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Unreliable and Anomalous: How the Credibility of Data Affects Belief Revision

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Abstract

Individuals often revise their belief in conditional relations when faced with contradictory evidence. However, individuals' beliefs about the reliability of particular sources may influence their acceptance of such evidence. In three experiments, we examined effects of source credibility on belief revision. Participants were presented with a description of a mechanical system comprised of conditional relations with either uniform or randomly alternating components. Next, participants received a contradictory observation from a reliable, unreliable, or neutral source. When evidence came from an unreliable source, participants often failed to revise the conditional belief, regardless of the design of the system.

Keywords: Belief revision; reasoning; source credibility

Influences on Belief Revision

What causes people to change what they know to reflect newly learned information inconsistent with their prior beliefs? Extant research in cognitive science suggests that individuals often revise their beliefs in conditional relationships (e.g., If A, then B) when presented with new information that contradicts those existing beliefs (Elio & Pelletier, 1997). Subsequent research building from this tradition has investigated factors that influence the likelihood of belief revision following contradictory or anomalous observations (Chinn & Brewer, 1993). For example, Markovits and Schmeltzer (2007) examined the likelihood of revising a belief in a conditional relationship when that relationship was embedded in a set of other conditionals. They presented participants with an electronic device consisting of a set of conditionals; when participants clicked a button in the top row, it would light up a corresponding button in the bottom row (e.g., clicking on a button labeled 'AA' would light up a box labeled 'BB'). The project assessed the effects of variability within the system of conditionals, and the experience participants had with the initial belief, on belief revision. Participants were presented with a contradictory observation, such as:

John is a student who used this program last night. He clicked on AA, but he says that BB did not light up.

Participants were asked to endorse one of two statements. Participants were considered to have revised their belief in the AA-BB relationship if they agreed that, "It is not always true that if one clicks on AA, then BB will light up." This statement suggests that the conditional is no longer true. If, instead, participants agreed that, "John did not click on AA," they were considered to have retained the AA-BB belief. In this case, the contradictory observation was rejected, but the conditional belief was maintained.

Participants were more likely to revise their belief in the AA-BB relationship when the system contained a button that operated randomly, lighting up one of two boxes in a randomly alternating fashion, as compared to a version of the system with a uniform operation, in which each button lit up one and only one box. In this latter uniform condition, participants were also less likely to revise the AA-BB belief if they had extended rather than limited experience with the relationship supporting that belief (e.g., pressing each button 5 vs. 15 times); in contrast, participants in the random condition were equally likely to revise the AA-BB belief regardless of prior experience with the relationship.

Thus, the presence of a randomly alternating element within a system of conditionals reduced participants' certainty in the AA-BB belief, and increased the likelihood of revising that belief when faced with a contradictory observation. These results indicate that belief certainty, prior experience, and systemic variability all influence the likelihood of revision following contradictory evidence. These features of the initial belief, or the context of that belief, reveal some conditions under which beliefs change.

The Quality of Contradictory Evidence

In everyday experiences, however, a number of more pragmatic factors can potentially affect belief revision. For example, the degree to which contradictory evidence is perceived as reliable, honest, and trustworthy might affect the likelihood of belief change. Chinn and Brewer (1993) note that the likelihood of belief revision in the event of anomalous data may depend on the credibility of the source of those data. Individuals may be more willing to accept contradictory observations from sources they know to be reliable, relative to sources they deem untrustworthy. Contradictory evidence provided by untrustworthy sources, therefore, may be much easier to discount or reject.

A large body of research from social psychology has evaluated the impact of source credibility on beliefs and attitude change. These studies have demonstrated that, on average, credible sources are persuasive, influencing beliefs and attitudes more so than non-credible sources (see Pornpitakpan, 2004 for a review). People are more likely to agree with messages provided by trustworthy sources and to disagree with messages provided by untrustworthy sources.

The current study employed a theoretical perspective from persuasion research to determine whether credibility influences beliefs about conditional relationships. In three experiments, we used an existing research paradigm (Markovits & Schmeltzer, 2007) to investigate whether the likelihood of revision following experiences with contradictory evidence could be influenced by whether that evidence was provided by a trustworthy, untrustworthy, or neutral source. If source credibility influences belief change, we would expect a greater likelihood of revision when contradictory evidence is provided by a trustworthy source, relative to both neutral and untrustworthy sources.

Individuals should be more likely to accept a contradictory observation from a trustworthy source, potentially revising their initial beliefs in order to resolve the inconsistency between the belief and the observation. An untrustworthy source should lead to minimal revision; individuals may discount the observation provided by an untrustworthy source, making initial belief retention more likely. In addition, we investigated whether any effects of source might interact with effects of systemic variability. Recall that the presence of randomness within a system of conditional relationships should lead to an increased likelihood of belief revision, relative to a uniform system.

Experiment 1

Participants were presented with a conditional belief embedded within a mechanical system containing a set of conditional relationships; the device had either uniform operation or contained a randomly operating element. An observation contradicting the conditional belief was then provided by a trustworthy, untrustworthy, or neutral source.

We predicted that participants would be more likely to engage in belief revision when the device contained a randomly operating element than when it operated uniformly. We also generated hypotheses with respect to the effect of source credibility on the likelihood of revision. A *source dependence hypothesis* predicts that individuals' acceptance or rejection of a contradictory observation will be influenced by the reliability of the source of that observation. In contrast, a *source independence hypothesis* suggests that the quality of the source may have little effect on an individual's belief in a conditional relation. This view is not a straw argument: Source credibility may be less influential when participants focus on the contents of the message that a source provides (i.e., the contradictory observation; Petty & Cacioppo, 1986). If participants ignore information about source credibility and attend solely to the contradictory observation and the device, we would expect revision to be equivalent across sources.

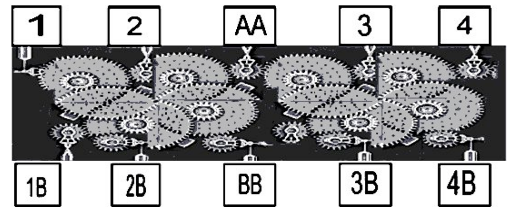

Figure 1: Image of mechanical device, Experiments 1-3.

Method

Participants. 124 Northwestern University undergraduates participated for either course credit or cash payment.

Materials and design. The materials used by Markovits and Schmeltzer (2007; Exp.2), were modified and compiled into a two-page booklet. The booklet first provided a general description of the device. This text description stated that some students had tested the device for an entire day. A graphical representation of the device followed (see Figure 1). The device featured two rows of five containers. Directly beneath the bottom row of containers, a description of the testing results for each top-row container was printed. The first four containers all operated in the same way: A marble placed in the top container would fall into the container directly below it (e.g., "Each time a marble was put into AA, it always fell into BB."). The result for container 4, the right-most container, was covered by a Post-it sticker. Container 4 had one of two possible results. In the *uniform* condition, the result below container 4 stated, "Each time a marble was put into 4, it always fell into 4B." In the *random alternation* condition, the result stated that "Each time a marble was put into 4, it sometimes fell into 4B, and sometimes into BB, in a totally unpredictable manner." Thus, in the uniform condition all of the containers operated identically, while the random device contained a single, randomly alternating element.

On page two of the booklet, participants were asked, "Suppose that you try the device and you put a marble into AA. According to you, is it true that the marble will fall into BB?" Respondents circled either "YES" or "NO" and then rated the certainty of their response (0% to 100%).

Next, statements constituting the report of an observation that contradicted the previously described AA-BB relationship were provided by a source varying in reliability. In the neutral source condition, these statements read: "John is a student who used the device last night. He claims that he put a marble into AA, but that the marble did not fall into BB." This description was identical to that used in prior work. In the reliable source condition, John was also described as a trustworthy honors student:

John is an honors student who used the device last night. He is hard working and consistently earns top grades. He wants experience working in a laboratory, so he has volunteered to help test this and several other devices during evening sessions. He claims that he put a marble *into AA, but that the marble did not fall into BB.*

In contrast, in the unreliable source condition, John was described as being irresponsible and inattentive:

John is an undergrad who used the device last night. He rarely takes his responsibilities seriously and is often careless in his assignments. Although he has volunteered to test devices in the lab, he doesn't complete tasks carefully because he thinks he isn't being paid enough. He claims that he put a marble into AA, but that the marble did not fall into BB.

These statements were followed by the critical belief revision question. Participants selected which of two statements they considered most believable. The *revise* statement read, "It is not always true that if one puts a marble into AA, then it will fall into BB." The *reject* statement read, "It is not true that John put a marble into AA." Statement order was counterbalanced across the versions of the booklet. Throughout all experiments presented here, participants who selected the revise statement were counted as having revised their belief in the AA-BB relationship, while participants who selected the reject statement were considered to have retained this belief.

Procedure. Participants were assigned to one of twelve experimental booklets constructed by fully crossing the Source, Device, and Statement Order factors. The experimenter read aloud the text description of the device and read the first four container results (i.e., 1, 2, AA, 3) while the participant followed along. The participant was then instructed to remove the Post-it note in order to learn the results for container 4. The experimenter read aloud the result, and the participant was instructed to answer the questions on page 2 of the booklet without further instruction from the experimenter.

Results and Discussion

Four participants were excluded for failure to follow directions; analyses reported below were conducted on the remaining 120 participants.

All participants expected that a marble placed into container 4 would fall into 4B, indicating that they expected the same uniform pattern of results that had been observed for all other containers. Table 1 presents the mean proportion of participants who agreed that rejecting the initial belief was the most believable option, as a function of device condition and source.

Table 1. Mean proportion of belief revisions, Experiment 1.

Source	Uniform	Random	*Mean*
Trustworthy	0.47	0.65	0.56
Untrustworthy	0.15	0.20	0.18
Neutral	0.50	0.52	0.51
Mean	0.37	0.46	

We examined the degree to which participants engaged in belief revision as a function of the experimental conditions using logistic regression analyses with revision (or not) of the AA-BB belief as the dependent variable. Model 1 included Device, and Trustworthy and Untrustworthy sources (with Neutral source as reference category) as predictors. This analysis indicated only that the probability of belief revision was less likely when the contradictory observation was provided by an untrustworthy source, in contrast to a neutral source ($\beta = -1.61$, Wald $\chi^2 = 9.46$, Odds Ratio = 0.20, $p < 0.01$). Model 2 added two interaction terms, Trustworthy by Device and Untrustworthy by Device, as predictors; neither of these predictors significantly influenced the likelihood of revision. There was no effect of Device on revision. There was also no difference in the likelihood of revision between Trustworthy and Neutral sources.

These analyses suggest that when an unreliable source offers anomalous data, individuals are more likely to reject that contradictory observation and less likely to revise their initial beliefs, in contrast to when information is provided by either trustworthy or neutral sources. Individuals appear to readily reject the unreliable source's observation, retaining their initial belief. The findings of Experiment 1 demonstrate initial evidence that source credibility influences conditional belief revision.

In contrast to previous work, however, we obtained no effect of systemic variability on the likelihood of revision. Participants were equally likely to revise the AA-BB belief regardless of whether the device was uniform or random. One potential explanation for this is that participants may not have fully attended to the device's design. While we recreated the methods used in previous experiments on belief revision as closely as possible, participants' attention to the device in the initial phase of the experiment may have been insufficient. Recall that participants were asked to both read and listen to a verbal description of the device while learning about its operation. This design may have incurred a substantial processing load, perhaps by requiring participants to attend to multiple modalities simultaneously (Mayer & Moreno, 2003), or by setting a pace for understanding that did not allow for careful consideration of the system. Experiment 2 was designed to reduce these potential limitations and to encourage participants' attention to the device's operation.

Experiment 2

To address the issues outlined above, we drew on theories and principles derived from research on multimedia learning and how individuals learn from a multimodal combination of words and images. In Experiment 1, participants learned about the device through text, narration, and an image. The modality principle of multimedia learning suggests that presenting verbal information in the form of auditory narration, thereby allowing learners to rely on multiple sense modalities to process information, can reduce cognitive load (e.g., Mayer & Moreno, 2003). Accordingly, we eliminated the printed descriptive text on the experimental booklet, hoping to facilitate participants' understanding of the device's operation.

We also provided additional guidance with respect to the device's operation, to help make the random or uniform mechanism particularly salient. The experimenter now provided pointing gestures, coupled with verbal narration, to introduce the device to participants. Pointing gestures are commonly used in conversation to encourage joint attention and facilitate communication about objects and pictures (Clark & Marshall, 1981). We hoped the gestures would help increase attention to the device's operation, and in turn, uncover any effects of device condition on revision.

Our predictions were identical to Experiment 1. In addition, we predicted that our modifications to the experiment would enhance participants' attention to the design of the device, and thus increase the likelihood of observing an effect of systemic variability. However, if our modifications failed to encourage adequate attention to the device, we would expect little effect of device condition on revision, as in Experiment 1.

Method

Participants. 144 Northwestern University undergraduates participated for either course credit or cash payment.

Materials and design. The materials were identical to those in Experiment 1, with the exception that the descriptive text was omitted from the experimental booklet.

Procedure. The procedure was modified from Experiment 1 in the following ways. The experimenter read aloud the verbal description of the device, and used pointing gestures to accompany their verbal description of the device's operation. The experimenter pointed at each container as it was mentioned in the testing results (e.g., in the random alternation condition, where a marble placed into 4 could fall out of either 4B or BB, the experimenter pointed at container 4, then to 4B, then back up to 4, then to BB, as she explained this result).

Results and Discussion

Data from three participants were excluded for failure to follow directions. In addition, three participants did not predict that a marble dropped in 4 would fall into 4B, and were thus excluded. Analyses reported below were conducted on the remaining 138 participants.

Table 2 presents the mean proportion of participants who revised their belief in the AA-BB relationship, by condition.

As in Experiment 1, logistic regression analyses with revision (or not) of the AA-BB belief as the dependent variable were conducted. Model 1 included Device, and Trustworthy and Untrustworthy sources (with Neutral source as reference category) as predictors. Because preliminary chi-square tests of independence revealed a significant effect for Statement Order on revision [χ^2 (1, N=138) = 3.90, $p < 0.05$], this variable was also included as a factor in the regression analyses.

Table 2. Mean proportion of belief revisions, Experiment 2.

Source	Uniform	Random	*Mean*
Trustworthy	0.61	0.68	0.65
Untrustworthy	0.09	0.21	0.15
Neutral	0.21	0.48	0.34
Mean	0.30	0.46	

As in Experiment 1, the likelihood of revision was reduced when the contradictory observation was provided by an untrustworthy compared to a neutral source (β = -1.12, Wald χ^2 = 4.49, Odds Ratio = .33, $p < 0.05$). Revision of the AA-BB belief was more likely when the observation was provided by a trustworthy source, compared to a neutral source (β = 1.33, Wald χ^2 = 8.50, Odds Ratio = 3.80, $p < 0.01$). Additionally, the probability of belief revision was significantly higher when the device contained a randomly operating element rather than a uniform operation (β = 0.82, Wald χ^2 = 4.07, Odds Ratio = 2.27, $p < 0.05$). Finally, we observed a marginally significant effect of question order (β = 0.76, Wald χ^2 = 3.60, Odds Ratio = 2.15, $p = 0.058$), such that participants were more likely to engage in belief revision if the "revise" option appeared before the "reject" option in the experimental booklet than if they appeared in the opposite order. Model 2 added Trustworthy by Device and Untrustworthy by Device interaction terms as predictors, and neither of these predictors significantly influenced the likelihood of revision. That is, the impact of device on the likelihood of belief revision did not vary between trustworthy and neutral sources, or between untrustworthy and neutral sources.

These results suggest that the modifications to the experiment encouraged participants to attend to the device's condition, as the likelihood of revision was influenced by the design of the device. As predicted, participants were more likely to revise their belief in the AA-BB relationship when the device contained a randomly alternating element rather than a uniform operation, which is consistent with the effect of systemic variability observed in prior work (Markovits & Schmeltzer, 2007). Examination of the mean proportion of belief revision suggests that this effect was primarily driven by the neutral source condition. The likelihood of revision in the random condition was 27 percentage points higher than in the uniform condition for these participants; in contrast, the revision differences between the random and uniform devices for the other source conditions were considerably smaller.

Regarding credibility effects, we replicated the findings of Experiment 1. Participants were less likely to revise their belief in the AA-BB relationship when contradictory evidence was provided by an untrustworthy source, relative to both neutral and trustworthy sources. In addition, participants were more likely to revise their belief in the conditional when that same contradictory observation was provided by a trustworthy source compared to a neutral source. The addition of instructions that focused participants' attention on the device enhanced the effects of the device's design, defining additional conditions that potentially influence belief revision.

Experiments 1 and 2 provide evidence for the *source dependence hypothesis*, but the presence of conflicting effects of device condition on revision across these experiments begs further investigation. Experiment 3 provides an additional analysis of the role of the device's operation in participants' revision decisions.

Experiment 3

One potential explanation for the mixed findings of the device's operation on participants' beliefs might be due to difficulties in understanding what it means for a device to operate randomly. People often demonstrate misunderstandings of chance and randomness. Thankfully, while people's intuitive notions of what "randomness" means can be quite inconsistent with how the laws of chance truly operate, training on principles such as the law of large numbers can improve their ability to employ statistical reasoning to solve problems (Fong, Krantz, & Nisbett, 1986). Thus, it may be possible to enhance participants' ability to distinguish between devices with uniform and random operation by providing them with a clear definition of what it means for a component to operate randomly. Accordingly, we incorporated additional clarification of the operation of the system in terms of what was meant by operating in a random or uniform fashion. The goal was to ensure that participants understood what was meant by a randomly operating system.

If this additional detail regarding the device's operation improved individuals' understanding of the device, we expected to observe greater differentiation between the likelihood of belief revision for uniform and for random devices, as compared to the pattern obtained in Experiment 2. Specifically, participants should be less likely to revise in the uniform condition, and the difference in proportion of revisions between random and uniform device conditions should be larger, in contrast to Experiment 2. However, if these instructions provided no added benefit to participants' understanding, or the rest of the experimental manipulation obviated any impact of systematic variability of the device, we would expect the effects obtained for device condition to be identical to those obtained in the previous experiment.

Method

Participants. 144 Northwestern University undergraduates participated for either course credit or cash payment.

Table 3. Mean proportion of belief revisions, Experiment 3.

Source	Uniform	Random	*Mean*
Trustworthy	0.33	0.48	0.40
Untrustworthy	0.05	0.04	0.04
Neutral	0.08	0.43	0.26
Mean	0.15	0.32	

Materials and design. The materials were identical to those in Experiment 2.

Procedure. The procedure was identical to Experiment 2, with the addition of extra detail about the device's uniform or random operation. In the random condition, the experimenter told participants that container 4 operated in a totally random way, such that "we cannot predict at all whether a marble placed in 4 will come out of 4 or out of 4B. The outcome will happen completely by chance." In the uniform condition, the experimenter stated that "If a marble is placed into 4, it will always come out of 4B. This outcome will happen each time we use the device." Thus, the uniform device was described as behaving completely predictably, while the random device was described as having a component with unpredictable behavior.

Results and Discussion

Data from nine participants were excluded for failure to endorse the AA-BB relationship. Analyses reported below were conducted on the remaining 135 participants.

Table 3 presents the mean proportion of participants who revised their belief in the AA-BB relationship by condition.

Logistic regression analyses were conducted. Model 1 included Device, and Trustworthy and Untrustworthy sources (Neutral as reference category) as predictors.

The odds of belief revision were significantly reduced when an untrustworthy source provided the contradictory observation, compared to a neutral source ($\beta = -2.04$, Wald $\chi2 = 6.31$, Odds Ratio = .13, $p < 0.05$). The odds of revision did not differ between trustworthy and neutral sources ($\beta = .77$, Wald $\chi2 = 2.60$, Odds Ratio = 2.16, $p = 0.11$). In addition, revision of the AA-BB belief was also more likely to occur when the device contained a randomly operating element, in contrast to a uniform operation ($\beta = 1.07$, Wald $\chi2 = 5.46$, Odds Ratio = 2.91, $p < 0.05$). The interaction terms added in Model 2 were not significant, but a linear probability model analysis revealed a significant interaction, such that the effect of device condition was significant in the neutral source condition, but not in the untrustworthy source condition ($\beta = -0.35$, $t = -2.12$, $p < 0.05$). Those in the untrustworthy source condition were not influenced by the condition of the device.

These results are consistent with those of the previous studies: When a contradictory observation is provided by an untrustworthy source, participants are less likely to revise their belief to accommodate that observation, relative to both trustworthy and neutral sources. In addition, this experiment replicated the effects of systemic variability obtained in Experiment 2 and prior work. Further, while additional detail about the device's operation reduced the overall likelihood of revision, the difference between random and uniform devices in the neutral source condition was 35 percentage points, as compared to 27 in Experiment 2, suggesting that our manipulations effectively enhanced understanding of the operation of the device.

General Discussion

In these three experiments, we examined whether the credibility of a source might influence the likelihood of belief revision. Consistent with a *source dependence hypothesis,* participants were less likely to revise their belief about a conditional relationship when evidence contradicting that relationship was provided by an untrustworthy source, as compared to when it was provided by a trustworthy or neutral source. Neutral and trustworthy sources, across the experiments, encouraged similar levels of revision. In addition, devices with randomly alternating components were more likely to encourage belief revision than uniform devices, except under conditions of relative cognitive load, as in Experiment 1; when participants' ability to process the components of the system was hindered, the likelihood of revision was only influenced by source credibility, while both factors had an impact on revision with a multimodal presentation of the device description. We also observed little in the way of an interaction between credibility and systemic variability, except in Experiment 3. When participants clearly understood the unpredictable nature of the system's operation, the tendency to revise was greater with the presence of a random element, while the presence of an untrustworthy source eliminated any effects of randomness on the odds of revision.

One potential concern with this project is the possibility of task demands. Making participants aware of source descriptions may have incurred decisions about not just the device itself, but also assumptions about whether they might be expected to reject an unreliable source's contribution. We note the data did not reveal wholesale shifts in beliefs as a function of source, which one might expect if task demands were particularly influential. Nevertheless, further methodological refinements permitting a subtler test of source credibility might help alleviate concerns about task demands in future extensions of this work. These extensions are important, as demonstrations of the effects of credibility on belief revision have remained understudied.

Instead, most accounts of belief revision have focused on the nature of conditional relationships, examining how understandings of different premises can change the ease with which people encode, update, or modify what they know about the world. Those projects have provided little consideration as to how the pragmatics of these logical scenarios, and people's familiarity with such pragmatics, might instill expectations for probabilities, reliabilities, and the nature of conditional relationships. In previous work, the underlying logic offered by particular premises and observations could be reinforced or mitigated by prior knowledge people had about the world (e.g., Griggs & Cox, 1982; Johnson-Laird, Legrenzi, & Legrenzi, 1972). In fact, the results of the systemic variability of the device may have arisen in part from everyday expectations (i.e., using items that break randomly; slot machines; etc.). But additionally, the current findings suggest that beliefs about the sources who provide information about conditional relationships can similarly inform people's expectations about causal (and other types of) relationships in the world. A more complete account of the conditions under which revision occurs necessitates consideration of such social and pragmatic influences on cognition.

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