant surface details when reconstructing and re-explaining experiments. However, this did not impact their assessment of explanations.

Author Keywords

understanding explanations; constructive activity; active activity; surface features; deep structure

ACM Classification Keywords

K.3.1 [Computers and education]: Computer uses in education

The Seduction of Details Over Structure

The knowledge-intensive and creative work of modern life forces us to evaluate statements about domains we don't know much about. Misunderstandings cause problems. For example, a 1993 study found that college students momentarily performed better on spatial reasoning when listening to Mozart [6]. This "Mozart Effect" experienced widespread acceptance. Florida passed a bill requiring day care programs to play classical music to infants, Georgia budgeted $105,000 to distribute classical music to newborns, and "Mozart Effect" products sold millions of copies [1]. The Mozart Effect paper only reported a temporary increase in spatial reasoning, yet numerous news articles claimed that Mozart makes people permanently "smarter". Compelling surface details like Mozart can overshadow the logic within the deep structure of an explanation.

Focusing on Surface Features Hinders Understanding
Experts generally notice the deep structure of a situation that lies within their area of expertise. Novices instead focus primarily on surface features: the literal objects, concepts, or entities explicitly described [4]. For science articles, surface features may include the stimuli of an experiment while deeper structure refers to the logical conclusions that the scientists draw from the experiment.

Even irrelevant surface features can make science explanations appear more compelling. For example, novices generally rate circular explanations less satisfying than logical ones. When an irrelevant reference to a brain scan is added to the explanations, however, novices rate circular explanations significantly more satisfying. In comparison, experts in neuroscience rate circular explanations negatively whether or not the explanations contain neuroscience information [7]. Novices focus on the patina of neuroscience instead of logical flaws.

Constructive Activities Reduce Surface Feature Fixation
One instructional method helps students understand deep structure by using constructive activities: students are asked to generate knowledge or inferences beyond the information directly given. For example, students may compare and contrast two problems [5] or self-explain a worked example [3]. Constructive activities improve understanding by encouraging learners to infer and repair knowledge using the underlying structure of a situation. [2].

Do Constructive Activities Improve Explanation Understanding?
This study compares the effect of a constructive activity to the effect of an recall activity for understanding science explanations. In the constructive activity, participants read an experiment description and are asked to imagine themselves as scientists reconstructing the experiment (the *Reconstruction* condition). Next, they answer questions on aspects of the experiment not directly mentioned within the explanation text. Participants in the recall activity, on the other hand, answer questions about information directly contained within the text (the *Recall* condition) (Table 1).

To determine whether these activities affect subsequent explanation assessment, participants complete the task in [7]: they rate the quality of explanations of psychology findings. Each explanation either proposes a logical mechanism or provides a circular restatement of the finding. In the With Neuroscience condition, each explanation also contains logically irrelevant neuroscience information (Table 2). In [7], novices rate circular explanations with neuroscience higher quality than the same explanations without neuroscience.

We hypothesized that compared to the recall activity, the reconstruction activity would better improve understanding by asking participants to infer knowledge beyond the surface details of the explanation. This hypothesis predicts that reconstructing an explanation reduces fixation on its surface features. This hypothesis also predicts that after reconstructing an explanation, participants will avoid the positive bias caused by neuroscience surface features in subsequent explanations.

Explanation: Information about stereotypical animals is stored in a certain way by CA3 brain cells, which have been shown to mediate memory. This makes the information more readily accessed and manipulated than information about rare animals.

Recall: Based on the explanation above, why was one type of animal easier to reason about than another?
Reconstruction: Suppose you are a scientist recreating this experiment and find similar results. Why might your subjects be better at reasoning about stereotypical animals than rare animals?

Table 1: Intervention explanation and conditions. The intervention also presented a description of the experiment (not shown).

Description: The researchers discovered that words spoken soon after a presented target word were words that sounded like the target, while words spoken later were words that had a similar meaning to the target.

Without Neuro, Logical: The researchers conclude that this happens because people categorize words first according to their sounds and later according to their meanings.

With Neuro, Circular: Patterns of brain activation in these subjects lead researchers to conclude that this happens because Broca's area, a part of the brain's language system, associates two different types of words with the target word at two different times.

Table 2: In the Rating task, participants rated the quality of one of the explanation versions shown.

Intervention	Ratings
Recall	Without Neuro
	With Neuro
Reconstruction	Without Neuro
	With Neuro

Table 3: Study Design—all participants rated 4 logical and 4 circular explanations in the Rating task.

Method

Participants

Undergraduates were recruited from social science courses at a Southern California university (n = 72, 54 female). Participants received course credit for participation and were informed that the results of their experiment would have no impact on their class performance.

Design

Participants completed an online study with two tasks: Intervention and Ratings. Participants were randomly divided into one of four conditions according to a 2 x 2 design: *Recall* vs. *Reconstruction* $\times$ *Without Neuroscience* vs. *With Neuroscience* (Table 3). Explanation Quality was a within-subject variable: each subject rated 4 logical and 4 circular explanations in a random order.

Measures

Independent variables are the intervention (recall vs. reconstruction), explanation quality (logical vs. circular), and explanation content (with neuroscience vs. without).

Dependent variables are the numeric ratings of explanation quality ranging from +3 (good) to -3 (bad) and the intervention text responses.

One independent rater coded each intervention response on three binary scales: Neuro, True, and Guessed. A response was marked as Neuro if it referenced the neuroscience information from the original explanation. A response was marked as True if it referenced the mechanism provided by the original explanation. Finally, a response was marked as Guessed if it proposed an alternative mechanism not directly present in the original explanation.

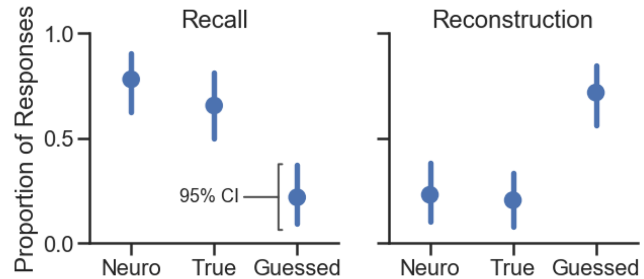

Figure 1: In the intervention, *Recall* participants utilize irrelevant neuroscience information, while *Reconstruction* participants propose alternative mechanisms without relying on neuroscience information.

Results

In the Intervention task, *Recall* participants relied on the explanation's text. When asked why a psychology finding occurred, they often included the explanation's provided mechanism but also its irrelevant neuroscience information (Figure 1). *Reconstruction* participants were less likely to include the explanation's mechanism and neuroscience information (True: $t(61.0) = 4.19$, $p < 0.01$; Neuro: $t(66.7) = 5.45$, $p < 0.01$). Instead, *Reconstruction* participants generated alternative mechanisms not directly given by the original explanation (Guessed: $t(68.0) = -4.79$, $p < 0.01$). This supports our hypothesis that reconstructing an explanation reduces fixation on its surface features.

Contrary to our hypothesis, in the Rating task participants rated circular explanations with neuroscience higher quality than circular explanations without (Recall: $t(125.6) = -2.10$, $p < 0.05$; Reconstruction: $t(157.2) = -3.233$, $p < 0.01$) (Figure 2a). This difference is consistent with prior work that did not include an intervention, suggesting that neither *Recall* nor *Reconstruction* mitigated the positive bias caused by neuroscience surface features.

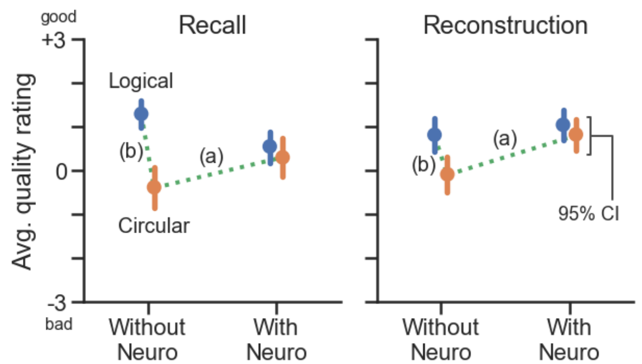

Figure 2: Contrary to our hypothesis, participants in both conditions rated circular explanations higher quality when explanations contained neuroscience information (a). Participants rated circular explanations without neuroscience lower quality than logical explanations (b).

When explanations did not include neuroscience, participants rated logical explanations higher quality than circular explanations (Recall: $t(119.1) = 5.69$, $p < 0.01$; Reconstruction: $t(180.4) = 3.22$, $p < 0.01$) (Figure 2b). This is also consistent with prior work, suggesting that participants are able to distinguish logical from circular explanations without neuroscience.

Discussion

Reconstruction Reduces Focus on Surface Details
When reexplaining why a scientific result occurred, *Reconstruction* participants seldom used details from the original text and instead proposed alternative mechanisms. One interpretation is that participants do not understand the text. If this is the case, the proposed mechanisms should either not relate to the text or contradict the information in text. Most *Reconstruction* participants, however, understood and extended the logical structure of the explanation — they propose mechanisms that account for the specific experimental results given in the text. Some proposed mechanisms reference the original explanation and add extra elaboration, demonstrating both knowledge of the text's content and ability to build further explanation on top of the text's structure. This supports the use of reconstruction activities to facilitate deep understanding.

Finding 1: *Reconstruction* participants understood the structure of the explanation without overly relying on irrelevant surface features.

Reconstruction Encourages Creative Problem-Solving
Reconstruction participants spontaneously invent alternative explanations despite having access to the original text while composing responses. Many responses to explanation recall were word-for-word copies of the text while responses to explanation reconstruction propose a variety of distinct mechanisms, such as having higher confidence:

> "it may be possible that not only is this information easier to access, but participants are more confident because of their familiarity with stereotypical birds."

Or having more prior knowledge:

> "people are more likely to have previous knowledge on stereotypical birds which makes it easier to understand the new information."

Finding 2: Framing a question as a reconstruction task encourages flexible strategies for problem-solving.

Teaching Reconstruction as an Explicit Evaluation Strategy
Despite relying less on surface features when reconstructing an explanation, participants are influenced by surface features when evaluating explanations. Although participants reconstructing an explanation might implicitly assess its quality, the reconstruction task in this study did not explicitly ask participants to rate the explanation's quality. Thus, it is possible that participants did not understand the relevance of the reconstructive activity for explanation evaluation. To facilitate application of this strategy, participants can be explicitly taught to evaluate explanation quality by reconstructing the explanation.

Finding 3: Although *Reconstruction* participants use an effective strategy for understanding explanations, they do not apply this strategy when evaluating explanations.

Conclusion

We tested whether a reconstruction activity improved understanding of science explanations compared to a recall activity. Participants reconstructing an experiment focused less on surface details of the explanation and showed more flexibility in problem-solving. When evaluating explanations, however, participants in both activities were still influenced by a patina of neuroscience. Although reconstruction is an effective strategy for understanding explanations, participants need guidance to apply this strategy when evaluating explanations.

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