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Belief in Corrective Feedback for Common Misconceptions: Implications for Knowledge Revision

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When correcting a common misconception, it seems likely that for corrective feedback to be effective, it needs to be believed. In 2 experiments, we assessed how participants' belief in the validity of corrective feedback regarding individual misconceptions influenced knowledge revision. After responding about the validity of a set of misconceptions, participants received either a refutation alone (feedback that they were correct or incorrect) or a refutation accompanied by a supporting explanation, and then rated their belief in the corrective feedback. One week later, participants once again responded about the validity of the misconceptions. Across both experiments, participants corrected their misconceptions more often when they believed the corrective feedback. In addition, participants corrected their misconceptions more often when they had earlier received a refutation with a supporting explanation than when they had received the refutation only. This benefit of supportive explanations on knowledge revision was mediated by belief in the feedback, suggesting that explanations enhance the effectiveness of a correction by increasing belief in the feedback. These findings imply that successful correction of common misconceptions is likely enhanced by techniques that increase people's belief in the validity of the corrective feedback.

Keywords: refutation text, misconceptions, knowledge revision, feedback, hypercorrection effect

Somewhere a bull charges at a matador waving his red cape. Is the bull enraged by the color red? Elsewhere, a child eats a bowl full of ice cream. Does she become more hyperactive because of all the sugar? Though many people will answer "yes" to both of these questions (74% in the current studies), the correct answer is "no." Bulls are unable to see the color red and sugar does not cause hyperactivity in children. Correcting such misconceptions is often difficult, so research has focused on identifying effective correction techniques (Chi, 2005; Ecker, Swire, & Lewandowsky, 2014; Guzzetti, 2000; Guzzetti, Snyder, Glass, & Gamas, 1993; Kendeou & O'Brien, 2014; Lewandowsky, Ecker, Seifert, Schwarz, & Cook, 2012; Tippett, 2010). One well-researched technique involves using refutation texts, which directly state and negate the common misconception (the refutation), provide the correct answer, and provide a supporting explanation. A refutation text for the misconception that bulls are enraged by red might state:

> Many people think that the color red enrages bulls, but this notion is false (the refutation). The color red does not enrage bulls (the correct answer) because bulls do not see the color red, and, instead, attack because they perceive the matador as a threat (the explanation).

Refutation texts improve memory for the correct answer over other alternatives (Guzzetti, 2000; Guzzetti et al., 1993; Sinatra & Broughton, 2011; Tippett, 2010). Prior studies have primarily focused on the importance of the refutation component, demonstrating that complete refutation texts—those containing the refutation, the correct answer, and the explanation—lead to better memory than texts containing only the correct answer and the explanation (Ariasi & Mason, 2011; Broughton, Sinatra, & Reynolds, 2010; Diakidoy, Mouskounti, & Ioannides, 2011; Hynd & Alvermann, 1986; Kendeou & Van den Broek, 2007; Kendeou, Walsh, Smith, & O'Brien, 2014). Nevertheless, corrective feedback alone (e.g., a refutation without an explicit explanation) does provide some benefits, including reducing reliance on outdated information (Johnson & Seifert, 1994; Mullet & Marsh, 2016), increasing use of correct information (Butler, Karpicke, & Roediger, 2007; Metcalfe & Finn, 2011; Mullet & Marsh, 2016), and even increasing the potency of retrieval practice (Roediger & Butler, 2011). However, these benefits of corrective feedback alone may be less potent than corrective feedback supported by supplementary information, like an explanation (Ecker et al., 2014; Rapp & Kendeou, 2007, 2009).

Most relevant to the present research, a correction, such as a refutation text, may only lead to better learning if the reader believes the corrective feedback. Consider the misconception about bulls. Most readers may believe the refutation text because

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they have never personally interacted with a bull and the supporting explanation makes sense given common knowledge that animals often attack when threatened. But readers might not always believe corrections of their misconceptions. For instance, some may disbelieve the correction that sugar does not cause hyperactivity because they can think of a time when a child seemed more rowdy after eating a sugary treat. So what happens when a reader does not believe the corrective feedback provided by the refutation text? Do explanations that support the refutation increase people's belief in corrective feedback and ultimately impact knowledge revision?

The goal of the current study was to answer these questions by investigating the role that belief in feedback plays in correcting common misconceptions. Although both the refutation and the explanation serve as corrective feedback, in the current article, we use the term *feedback* to refer specifically to the yes–no refutation only and the term *explanation* to refer to the explanation that supports the refutation. The importance of belief in this feedback—that one's response is correct or incorrect—may be further understood through the knowledge revision components (KReC) framework proposed by Kendeou and O'Brien (2014). The KReC framework has five principles—encoding, passive activation, coactivation, integration, and competing activation. Although all five principles are critical to knowledge revision, our focus is primarily on coactivation, integration, and competing activation. In order, both the old information (e.g., the misconception) and the new information (e.g., the corrective feedback and explanation) must be activated simultaneously for knowledge revision to occur (coactivation principle). The new information must then become integrated with any relevant old information, including any incorrect information (integration principle). Once this occurs, at any future point when either the old or new information becomes relevant, such as when later asked about the validity of a misconception, they both compete for activation (competing activation principle).

If a reader does not believe the feedback they receive, they may not undergo successful knowledge revision. Based on the stages of integration and competing activation, belief in the feedback may impact knowledge revision by two compatible routes. First, readers with low belief in the feedback may reject and fail to integrate the feedback. Thus, when later encountering the initial misconception, the feedback would become activated less often. For instance, someone who does not believe the feedback about the color red enraging bulls may reject it, fail to integrate it with their misconception, and later continue to respond that bulls are enraged by the color red because the feedback does not come to mind. Second, if the feedback does become activated when the reader later encounters the initial misconception, the reader may remember their low belief in the feedback. The reader can then use their memory for low belief in the feedback to reject the feedback so as to resolve the competing activation between the misconception and the feedback. For instance, someone who does not believe the feedback about the color red enraging bulls would more likely reject the feedback when later asked about their knowledge relating to the misconception. Note that both of these routes lead to the same prediction about the relationship between belief in the feedback and knowledge revision: Less belief in the feedback would be associated with *decreased* accuracy on later tests of the misconceptions.

Accordingly, the first major goal of the current study was to investigate whether belief in the feedback would be related to increased accuracy on later tests of the misconception. To achieve this goal, participants answered a series of true–false statements based on common misconceptions. After answering the misconceptions, participants received feedback consisting of the initial misconception, the original response, and whether that response was correct or incorrect. Following this feedback, participants rated their belief in the feedback (hereafter referred to as *feedback belief*) on a scale from 0 (*not at all*) to 100 (*absolutely*). After 1 week, participants returned and answered the same set of true–false statements, with performance on this second test as the primary dependent variable. Given the proposed routes by which feedback belief influences knowledge revision, when participants have a misconception, the less they believe the feedback, the worse they should perform on the final knowledge test.

If feedback belief predicts later accuracy, then information that provides readers with a reason to believe the feedback should increase both feedback belief and subsequent accuracy. For example, refutation texts may effectively correct misconceptions because the explanation provided by the refutation text increases readers' belief in the corrective feedback. Prior studies have shown that explanations support knowledge revision. For instance, in a study by Kendeou and colleagues (2014), texts that included an explanation reduced subsequent reading disruptions (caused by the conflict between the misconception and the correct information) compared with a text containing no explanation. In addition, studies have shown that explanations help readers correct mistaken information in news reports (Ecker, Lewandowsky, & Apai, 2011; Ecker, Lewandowsky, & Tang, 2010; Johnson & Seifert, 1994; Rich & Zaragoza, 2016; van Oostendorp & Bonebakker, 1999) and update their knowledge about a character in a narrative (Kendeou, Smith, & O'Brien, 2013; Rapp & Kendeou, 2007, 2009). Though prior studies have indicated that explanations improve knowledge revision, whether they do so by increasing how much readers believe the feedback remains unknown. Hence, another major goal of the current study was to investigate whether feedback belief mediates the effect of explanations on knowledge revision and, ultimately, accuracy on the final test. To address this goal, when participants received feedback, half of participants received an explanation supporting the correct answer (refutation-explanation) and half did not (refutation-only).

Finally, the relationship between feedback belief and later accuracy may be influenced by people's *initial* confidence in their misconceptions in a manner that could diminish the relationship between feedback belief and final performance. In particular, the more confident people are initially that bulls are enraged by the color red, the less they should believe the feedback that this statement is false. However, in prior studies, the more confident people are in their incorrect knowledge, the more accurate they are (after receiving feedback) on the final test, which has been referred to as the *hypercorrection effect* (Butler, Fazio, & Marsh, 2011; Butterfield & Metcalfe, 2001, 2006; Fazio & Marsh, 2009, 2010; Metcalfe & Finn, 2011; Sitzman, Rhodes, & Tauber, 2014; Van Loon, Dunlosky, Van Gog, Van Merriënboer, & de Bruin, 2015). Thus, high initial confidence in a misconception (which would lead to higher accuracy as per the hypercorrection effect) may diminish the predicted, positive relationship between feedback belief and final test accuracy (i.e., the more one believes the feedback, the more likely they will respond correctly on the final test). Hence, we also investigated the relationship between initial confidence and feedback belief; if a relationship exists, we will then control for initial confidence when estimating the relationship between feedback belief and final test accuracy. To address this issue, we had participants judge their confidence on each answer on the initial true–false test on a 0-to-100 scale.

In Experiment 1, we had two main predictions corresponding to the two major goals of this research:

1. Feedback belief would be positively related to accuracy on the final knowledge test (controlling for initial confidence, if, in fact, initial confidence is negatively related to feedback belief, as expected).

2. Feedback belief would mediate the effect of providing an explanation on later accuracy.

Experiment 1

Method

Participants and design. Based on prior studies investigating similar effects (Butler et al., 2011; Kendeou et al., 2013, 2014; Sitzman et al., 2014), we collected data from 62 participants from a large Midwestern university (48 women; 15–35 years old, M = 19.48) who completed the experiment for credit for a course requirement. Participants were randomly assigned to two groups: refutation-only (n = 32) or refutation-explanation (n = 30).

Materials. The primary materials consisted of 60 statements based on common misconceptions, with 34 false statements (e.g., "bulls are enraged by the color red," "sugar causes hyperactivity in children") and 26 true statements (e.g., "the Sahara desert is mostly rocky plateaus," "a camel stores fat in its humps").[1] The 60 statements were randomly divided into two sets of 30 statements used for counterbalancing (described below). Similar to Butler et al. (2011), these statements were generated by consulting Wikipedia (wikipedia.org) and multiple books on common misconceptions (Burnam, 1986; Shenkman, 1993). Explanations for the refutation-explanation group were generated using these same sources and consisted of up to three sentences supporting the correct answer (e.g., "Bulls are unable to see the color red. Bulls are instead enraged by the matador who is perceived as a threat," and "A majority of the Sahara desert consists of rocky plateaus with little sand, called hamada. These rocky sections are caused by the winds which gather the sand into the dunes the desert is famous for").

In the current study, we opted to use true–false statements because a recent study by Van Loon and colleagues (2015) suggests that refutation texts improve accuracy more on true–false tests than on open-ended tests. Hence, true–false tests may be especially sensitive to the effects of explanations on knowledge revision. Because one goal of the current study was to investigate whether feedback belief mediates the effect of explanations on later accuracy, we opted to use a method that may make the effect of explanations more pronounced.

Procedure. Participants came to the lab on two separate days to complete the study at their own pace, which was administered using a LiveCode program run on Dell computers. Day 1 consisted of two phases: the initial misconception test and the test feedback. On the initial misconception test, participants were randomly assigned one of the two sets of 30 misconception statements, responded true or false to each, and rated their *initial confidence* on a scale from 0 (*not at all confident*) to 100 (*absolutely confident*).

The test feedback phase began immediately after the participant responded to all 30 misconception statements. During this phase, participants received feedback for each of their responses one at a time and in the same order as the initial test. The feedback consisted of the initial misconception, the participant's original response, and whether that response was correct or incorrect (i.e., "Your answer was correct"). If the participant had answered correctly, they received no additional feedback or information. If the participant had answered incorrectly, participants in the refutation-only group also received the correct answer (i.e., "The correct answer is that the statement is false"), whereas participants in the refutation-explanation group received both the correct answer and the explanation. Participants then rated their belief in the feedback from 0 (*do not believe the feedback at all*) to 100 (*absolutely believe the feedback*).

Participants returned to the laboratory 1 week later to complete a second misconception test designed to assess whether the feedback was effective. On this test, participants responded "true" or "false" to both sets of misconception statements (all 60 presented in random order) and rated their confidence using the same 0-to-100 scale. Participants' performance on the second set of 30 novel misconception statements showed that responses on these items were unaffected by having received feedback regarding the initial set of misconceptions. Specifically, performance on the initial set of misconceptions on the first test and performance on the novel set of items on the final test (after the feedback manipulation) did not differ. Because this same result was observed in both experiments, the results from the 30 novel misconceptions will not be reported.

Analytic plan. Given that each participant responded to multiple misconceptions, the overall data structure is nested, with the variables related to each misconception statement (item-level variables: initial confidence, feedback belief, final test accuracy) nested under each participant. Traditionally researchers collapse across nested data by calculating participant averages on the nested data (i.e., the misconceptions). However, collapsing across nested data both reduces the effective power by ignoring additional degrees of freedom granted by the nested data points, and requires categorizing misconceptions based on the feedback belief ratings (e.g., "low" and "high" confidence misconceptions based on tertile splits) removing variability in this predictor. Thus, we analyzed the data using multilevel modeling, a technique considered more appropriate when analyzing nested data (Hox, 2002; Raudenbush & Bryk, 2002; Tabachnick & Fidell, 2012). Though similar to traditional regression (e.g., both involve predicting an outcome variable using one or more predictor variables, and the effects of these predictors are interpreted using regression coefficients), multilevel models can account for the relationships between responses from

[1] Consistent with previous studies (e.g., Gilbert, 1991), participants demonstrated a truth bias, as indicated by significantly better performance on true statements than false statements on both the initial test and final test ($ps < .001$). However, this truth bias did not significantly affect the rest of the reported results and hence will not be discussed further.

the same participant. Conceptually, these models use the item-level data to predict the outcome variable at the item-level first, and then account for the relationship between item-level data from the same participant.

Accuracy on the final misconception test for those items that participants answered *incorrectly* on the initial misconception test served as our primary outcome variable. We restricted our analysis to these items for two reasons. First, the explanation manipulation only occurred on these items, and, second, both the feedback and explanation likely have the strongest effects when the participants do not know the correct answer. Because of this restriction, each participant provided a different number of item-level observations in the final analysis, meaning that the design is unbalanced. For example, a participant who answered incorrectly on only five of the initial 30 misconceptions would only provide five item-level observations, but a participant who answers incorrectly on 20 of the initial misconceptions would provide 20 item-level observations. Unlike other approaches to analyzing the data, multilevel modeling accounts for the fact that different participants may have different numbers of item-level observations, again indicating that multilevel modeling is the most appropriate analysis technique given the nature of our data.

In all of the models reported here, we standardized the continuous item-level predictors—feedback belief and initial confidence—for ease of interpretation.

Finally, because our item-level outcome variable (accuracy on the final test) is a binary outcome (correct vs. incorrect), we used logistic multilevel modeling.

Results and Discussion

Descriptive statistics on focal measures. As expected, given that the statements were based on common misconceptions, participants in both the refutation-only ($M = .35$), $t(31) = 6.99$, $p < .001$, $d = -1.26$, and refutation-explanation groups ($M = .37$), $t(29) = 6.38$, $p < .001$, $d = -1.20$, performed significantly worse than chance on the initial misconception test. Also, as shown in Table 1, both performance on the initial test, $t(60) = 0.74$, $p = .46$, and ratings of confidence on the initial test, $t(60) = 1.02$, $p = .31$, did not differ by group, which was also expected, given that the initial test preceded the explanation manipulation. Finally, initial confidence negatively correlated with feedback belief ($r = -0.23$, $p < .001$), suggesting that initial confidence should be controlled for when analyzing the relationship between feedback belief and accuracy.

Feedback belief. Our first goal was to evaluate whether feedback belief is associated with reporting of the correct answer on the final test. To estimate the relationship between feedback belief and accuracy, we analyzed the data with a logistic multilevel model predicting accuracy on the final test (item level) based on feedback belief (item level), controlling for initial confidence (item level) and explanation group (participant level). Consistent with the first prediction, feedback belief significantly and positively predicted performance on the final test, with a one-standard-deviation increase in feedback belief associated with 39% greater odds of reporting the correct answer (see Table 2 for model estimates). These results indicate that when participants believe the feedback, they are more likely to report the correct answer a week later.

Impact of providing explanations. As shown in Figure 1 consistent with the expectation that explanations increase feedback belief, participants who received both a refutation and explanation had greater feedback belief, $t(60) = 4.77$, $p < .001$, $d = 1.21$, and performed better on the final test, $t(60) = 5.99$, $p < .001$, $d = 1.52$, than participants who received only the refutation. In addition, participants who received the explanations had greater confidence in the answers they provided on the final test, $t(60) = 3.11$, $p < .01$, $d = 0.79$.

To evaluate whether explanations lead to greater accuracy on the final test by influencing feedback belief, we estimated a mediation model with feedback belief mediating the relationship between explanation group and accuracy on the final test. Consistent with the second prediction, a bootstrapped mediation analysis revealed that feedback belief positively mediated the relationship between explanation and accuracy ($ab = 0.13$, bootstrapped 95% confidence interval [CI] [0.08, 0.18]). However, as shown in Table 2, even after controlling for feedback belief, explanation group significantly predicted later accuracy. Thus, explanations do benefit later accuracy by increasing feedback belief, although they may also benefit accuracy through other mechanisms as well.

The extent to which explanations increase feedback belief may depend on how much participants believe the feedback *prior* to receiving explanations. If participants do not believe the feedback initially, the explanations may provide them a concrete reason to believe the feedback. In contrast, if participants do believe the feedback, then explanations may provide them little additional reason to believe the feedback. Hence, the extent to which explanations increase feedback belief may depend on the level of initial belief in the feedback (i.e., refutation). Alternatively, explanations may increase feedback belief regardless of how much the participant believes the feedback prior to receiving explanations.

To evaluate these possibilities, we conducted a follow-up analysis on the misconception statements. For each statement, feedback belief ratings were provided both before receiving an explanation (refutation-only ratings) and after receiving an explanation (refutation-explanation ratings). We conducted a median split based on feedback belief before an explanation ($Mdn = 55.5$) into statements with high preexplanation feedback belief and low preexplanation feedback belief. We then analyzed the feedback belief

Table 1
Outcomes on Dependent Measures for Each Feedback Condition on Misconceptions Answered Incorrectly on the Initial Test

	Refutation-only		Refutation-explanation	
Dependent Measure	*M*	*SE*	*M*	*SE*
Experiment 1				
Initial confidence	58.59	2.17	61.81	2.28
Feedback belief	49.18	2.57	67.95	3.00
Final test accuracy	.43	.04	.74	.03
Final test confidence	60.67	2.67	72.37	2.65
Experiment 2				
Initial confidence	62.57	2.13	63.20	2.46
Feedback belief	48.15	3.45	52.33	2.66
Explanation belief	—	—	64.09	2.47
Final test accuracy	.40	.06	.62	.06
Final test confidence	66.79	2.83	70.79	2.43

Table 2
Parameter Estimates for Each Logistic Multilevel Model in Experiment 1 on Misconceptions Answered Incorrectly on the Initial Test

Predictors	Coefficient	T ratio	Odds ratio
Model 1 – Feedback belief			
Intercept	$.43^{**}$	3.48^{a}	1.54
Feedback belief	$.33^{***}$	4.09^{b}	1.39
Covariate: Explanation condition	$.65^{***}$	5.15^{a}	1.91
Covariate: Initial confidence	−.10	-1.33^{b}	.90
Model 2 – Hypercorrection effect			
Intercept	$.41^{**}$	3.35^{a}	1.51
Initial confidence	−.10	-1.27^{b}	.91
Explanation condition	$.65^{***}$	5.19^{a}	1.92
Confidence × Explanation	$.17^{*}$	2.35^{b}	1.19
Covariate: Feedback Belief	$.31^{***}$	3.80^{b}	1.37

[a] $df = 60$. [b] $df = 1,120$.
[*] $p < .05$. [**] $p < .01$. [***] $p < .001$.

ratings for all misconception statements in a 2 (explanation: refutation-only vs. refutation-explanation) × 2 (pre-explanation feedback belief: low vs. high) mixed-design ANOVA. The analysis revealed that feedback belief before an explanation moderated how much feedback belief increased after an explanation, $F(1, 57) = 25.56$, $p < .001$, $\eta_p^2 = 0.31$, Mean Squared Error = 107.36. Specifically, though feedback belief increased overall after an explanation, $F(1, 57) = 112.07$, $p < .001$, $\eta_p^2 = 0.66$, feedback belief increased more for items with low preexplanation feedback belief, $M_{\text{refutation-only}} = 40.42$, $M_{\text{refutation-explanation}} = 70.26$, $F(1, 57) = 120.30$, $p < .001$, $\eta_p^2 = 0.68$, than items with high preexplanation feedback belief, $M_{\text{refutation-only}} = 58.99$, $M_{\text{refutation-explanation}} = 69.54$, $F(1, 57) = 15.56$, $p < .001$, $\eta_p^2 = 0.21$. Importantly, as ceiling effects cannot explain these results (belief ratings after the explanation fell below 75 on a 100-point scale), these results indicate that explanations increase feedback belief more when feedback belief prior to the explanations is low (perhaps because greater change can occur when beginning with lower than higher feedback beliefs).

Initial confidence. Given that feedback belief relates to both initial confidence and later accuracy, we investigated whether feedback belief mediated the relationship between initial confidence and accuracy. Specifically, as initial confidence in mistaken responses is negatively associated with feedback belief, and feedback belief is positively associated with later accuracy (i.e., corrected knowledge), then this pathway from initial confidence to later accuracy *through* feedback belief should also be *negative*. Given the established hypercorrection effect, in which initial confidence in mistaken information is *positively* associated with final accuracy, the negative relationship between initial confidence and feedback belief may diminish the effect of initial confidence on final accuracy. Consistent with this expectation, a bootstrapped mediation analysis revealed that feedback belief negatively mediated the relationship between confidence and accuracy ($ab = -0.08$, bootstrapped 95% CI [−0.12, −0.03]).

As feedback belief reduced the relationship between initial confidence and accuracy, we conducted a follow-up analysis of the hypercorrection effect controlling for feedback belief. We analyzed the data with a separate model predicting accuracy on the final test based on initial confidence, explanation group, and the interaction between these variables, controlling for the effect of feedback belief (see Table 2). Consistent with results reported by Van Loon and colleagues (2015), initial confidence moderated the effect of explanations. As shown in Table 3, explanations had a greater effect on items participants held with high initial confidence, $z = 1$, $\beta = 1.64$, $t(60) = 5.60$, $p < .001$, odds ratio [OR] = 5.17, than those held with low initial confidence, $z = -1$, $\beta = 0.96$, $t(60) = 3.37$, $p = .001$, $OR = 2.62$. This conceptually replicates the hypercorrection effect demonstrated with refutation texts—explanations had the greatest effect when participants had high confidence in their initial, incorrect answer. But contrary to the traditional hypercorrection effect, initial confidence *negatively* predicted accuracy on the final test in the refutation-only group, $\beta = -0.26$, $t(1119) = 2.56$, $p = .01$, $OR = 0.77$, and did not significantly predict accuracy in the refutation-explanation group, $\beta = 0.07$, $t(1119) = 0.71$, $p = .48$, $OR = 1.08$.

Experiment 2

Experiment 1 provides initial evidence that feedback belief is associated with whether someone outdates their initial misconception and answers correctly on a later test. The purpose of Experiment 2 was to extend Experiment 1 by separating feedback belief into two component parts: belief in the feedback (i.e., that bulls are not enraged by the color red) and belief in the explanation (i.e., that bulls are enraged by the presence of the matador that they perceive as a threat). In Experiment 1, participants in the refutation-explanation group rated feedback belief *after* reading the explanation. For these participants, belief in the refutation and belief in the explanation are inextricable, so low ratings of feedback belief in Experiment 1 may have reflected either low belief in the refutation (feedback belief) or low belief in the explanation (explanation belief). By separating feedback belief from explanation belief, we can explore separately the contributions of both feedback belief and explanation belief to subsequent reporting of the correct answer.

In addition, the results of Experiment 1 indicate that (a) explanations lead to increased accuracy in part because they boosted feedback belief, and (b) explanations especially boosted feedback belief when feedback belief was initially low. Given these outcomes, then explanations may lead to greater improvements in *accuracy* when feedback belief is initially low, rather than high.

Table 3
Final Proportion Correct [Standard Error] on Misconceptions Answered Incorrectly on the Initial Test by Level of Initial Confidence for Each Condition in Experiments 1 and 2

	Initial confidence		
Explanation Group	Low ($z < -1$)	Middle ($-1 < z < 1$)	High ($z > 1$)
Experiment 1			
Refutation-only	.54 [.06]	.44 [.04]	.31 [.06]
Refutation-explanation	.75 [.06]	.75 [.04]	.71 [.05]
Experiment 2			
Refutation-only	.45 [.06]	.40 [.06]	.31 [.07]
Refutation-explanation	.58 [.08]	.61 [.06]	.65 [.07]

By separating feedback belief from explanation belief, we can investigate whether the explanations are more effective at increasing accuracy when feedback belief is initially low.

To address these issues in Experiment 2, participants in the refutation-explanation group first received the refutation and correct answer alone and rated their belief in this feedback (*feedback belief*). Immediately after this rating, they received the explanation and rated their belief in it (*explanation belief*). Given the evidence from Experiment 1 that explanations primarily counteract low feedback belief, the feedback belief ratings in Experiment 2, which come before the explanations, should only weakly predict later accuracy for these participants. Participants with low feedback belief subsequently receive explanations, giving them a reason to now believe the feedback and report the correct answer on the final test. Participants with high feedback belief would have likely reported the correct answer on the final test even without the explanations, so the explanations may provide little additional benefit. According to this rationale, feedback belief will show little—to no—relationship with performance on the final test. By contrast, explanation beliefs may predict later accuracy. The more a participant believes the explanations, the more they should believe the feedback and report the correct answer.

Participants in the refutation-only group instead only rated their feedback belief and did not receive an explanation, replicating the refutation-only group from Experiment 1. Hence, feedback belief should still predict later accuracy. Overall, the relationship between feedback belief and subsequent accuracy should be moderated by whether the participant received a refutation alone or a refutation with a supporting explanation.

In Experiment 2, we had three major predictions:

1. Controlling for initial confidence, feedback belief would be strongly and positively related to accuracy on the final test for participants in the refutation-only group but less strongly related for participants in the refutation-explanation group.

2. The effect of explanations on accuracy would be moderated by feedback belief, with explanations providing the greatest benefit when participants had low feedback belief.

3. Explanation belief would be positively related to accuracy on the final test.

Method

Participants and design. We collected data from 48 participants from a large Midwestern university (33 women; 16–23 years old, $M = 19.81$) who completed the experiment for credit for a course requirement. Participants were randomly assigned to two groups: refutation-only ($n = 25$) or refutation-explanation ($n = 23$).

Materials and procedure. Experiment 2 was identical to Experiment 1 except for one change to the test feedback phase designed to separate *explanation belief* from *feedback belief*. For participants in the refutation-only group, the method was identical to Experiment 1. For participants in the refutation-explanation group, the feedback again consisted of the initial misconception, the participant's response, and whether that response was correct or incorrect. Immediately following, these participants received the correct answer and then rated their feedback belief from 0 (*not at all*) to 100 (*absolutely*). Immediately after rating their belief in the refutation, they received the explanation for the correct answer and rated their explanation belief using the same scale.

Analytic plan. As in Experiment 1, we analyzed performance on the final test for those items that participants got incorrect on the initial misconception test using logistic multilevel modeling. Again, in all of the models reported here, we standardized our continuous item-level predictors—feedback belief, explanation belief, and initial confidence—at the participant level.

Results and Discussion

Descriptive statistics on focal measures. As in Experiment 1, on the initial misconception test, participants performed significantly worse than chance both in the refutation-only group ($M = .34$), $t(25) = 5.92$, $p < .001$, $d = -1.18$, and in the refutation-explanation group ($M = .34$), $t(23) = 7.63$, $p < .001$, $d = -1.59$. As shown in Table 1, given that the initial test and feedback belief ratings preceded the manipulation, groups did not differ on initial test performance, $t(46) = 0.23$, $p = .82$, confidence on the initial test, $t(46) = 0.19$, $p = .85$, and feedback belief, $t(46) = 0.95$, $p = .35$. Finally, feedback belief was significantly and negatively correlated with initial confidence ($r = -0.36$, $p < .001$), suggesting that initial confidence should be controlled for when analyzing the relationship between feedback belief and final accuracy.

Feedback belief. To address whether feedback belief is associated with greater accuracy on the final test, we analyzed a model predicting accuracy on the final test based on feedback belief and explanation group, controlling for initial confidence. Given that we expected feedback belief to predict accuracy for refutation-only participants and not refutation-explanation participants, we also included the interaction between feedback belief and explanation group. Overall, feedback belief significantly and positively predicted performance on the final test, with a one-standard-deviation increase in feedback belief associated with 29% greater odds of reporting the correct answer (see Table 4 for the model estimates). Consistent with our first and second predictions, explanation group

Table 4
Parameter Estimates for Each Logistic Multilevel Model in Experiment 2 on Misconceptions Answered Incorrectly on the Initial Test

Predictors	Coefficient	T ratio	Odds ratio
Model 1 – Feedback belief			
Intercept	.06	$.32^{a}$	1.06
Feedback belief	$.26^{**}$	2.69^{b}	1.29
Explanation condition	$.60^{**}$	3.09^{a}	1.82
Feedback Belief × Explanation	$-.35^{***}$	-3.97^{b}	.70
Covariate: Initial confidence	.06	$.65^{b}$	1.06
Model 2 – Hypercorrection effect			
Intercept	.05	$.23^{a}$	1.06
Initial confidence	.08	$.90^{b}$	1.08
Explanation condition	$.60^{**}$	2.99^{a}	1.82
Confidence × Explanation	$.29^{***}$	3.50^{b}	1.34
Covariate: Feedback belief	$.28^{**}$	2.92^{b}	1.32

[a] $df = 46$. [b] $df = 899$.
$^{**} p < .01$. $^{***} p < .001$.

significantly moderated the effect of feedback belief on accuracy. Simple slopes for the effect of feedback belief revealed that feedback belief positively predicted performance on the final test in the refutation-only group, $\beta = 0.61$, $t(899) = 4.79$, $p < .001$, $OR = 1.84$, and not the refutation-explanation group, $\beta = -0.09$, $t(899) = 0.70$, $p = .48$, $OR = 0.91$. Thus, as predicted, these results indicate that when an explanation was given, how much readers believed the feedback was no longer associated with their later performance.

Impact of providing explanations. After receiving an explanation, participants in the refutation-explanation group had higher explanation belief ratings than their feedback belief ratings, indicating that explanations supplemented the refutation, $t(22) = 4.63$, $p < .001$, $d = 0.98$. As shown in Figure 1, participants in the refutation-explanation group performed better on the final test, $t(46) = 2.83$, $p = .01$, $d = 0.82$, although this did not translate to increased confidence on the final test, $t(46) = 1.06$, $p = .29$.

Consistent with our second prediction, the effect of feedback group was moderated by feedback belief (as reported in Table 4). As shown in Figure 1, simple slopes analysis revealed that explanations had a greater effect on items for which participants had relatively low feedback belief, $z = -1$, $\beta = 1.91$, $t(46) = 4.41$, $p < .001$, $OR = 6.73$, than those for which they had relatively high feedback belief, $z = 1$, $\beta = 0.50$, $t(46) = 1.18$, $p = .25$, $OR = 1.64$. These results suggest that explanations improve later performance and updating of the misconception in part by counteracting low feedback belief.

Explanation belief. To address whether greater *explanation* belief was associated with better memory for the correct answer on the final test, we analyzed an additional model predicting accuracy on the final test based on explanation belief (item level) and controlling for feedback belief and initial confidence (item level). As participants in the refutation-only group did not receive an explanation and did not rate their explanation belief, this model used data from those participants in the refutation-explanation group. Contrary to the third prediction of Experiment 2, belief in the explanations did not significantly predict accuracy on the final test, $\beta = 0.23$, $t(432) = 1.66$, $p = .10$, $OR = 1.26$, suggesting that the degree to which readers believe explanations may not affect the benefits of receiving explanations.

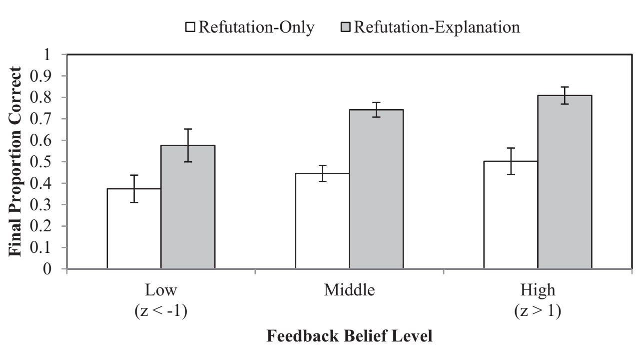

Figure 1. Average accuracy on the final true–false misconception test for misconceptions answered incorrectly on the initial test broken down by explanation group (refutation-only and refutation-explanation) and low ($z < -1$), middle ($-1 < z < 1$), and high ($z > 1$) standardized scores of feedback belief ratings in Experiment 1. Error bars represent the between-participants standard error for each group.

Initial confidence. Consistent with Experiment 1, a bootstrapped mediation analysis revealed that feedback belief slightly, negatively mediated the relationship between confidence and accuracy ($ab = -0.07$, bootstrapped 95% CI [−0.14, 0.00]). Hence, we conducted a follow-up analysis of the hypercorrection effect controlling for feedback belief. We analyzed the data with a model predicting accuracy on the final test based on initial confidence, explanation group, and the interaction between these variables, controlling for the effect of feedback belief (see Table 4). As in Experiment 1, initial confidence significantly moderated the effect of the provided feedback. As shown in Table 3, simple slopes for the effect of explanations revealed that the benefit of explanations was stronger on items for which participants had relatively high initial confidence, $z = 1$, $\beta = 1.78$, $t(46) = 4.07$, $p < .001$, $OR = 5.92$, than those with relatively low initial confidence, $z = -1$, $\beta = 0.61$, $t(46) = 1.43$, $p = .16$, $OR = 1.84$. This again supports the hypercorrection effect as explanations improve accuracy the most when participants were highly confident in their initial, incorrect answer. In addition, though initial confidence again *negatively* predicted accuracy on the final test in the refutation-only group, $\beta = -0.21$, $t(899) = 1.84$, $p = .07$, $OR = 0.81$, initial confidence *positively* predicted performance on the final test in the refutation-explanation group, $\beta = 0.37$, $t(899) = 2.84$, $p < .01$, $OR = 1.45$, providing some additional evidence of the hypercorrection effect.

General Discussion

So what about that matador waving his red cape at a bull? Does the bull charge at the matador because it is enraged by the color red? The answer to this question is definitively "no," and after reading this feedback, people have to undergo knowledge revision to correct their initial misconception. How people's beliefs about provided feedback influence knowledge revision remains relatively unstudied. To fill this gap, the current study accomplished two major goals, which involved evaluating (a) whether belief in feedback affects later reporting of the correct information, and (b) whether explanations increase accuracy by increasing feedback belief. Regarding the first goal, the present results provide the first evidence that readers' belief in the feedback is associated with later reporting of the correct information. As shown in Figure 1 and Figure 2, the less readers believed the feedback, the less often they responded correctly on the final test.

Though our evidence establishes a relationship between belief in feedback and knowledge revision, it does not indicate *why* this relationship occurs. As noted in the introduction, the KReC principles of integration and competing activation may explain this relationship (Kendeou & O'Brien, 2014). First, feedback belief may affect the integration of the feedback with the misconception and other prior knowledge. Readers who do not believe the feedback may reject the feedback and fail to integrate it with their prior knowledge. Second, even if integration occurs, feedback belief may affect the competing activation between the feedback and the misconception when the reader later encounters the misconception. Specifically, the reader may use their feedback belief to accept or reject the feedback, resolving the competing activation. As noted previously, these possible routes for the effect of feedback belief are not mutually exclusive. In some cases, readers may not integrate the feedback because of their low feedback belief. In others,

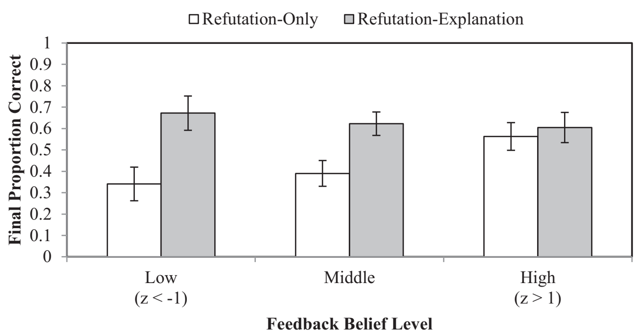

Figure 2. Average accuracy on the final true–false misconception test for misconceptions answered incorrectly on the initial test broken down by explanation group (refutation-only and refutation-explanation) and low ($z < -1$), middle ($-1 < z < 1$), and high ($z > 1$) standardized scores of feedback belief ratings in Experiment 2. Error bars represent the between-participants standard error for each group.

even if the reader integrates the feedback, they may opt to reject it during competing activation because of their low feedback belief. Although the current results cannot disentangle the contribution of each of these routes to the effects of feedback belief on knowledge revision, future studies should investigate the contribution of each route.

In regard to the second major goal, these results also reveal one of the benefits of providing explanations to support the refutation: They affect whether people believe that refutation. Not only did explanations increase belief in the feedback (see Table 1)—this increase in feedback belief partially explained how explanations boost later accuracy. Furthermore, explanations boosted accuracy more when participants did not believe the initial refutation (see Figure 1) perhaps because explanations boost feedback belief more when this belief is initially lower (as supported by item-level analysis in Experiment 1). Although this study suggests explanations benefit accuracy by increasing feedback belief, explanations likely benefit accuracy for other reasons as well. First, explanations may lead readers to spend more time processing and elaborating on the correct answer. The additional processing and elaboration may allow the correct answer to become more integrated with the misconception and other relevant knowledge. Second, as argued by Kendeou and colleagues (2014), explanations provide additional information for the reader to integrate with the misconception and other prior knowledge. With this extra information, the correct answer (vs. the misconception) may be more highly activated during subsequent competition between the correct answer and the misconception. Additional studies should be conducted to estimate the joint contribution of these mechanisms (integration, competing activation, and feedback belief) to boosting later accuracy.

In addition, a key implication of these findings is that any factor that affects belief in the feedback should also influence knowledge revision, and hence could be targeted by interventions to improve knowledge revision. Factors such as perceived plausibility (Lombardi, Sinatra, & Nussbaum, 2013) and source credibility (Bråten, Strømsø, & Salmerón, 2011) could influence whether a reader believes the feedback. For instance, a reader who receives feedback from a source they do not think is credible may be less likely to believe this feedback. If so, then a potentially effective technique may be having a credible source provide the refutations and explanations.

Finally, the results of the current study may only apply on tests for which participants can answer correction merely by knowing the incorrect answer. In the current study, we tested participants' knowledge using true–false tests of people's misconceptions. As argued by Van Loon and colleagues (2015), performance on true–false tests may primarily reflect whether participants have successfully outdated the misconceptions; that is, *outdating* refers to cases in which people know a misconception is wrong. When responding to a true–false question, participants only need to recall that the misconception is incorrect to provide the correct answer ("no, bulls are not enraged by the color red"), and do not need to recall the correct information (that bulls are color blind and feel threatened by the matador). By contrast, performance on open-ended tests may reflect whether knowledge has been successfully *updated* with the new information. Accuracy on such tests is based on knowing the correct answer and, when provided, the supporting explanation. The current study indicates that feedback belief impacts the success of outdating, but whether feedback belief impacts updating is an unresolved mystery. However, we expect that feedback beliefs likely predict updating as well, given prior evidence of a strong relationship between outdating and updating (Van Loon et al., 2015).

Initial Confidence and Hypercorrection for Misconceptions

The results of the current study also have implications for the relationship between initial confidence and final test accuracy, which is relevant to the hypercorrection effect. First, we found evidence that feedback belief significantly mediates the relationship between confidence and accuracy. Specifically, increased confidence correlated with lower feedback belief, and lower feedback belief correlated with poorer performance on the final test. Accordingly, the mediating role of feedback belief may have reduced the magnitude of the hypercorrection effect in the present experiments, which was only significant in Experiment 2 (see refutation-explanation group in Table 3).

Second, the results replicate recent findings indicating that confidence in the initial misconception magnifies the benefit of the explanation (Van Loon et al., 2015). To understand why, consider results from Experiment 2 presented in Table 3. The improvement in accuracy for the refutation-explanation group (over the refutation only) was greater for misconceptions initially provided with high confidence (a difference of .34) than for misconceptions initially provided with low confidence (.13). Even so, we did not find consistent evidence for the traditional hypercorrection effect wherein accuracy on the final test improves more for higher (vs. lower) initial confidence *within a group*. In particular, the refutation-explanation group in Experiment 2 demonstrates this relationship (see Table 3), yet the similar group in Experiment 1 did not demonstrate it, suggesting that the traditional hypercorrection effect is not robust in the current context.

Most interesting, the principle of integration within the KReC framework can explain the moderating effect of initial confidence (in which explanation is more effective with higher initial confidence). Recent research suggests that initial confidence in incorrect knowledge (e.g., bulls are enraged by the color red) may reflect, in part, access to related knowledge (e.g., knowledge of bulls, bull fighting, bull riding; Metcalfe & Finn, 2011; Sitzman et al., 2014). Those who access more knowledge should have greater confidence (e.g., Koriat, 1993) and have more information to integrate with the explanation, leading to greater knowledge revision. This related knowledge (e.g., bull riders anger bulls) may also integrate with the explanation (e.g., matadors anger bulls) better than the misconception (e.g., the color red angers bulls). This may also explain why initial confidence *negatively* predicted reporting of the correct answer when only a refutation is given (see Table 3), as the refutation provides little context to allow integration with related knowledge.

One issue that remains unresolved is why the hypercorrect effect was not robust in the current studies, whereas prior research has consistently demonstrated the hypercorrection effect (e.g., Butler et al., 2011; Butterfield & Metcalfe, 2001, 2006; Fazio & Marsh, 2009, 2010; Sitzman et al., 2014; Van Loon et al., 2015). Although speculative, we suspect that this discrepancy may result from feedback belief playing a larger role in the current context, and less of one in much of the prior research, which has used simpler materials (e.g., general knowledge questions). For instance, when told that the answer to "What is the capital of Australia?" is not Sydney but is Canberra, people may consistently have high feedback belief—they do not need an explanation but merely believe the feedback regardless of their initial confidence in their inaccurate response. In fact, people may believe the feedback because they knew the correct answer all along but just did not retrieve it when initially questioned (Metcalfe & Finn, 2011). In such cases, feedback belief would not play a role in the hypercorrection effect, and other mechanisms explain the effect, such as knowing the answer all along (as mentioned above) or being surprised by the feedback (Butterfield & Metcalfe, 2006). Future research will be required to systematically examine reasons for the discrepancy.

Conclusion

The current research indicates that beliefs in feedback (the refutation) are substantially related to the correction of misconceptions. Specifically, people were less likely to report correct concepts when they did not initially believe the feedback. Furthermore, explanations counteracted low beliefs in the feedback and hence were related to significant improvements in knowledge revision. Thus, when correcting someone who believes bulls are enraged by the color red, the correction needs to be believable to be effective. In fact, the current study suggests that the true explanation—that bulls are colorblind and enraged by the presence of the matador—improves knowledge revision in part because people believe this explanation. By working with people to understand why they do not believe some feedback, we can develop more believable feedback and explanations that should, in turn, reinforce knowledge revision.

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