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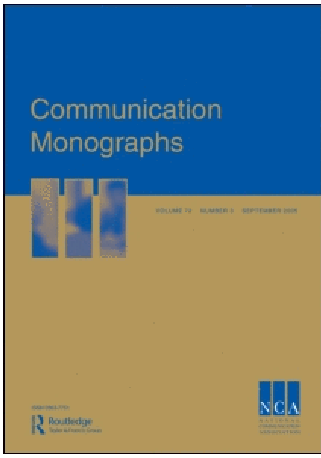

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The Comparative Statics and Dynamics of Beliefs: The Effect of Message Discrepancy and Source Credibility

Sungeun Chung, Edward L. Fink, & Stan A. Kaplowitz

Two models of belief change, Laroche's (1977) comparative statics model and the single-push with friction dynamic model (Kaplowitz, Fink, & Bauer, 1983), were combined and tested. Beliefs about two issues (criminal sentencing and tuition increase) were measured every 77 ms, N = 95. *Eleven time points from each participant's belief trajectory were analyzed. Message discrepancy and source credibility were manipulated. As predicted, belief change monotonically increased over time and the rate of belief change decreased for both issues. For the criminal-sentencing issue, the relationship between message discrepancy and belief change was found to be positive and monotonic for messages from a high-credibility source but nonmonotonic for messages from a low-credibility source. For the criminal-sentencing issue the predicted over-time increase of the effect of message discrepancy on belief change for a high-credibility source and an over-time increase of the effect of source credibility on belief change were found*

Keywords: Comparative Statics; Cognitive Dynamics; Message Discrepancy; Source Credibility; Belief Trajectories; Decision Making

> In scientific thought we adopt the simplest theory which will explain all the facts under consideration and enable us to predict new facts of the same kind. The catch in this criterion lies in the word "simplest." It is really an aesthetic canon

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> such as we find implicit in our criticisms of poetry or painting. The laymen finds a law as $dx/dt = K(d^2x/dy^2)$ much less simple than "it oozes," of which it is the mathematical statement. The physicist reverses this judgment, and his statement is certainly the more fruitful of the two, so far as prediction is concerned. (Haldane, 1927, p. 227)

In a typical persuasion study, participants' beliefs or attitudes are measured only once after message receipt; such designs compare the responses of participants in two groups and infer change based on the result of this comparison. This type of study implicitly assumes that immediately after receipt of a persuasive message, the receiver's belief position changes and will not change again until encountering new information about the belief object. However, several studies have shown that beliefs change in the absence of new external information (Brehm & Wicklund, 1970; Chung & Fink, 2008; Fink, Kaplowitz, & Hubbard, 2002; Kaplowitz, Fink, & Bauer, 1983; Tesser, 1978; Vallacher, Nowak, & Kaufman, 1994; Walster, 1964). These studies suggest that beliefs or attitudes that have changed as a result of an experimental induction may not be in equilibrium at the time of measurement. The above typical assumption about belief change after receipt of a message results from the common lack of attention to the role of time in the process of persuasion (Kaplowitz & Fink, 1988).

In spite of the lack of attention to the role of time, several researchers have attempted to theoretically specify the over-time patterns of belief change (e.g., Brehm & Wicklund, 1970; Chung & Fink, 2008; Kaplowitz & Fink, 1982;, Kaplowitz et al., 1983; Tesser, 1978; Vallacher et al., 1994; Walster, 1964). However, in most of these studies, the predicted over-time pattern of belief change was not presented as a mathematical equation but as a verbal statement. As Haldane suggested in the above epigraph, equations prove more precise by providing clearer predictions about the phenomenon under consideration. The present study proposes and tests a mathematical model of belief change over time.

In the present study, a model that predicts the effect of two key persuasion variables—message discrepancy and source credibility—on belief change over time is proposed. Research on the effects of these two variables has a long history in the literature (for message discrepancy, see, e.g., Aronson, Turner, & Carlsmith, 1963; Bochner & Insko, 1966; and Freedman, 1964; for source credibility, see, e.g., Benoit & Strathman, 2004; Birnbaum & Stegner, 1979; Hovland, Janis, & Kelley, 1953; Pornpitakpan, 2004; and Slater & Rouner, 1996). Because the extensive research on message discrepancy and source credibility indicates that these variables have effects on both initial belief change and on final belief change, these effects must be incorporated into a model predicting belief change over time. Message discrepancy and source credibility will be examined for effects on the final equilibrium value of belief change (which is known as comparative statics; see, e.g., Braun, 1990), as well as for effects on the time course of belief change (dynamic, or over time, effects).

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Comparative Statics of Belief Change

Message Discrepancy

Message discrepancy refers to the difference between the belief position advocated by a message, P_M, and the recipient's initial belief position, P_0. $D_P = P_M - P_0$, where D_P is message discrepancy. Message discrepancy and the indicated belief positions (P_0 and P_M) are assumed to be expressed on the same scale. So, for example, if a receiver initially believed that college tuition at some university should be increased by 1% (P_0) and a message advocated a tuition increase at that university of 6% (P_M), D_P would equal 5%.

In most studies of belief change, there exists one posttreatment measure of the respondent's belief position. The posttreatment measure is assumed to occur after the respondent's position has moved to a new equilibrium belief position, P_{Eq}, at which it will remain until new external forces cause it to move. The amount of belief change when the new position has reached equilibrium, y_{Eq}, is $P_{Eq} - P_0$. Two different models predicting y_{Eq} from discrepancy and credibility, the distance-proportional model (Anderson & Hovland, 1957) and Laroche's nonlinear model (1977), are discussed.

The Distance-Proportional Model

The oldest and simplest mathematical model of message discrepancy is the distance-proportional model proposed by Anderson and Hovland (1957):

$$P_{Eq} = P_0 + \beta(P_M - P_0), \tag{1}$$

where β is called the proportionality factor. In this model, belief change is a function of message discrepancy:

$$y_{Eq} = P_{Eq} - P_0 = \beta(P_M - P_0) = \beta D_P. \tag{2}$$

As seen in Equation 2, the distance proportional model predicts that the amount of belief change is a linear function of message discrepancy. Information integration theory (Anderson, 1971; Anderson & Farkas, 1973) makes the same prediction (see also Himmelfarb, 1974; Saltiel & Woelfel, 1975).

However, research on the effect of discrepancy on belief change generates results at odds with the distance-proportional model. For example, Aronson et al. (1963) and Bochner and Insko (1966) found that when a message source had low or moderate credibility, the amount of belief change initially increased with increasing discrepancy but then decreased with further increases in discrepancy; in other words, the pattern of belief change as a function of discrepancy was an inverted-*U*. Thus, Aronson et al. and Bochner and Insko found that the effects of message discrepancy depended, in part, on the associated level of source credibility, requiring that the effects of these two variables on belief change not be examined in isolation.

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Laroche's Nonlinear Model

Laroche (1977) proposed a nonlinear model for the effect of message discrepancy and source credibility on belief change. Laroche's model makes the following assumptions: (a) If the source is perfectly credible and the content of the communication perfectly non-ego-involving, the amount of change is identical to the discrepancy (p. 247); (b) holding both discrepancy and the level of ego involvement constant, the greater the credibility of the source, the greater the change in attitude (p. 248); and (c) holding discrepancy and source credibility constant, the lower the recipient's ego involvement with the contents of the communication, the greater the attitude change (p. 248).

Laroche's model predicts the belief position after the message has been fully processed and the belief has reached a new equilibrium. Laroche's model is a comparative statics model in that it does not take time into account. Laroche's mathematical message discrepancy model is as follows:

$$y_{Eq} = D_P e^{-\gamma D_P};\ 0 \leq D_P \leq 1.00;\ 0 \leq y \leq 1.00;\ \gamma \geq 0, \tag{3}$$

where D_P is message discrepancy and is measured on a proportional scale (i.e., $D_P = 0$ when the position advocated by the source equals the initial position of the receiver, and 1.00 is the maximum possible value of D_P in this context), y_{Eq} is the amount of belief change at equilibrium from the initial position measured on the same scale as D_P, C is source credibility, NI is the degree of noninvolvement of the recipient with the topic of the message and is negatively related to value-relevant involvement, and $\gamma = -k\ln(C) - k'\ln(NI), \gamma \geq 0$. Like D_P, both C and NI are assumed to vary between zero and one, and k and k' are positive coefficients. Johnson and Eagly (1990) discussed three types of involvement in persuasion studies: value-relevant involvement, outcome-relevant involvement, and impression-relevant involvement. Noninvolvement in Laroche's model is negatively related to value-relevant involvement.

In this model, γ determines the degree to which the relationship between message discrepancy and belief change departs from linearity: If $\gamma = 0$, then y_{Eq} linearly increases as D_p increases. If γ is greater than zero but less than one, y_{Eq} monotonically but nonlinearly increases as D_p increases. If γ is greater than 1.00, y_{Eq} increases then decreases as D_p increases, thereby exhibiting a nonmonotonic relationship between message discrepancy and belief change (see Figure 1). Laroche's (1977) model predicts that γ is a decreasing function of credibility and an increasing function of ego involvement. Based on this model, Laroche proposed that the relationship between message discrepancy and belief change is nonmonotonic for low-credibility sources ($\gamma > 1.00$) and is monotonic for high-credibility sources ($0 \leq \gamma \leq 1.00$).

Laroche (1977) estimated the model using the condition means of 12 previously published studies, treating each topic and each combination of credibility and involvement as a separate study. He found that γ was usually greater than zero, indicating that the rate of belief change as a function of discrepancy decreased. He found that, as predicted, γ was generally higher for low-credibility sources than for high-credibility sources and higher for conditions with high involvement than for

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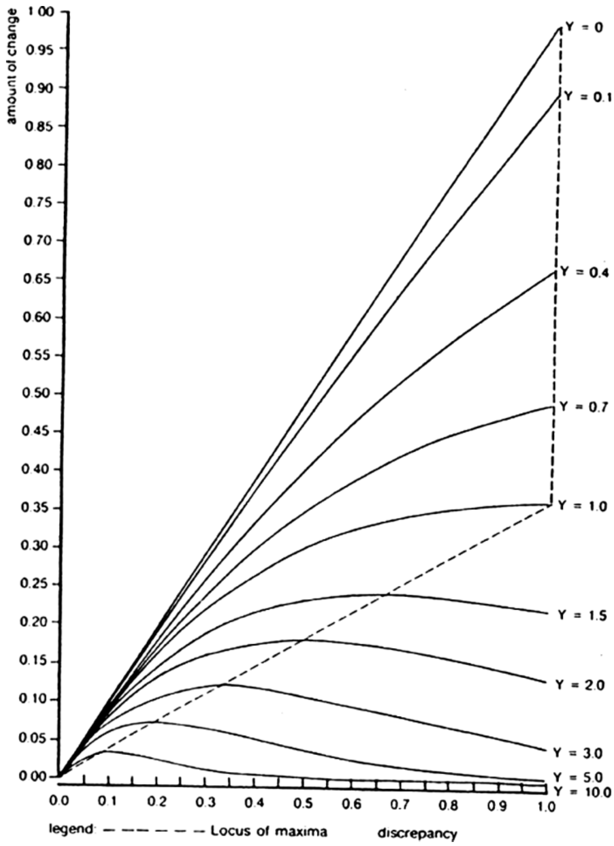

Figure 1 The proposed comparative statics model for different values of the parameter γ (from "A Model of Attitude Change in Groups Following a Persuasive Communication: An Attempt at Formalizing Research Findings" by M. Laroche, *Behavioral Science,* 1977, *22,* 246–257. Copyright 1977. Reprinted by permission of the publisher).

those with low involvement. Fink, Kaplowitz, and Bauer's (1983) mathematical model and Fishbein and Ajzen's (1975) mathematical model basically predict the same relationship between message discrepancy and belief change that Laroche's model predicts.

Dynamics of Belief Change

The present study used belief trajectories to analyze dynamic processes of belief change. A new mathematical model of belief change over time, incorporating the Laroche's (1977) comparative statics model, is tested with these belief trajectories.

Models of Belief Change Over Time

According to McGuire (1960), after receipt of a message, beliefs change and continue to do so for some time after message receipt until a new equilibrium belief value is

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achieved. Thus, belief change is a dynamic process. A dynamic model predicts the time course of belief change (Kaplowitz & Fink, 1982). Tesser's self-generated attitude change model (see Tesser, 1978, for a review), cognitive response models (e.g., Greenwald, 1968; Petty, Ostrom, & Brock, 1981), and Kaplowitz et al.'s (1983) model are among the few models of belief change that attempt to predict the time course of belief change.

Self-Generated Attitude Change and Cognitive Response Models

The self-generated attitude change model suggests that *mere thought* can make an existing attitude more extreme. Tesser and his colleagues provided empirical evidence that, under some conditions, attitudes polarize as a result of mere thought (Millar & Tesser, 1986; Sadler & Tesser, 1973; Tesser, 1976, 1978; Tesser & Conlee, 1975). During judgment, people generate cognitions that are consistent with an existing schema and these schema-consistent cognitions make attitudes more extreme (Tesser, 1978). Thus, beliefs or attitudes are gradually shifted in one direction as schema-consistent cognitions are generated.

The self-generated attitude change model assumes that the direction of belief change while thinking is determined by the respondent's thoughts. The cognitive response model (see Greenwald, 1968; Petty, Ostrom, et al., 1981) makes a similar assumption but also assumes that persuasive messages are those that induce primarily favorable thoughts, whereas unpersuasive messages primarily induce subvocal counterarguments.

Although the cognitive response approach assumes that cognitive responses occur over time, research in this tradition has never examined the time course of belief change after a persuasive message. Instead, the cognitive response approach has focused on belief outcomes at some arbitrary time point after message receipt. Similarly, the self-generated attitude change model suggests a gradual shift in one direction over time, but no functional form for belief change over time has been tested. In other words, these two models (the self-generated attitude change model and the cognitive response approach) provide a general description of the expected trajectory of belief change but do not provide a formal model (e.g., an equation) that unambiguously predicts the time course of belief change.

A Single-Push with Friction Dynamic Model

Kaplowitz et al. (1983) proposed a mathematical model for the over-time pattern of belief change. They used a mechanical metaphor for cognitive systems: Like a physical object, (a) a concept in a cognitive system is assumed to have both a location (one's belief position) and mass (i.e., inertial resistance to acceleration) in a cognitive space; (b) change in a belief or attitude regarding a particular concept is assumed to be equivalent to motion of that concept in the cognitive space; and (c) the motion of a concept is assumed to be governed by Newtonian mechanics.

Consistent with the Newtonian metaphor, the model assumes that there are three kinds of forces operating on the belief or attitude: (a) a single instantaneous push provided by the force of the message, which causes motion (i.e., belief change) toward

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the new equilibrium location; (b) spring-like restoring forces (from interattitudinal constraints and cognitive responses; see Chung & Fink, 2008; Dinauer & Fink, 2005) that cause oscillation around the new equilibrium location; and (c) a frictional force that slows down and eventually stops both the initial motion from the push and any oscillations.

Based on these assumptions, Kaplowitz et al. (1983) developed equations for the motion of a concept. The model posits two components of message-induced motion: movement of a concept from its initial position to a new equilibrium, and oscillation (with damping, i.e., decreasing amplitude) around that movement toward equilibrium (Kaplowitz et al., 1983). In prior research on oscillation, over half of the individual belief trajectories showed some oscillation (i.e., at least one change in direction; see Fink et al., 2002, Table 2.1). Because changes of direction occur at different times for different individuals, estimating a model involving these oscillations is difficult.

In this study, for each experimental combination of discrepancy and credibility the trajectory of average belief change will be examined. This strategy averages out and therefore removes any unreliability in the composite trajectory but also prevents examining individual oscillations. Such an averaging strategy is often followed: Hamblin (1971a, 1971b) discussed this procedure as employed by Galileo as well as employed in his own social-scientific research. Using this procedure, the following questions are investigated:

1. Is the average trajectory in each condition monotonic with respect to time? In other words, does the average belief position in a condition change in one direction over time or are there some conditions in which the belief initially moves in one direction and later reverses direction?
2. If the average trajectory in a condition is monotonic with respect to time, what are the trajectory's parameters and how do these parameters vary as a function of discrepancy and credibility?

Because oscillation in the individual belief trajectories will not be examined, the model for belief trajectories can be simplified to one that ignores the restoring force that may produce these oscillations. The differential equation for this *single-push with friction model* is:

$$m\ddot{y} + c\dot{y} = 0, \tag{4}$$

where m is the mass of the relevant concept (here, a belief object), c is the coefficient of friction, y is the location of the belief relative to the initial location, and $\ddot{y}$ and $\dot{y}$ indicate the second derivative and first derivative of y with respect of time (i.e., acceleration and velocity), respectively. The above equation, based on Newtonian mechanics, specifies that (a) the belief's acceleration is inversely proportion to its mass, and (b) the frictional force is proportional to and in the opposite direction of the velocity of the belief change.

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To interpret this model psychologically, *m* is the degree to which the belief resists change and *c* represents those processes that prevent the belief from continuing to change at a constant rate indefinitely; these processes include forgetting, distraction from other cognitions, and environmental demands (see Kaplowitz et al., 1983, p. 235).

Solving the above differential equation and setting the initial position to 0 leads to the following time course of belief change:

$$y_t = a(1 - e^{-bt}), \tag{5}$$

where t is time, and y_t is the amount of belief change from the initial position at a certain time point t. The model predicts that the belief movement is initially rapid in the direction toward the equilibrium value and that the motion continues in that direction but gradually slows down (see Figure 2). In this model, a reflects the amount of belief change at the new equilibrium position, and b reflects the rate of deceleration of the belief and therefore, indirectly, the amount of time required to reach the new equilibrium (Kaplowitz et al., 1983). In this model, the amount of belief change is initially zero (i.e., when $t = 0$, $y_t = 0$) but approaches a as time increases (i.e., as $t \to \infty$, $y_t \to a$).

The comparative statics of message discrepancy and source credibility on belief change can be incorporated into this dynamic single-push with friction model. Coefficient a in Equation 5, the amount of belief change at equilibrium, is, from Equation 3, equal to $D_p e^{-\gamma D_p}$, which, as explained above, is a function of message discrepancy and credibility.

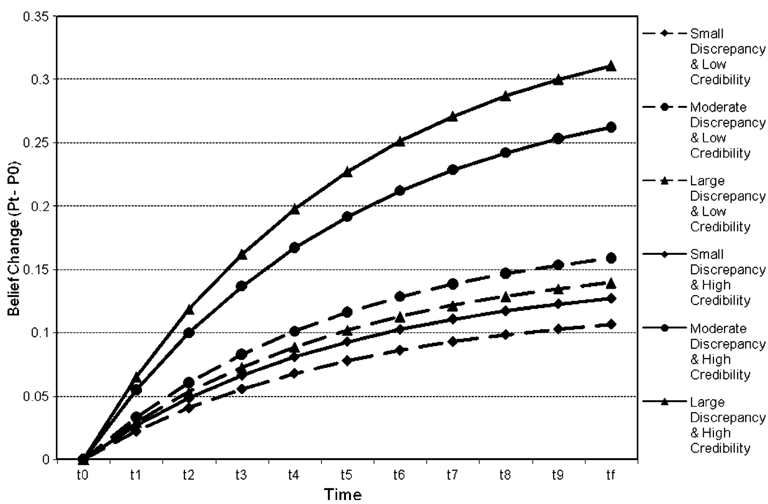

Figure 2 The single-push with friction model of belief change over time incorporating the effects of message discrepancy and source credibility, $y_t = (D_p e^{-\gamma D_p})(1 - e^{-bt})$. $D_p =$ .175 for low discrepancy, .500 for moderate discrepancy, and 1.000 for extreme discrepancy; $\gamma = 0.700$ for high credibility and 2.00 for low credibility; $b = 0.200$.

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Incorporating Equation 3 into Equation 5 generates the following equation:

$$y_t = (D_p e^{-\gamma D_p})(1 - e^{-bt}); \quad 0 \le D_p \le 1.00; \gamma \ge 0. \tag{6}$$

Equation 6 is the extended single-push with friction model, which incorporates both the comparative statics and the dynamics of message discrepancy and source credibility on belief change. Figure 2 exhibits the behavior of the single-push with friction model for some illustrative values of D_p (.175 for low discrepancy, .500 for moderate discrepancy, and 1.000 for extreme discrepancy), γ (0.700 for high credibility and 2.000 for low credibility), and b (0.200). As Figure 2 shows, Equation 6 predicts that (1) in all conditions, belief change increases monotonically over time but the rate of change decreases; (2) if b, the rate of deceleration, is the same for different conditions, then at all time points the belief change induced is proportional to the final belief change for that condition; as a consequence, none of the trajectories cross over time.

As stated above, Laroche's model (1977) predicts that regardless of the level of discrepancy, messages from higher credibility sources should produce greater final belief change. Moreover, the single-push with friction model indicates that at all time points, the belief change induced is proportional to the final belief change for that condition. Therefore, the model predicts that the effect of credibility on belief change (the difference between the change induced by high- vs. low-credibility sources) increases over time. Using Equation 6, Δ_t, the difference in belief change between a high credibility source and a low-credibility source at a certain time point t, is:

$$\Delta_t = [D_p(e^{-\gamma_h D_p} - e^{-\gamma_l D_p})](1 - e^{-bt}); 0 \le D_p \le 1.00; \gamma_h \ge 0; \gamma_l \ge 0, \tag{7}$$

where γ_h is the coefficient of message discrepancy for a high credibility source, and γ_l is the coefficient of message discrepancy for a low credibility source. Equation 7 indicates that when $t = 0$, Δ_t is zero. As time increases, Δ_t increases and approaches $D_p(e^{-\gamma_h D_p} - {}^{-\gamma_l D_p})$, which is Δ_t at equilibrium. Therefore, the effect of source credibility on belief change increases over time.

Studies of source credibility and cognitive responses support the idea that the effect of source credibility on belief change increases over time. For example, Cook (1969) found that participants generated fewer counterarguments for a message from a high-credibility source than the same message from a low-credibility source. Assuming that a message is counter to one's beliefs, (a) messages from a high-credibility source lead to more supportive cognitive responses than messages from a low-credibility source, (b) messages from a low-credibility source lead to more counterarguments than messages from a high-credibility source, and (c) these differing cognitive responses occur after the beginning of judgment.

The model also predicts that for high-credibility sources the difference in belief change between extremely discrepant messages and low-discrepant messages increases over time for high-credibility sources (see Figure 2). On the other hand, for low-credibility sources the model does not predict an increase of the effect of message discrepancy on belief change over time because the relationship between message discrepancy and belief change is nonmonotonic.

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The following hypotheses for the extended single-push with friction model are proposed:

H1: For all levels of discrepancy and credibility, belief change is a monotonic but decelerating function of time (i.e., as time progresses, the belief moves steadily, though at a decreasing rate, toward the final equilibrium position). As a result, the coefficient of time in the proposed single-push model ($-b$) is less than zero, which indicates that belief change from the initial belief position increases monotonically over time but the rate of change decreases.

H2a: For messages from a low-credibility source, the coefficient of message discrepancy in the single-push with friction model ($-\gamma$) is less than -1.00, which indicates that the relationship between message discrepancy and belief change is nonmonotonic for low-credibility sources.

H2b: For messages from a high-credibility source, the coefficient of message discrepancy in the model ($-\gamma$) is between 0 and -1.00, which indicates that the relationship between message discrepancy and belief change is monotonic for high-credibility sources.

H1 and H2 together suggest that the effect of message discrepancy on belief change increases over time for high-credibility sources and the effect of source credibility on belief change increases over time.

A Push-with-Pullback Model

The single-push with friction model assumes that final belief change is determined by the strength of the initial push from the message, which in turn is determined by source credibility, message discrepancy, and possibly other message characteristics. Although cognitive responses may be generated by a message, the net effect of any cognitive responses that occur is assumed to be proportional to the unidirectional push provided by the message.

However, the number and direction of cognitive responses generated during message processing may differ for different levels of message discrepancy and source credibility. Brock (1967) investigated the effect of message discrepancy on recipients' counterarguments when anticipating counterbelief messages. He found that as message discrepancy increased, the number of counterarguments increased. Similarly, Toy (1982) found that as message discrepancy increased, the number of counter-arguments linearly increased and the number of supportive arguments linearly decreased. These counterarguments are expected to induce belief change back toward the receiver's initial position.

Cook (1969) found that fewer counterarguments are generated in response to a message from a high-credibility source than in response to the same message from a low-credibility source. Therefore, especially for low-credibility high-discrepancy messages, the amount of belief change may not monotonically increase over time as the single-push with friction model predicts; rather, there may be belief change that is nonmonotonic with respect to time.

Gilbert, Krull, and Malone (1990) found that people first entertain an assertion as true before they assess the truth value of the information in a message, which they

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term the Spinozan procedure model. According to this model, both true and false information are initially accepted; rejecting a false idea apparently requires the extra cognitive step of unaccepting the idea after viewing it as correct. Assuming that a similar process works for messages that are discrepant rather than factually true or false implies that an extremely discrepant message may be viewed initially as a reasonable assertion, but it may be rejected after further thought regarding it. Thus, in addition to the cognitive response approach, the Spinozan procedure model suggests a possible nonmonotonic relation between time and belief change at some point in the belief change trajectory.

The above discussion suggests that a belief, initially moving in one direction, may be pulled back toward the initial view. The plausibility of nonmonotonicity over time, a push-with-pullback model, was investigated as an alternative to the single-push with friction model. The push-with-pullback model predicts the following:

> $H1_{ALT}$: When source credibility is low and discrepancy is not low, the time course of belief change is nonmonotonic: The initial slope relating time and belief change is positive (i.e., in the direction of the position advocated by the message), but later the slope of the time course becomes and remains negative so that the entire trajectory looks like an inverted U.

Method

Participants and Procedures

To examine the hypotheses predicted by the single-push with friction model and the push-with-pullback model, an experiment was conducted. Ninety-seven undergraduate students at a large Midwestern university participated in the study: 72 females (75%) and 24 males (25%); one participant did not report his or her sex. The responses from two participants were excluded because of their failure to follow experimental instructions, so the valid $N = 95$. All participants indicated their beliefs about two issues as described below. For both issues, message discrepancy and source credibility were manipulated, and belief positions about those two issues were measured relatively continuously over time. These data have received some discussion in Fink et al. (2002) and in Kaplowitz and Fink (1996). However, Fink et al.'s chapter focused on the frequency and the amplitude of oscillation. Although Kaplowitz and Fink gave some attention to the effects of message discrepancy and source credibility on beliefs over time, those chapters did not examine the hypotheses that are tested in this article. The time course of belief change was measured approximately every 77 ms using a computer mouse. This computer-mouse technique has been discussed in Fink and Kaplowitz (1993), Fink et al. (2002), Kaplowitz and Fink (1996), McGreevy (1996), and Wang (1993). Vallacher et al. (1994) used a similar computer-mouse technique to obtain belief trajectories.

At the start of the experiment, all participants were told:

> Social scientists often study people's attitudes and opinions. Typically, this is done by giving them a number of questions and expecting quick answers. There is, however, evidence that the way people answer under these circumstances is

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> sometimes quite different from the way they answer when given more time to think about and reconsider their attitudes.
>
> You are being asked to respond in a way which records the full progress of your attitude or opinion. The way we are going to measure your opinion is with a computer mouse. Some people almost never change their minds. Other people may change their view several times as they think about an issue. . . .
>
> In order to record your view as you think about an issue, we will be giving you this computer mouse. As your view changes, please move the mouse to reflect that change. If your view stays the same, please keep the mouse still.

After these instructions, participants practiced using the mouse to record their instantaneous belief positions and were shown that they could see on a computer screen the belief positions that they had selected.

There were two issues about which the participants responded, one suggesting the sentence for a criminal defendant and the other recommending a level of tuition increase at their university. Participants first received information about the criminal-sentencing issue and indicated their beliefs. They next received information about the second issue, the tuition-increase issue, and similarly indicated their beliefs about this issue.

The two issues differ in terms of personal involvement (Johnson & Eagly, 1990; Petty, Cacioppo, & Goldman, 1981). Compared to the criminal-sentencing issue, the tuition-increase issue had greater consequences on the personal life of participants, who were college students.

The Criminal-Sentencing Issue

Participants responded to a scenario originally created by Kaplowitz and Fink (1991). Participants were first asked to read the (alleged) sentencing guideline for the crime of armed robbery, which stated that 10 years in prison is the appropriate sentence for this crime. Next, participants indicated initial beliefs about the proper sentence for armed robbery.

Participants received information about a judge and his sentence for a defendant allegedly committing this crime. The information contained the text of the speech the judge supposedly delivered when sentencing the defendant. This text was the judge's explanation of the sentence and can be regarded as an attempt to convince others that this sentence was appropriate. After reading the message, participants were asked to think about the proper sentence for this criminal and to indicate this belief using a computer mouse. The scale displayed on the screen allowed participants to choose any sentence between zero and 60 years in prison. Participants indicated when they finished considering the issue and made their final judgment. After completing this task, participants answered other questions related to the manipulations.

Independent variables. Based on pilot studies with undergraduate students at the same university at which this experiment was conducted, Kaplowitz and Fink (1991) found that the median proposed sentence for armed robbery was 10 years. In the present study, the mean belief position (sentence for armed robbery) was found to be 10.12 years ($SD = 4.95$), which was close to the one suggested by the (fictitious) sentencing guidelines.

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To create different levels of message discrepancy, the judge's reported sentence for the defendant was varied. For the low-discrepancy condition, the judge's reported sentence was 17 years, resulting in an average message discrepancy of 7 years; for the moderate-discrepancy condition, the judge's reported sentence was 30 years, thus inducing an average message discrepancy of 20 years; for the extreme-discrepancy condition, the judge's reported sentence was 50 years, resulting in a discrepancy of 40 years. This design kept the ratio of successive discrepancies approximately constant (between 1.67 and 1.76; see Lodge, 1981).

To manipulate source credibility, the judge was described as either not respected in the state (low credibility) or as one of the most respected judges in the state (high credibility). For a manipulation check, participants were asked to evaluate the fairness and expertise of the judge on a seven-point Likert-type scale in which higher values indicated greater credibility. Results of this manipulation check showed that credibility was successfully manipulated: fairness: $M = 4.89$, $SD = 1.06$, for the high-credibility source, $M = 4.09$, $SD = 1.08$, for the low-credibility source, $t(91) = 9.32$, $p < .001$, $\eta = .70$; expertise: $M = 5.33$, $SD = 1.37$ for the high-credibility source, $M = 4.34$, $SD = 0.96$ for the low-credibility source, $t(91) = 8.45$, $p < .001$, $\eta = .66$. Messages were the same in all conditions except for the alleged sentences and the descriptions of the source.

Dependent variable. The dependent variable was the change from the participant's initial belief position about the appropriate sentence for the criminal. Final belief change refers to the amount of belief change between the initial position and the final position. Participant indicated their instantaneous belief positions using a computer mouse and could see the position that they had selected as they moved the mouse on a computer monitor. The set of positions, along with data as to the time of each belief position, allowed the generation of belief trajectories for each individual's belief position; see Figure 3 for an example of a belief trajectory.

Belief trajectories obtained by the computer-mouse technique provided each individual's belief position at more than 100 time points. Over all participants, the minimum number of time points was 111 (8.55 s), the maximum number of time points was 1,908 (146.92 s), $M = 629.67$ (48.48 s), $SD = 433.15$ (33.35 s). The average time to completion of judgment was not significantly different across the different levels of the independent variables: $F(2, 89) = 0.06$, *ns*, for message discrepancy; $F(1, 89) = 0.17$, *ns*, for source credibility; $F(2, 89) = 0.04$, *ns*, for the interaction between message discrepancy and source credibility.

To aggregate these trajectories, eleven time points were selected from each participant's trajectory. The first time point is the starting point, t_0, with belief change $= 0$. The second time point, t_1, is the 10-percentile (first decile) time point of that person's trajectory; the third time point, t_2, is the 20-percentile time point of that person's trajectory, and so on. The last time point, t_f, is the trajectory's end point. In estimating the dynamic model, the 11 ordinal time points are assigned the values from zero through 10.

Means and standard deviations of belief change time points for each condition are reported in Figure 4.

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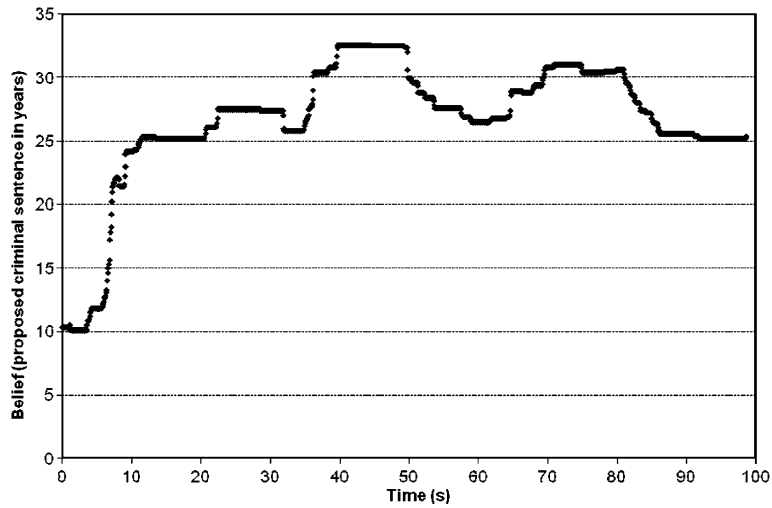

Figure 3 An example of a belief trajectory from an individual participant during judgment in the moderate-discrepancy and high-credibility condition, for the criminal-sentencing issue.

The Tuition-Increase Issue

Participants responded to the tuition-increase issue originally created by Fink et al. (1983). Participants were told that the board of trustees at their university had recently voted to increase undergraduate tuition by 7%, and that there was further

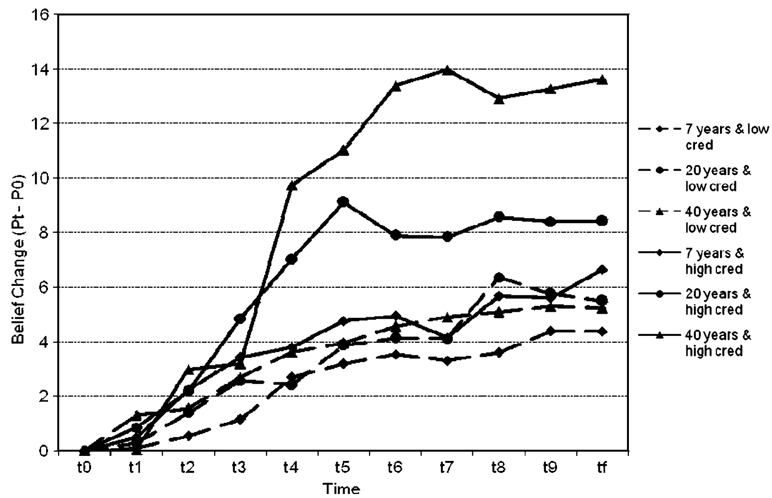

Figure 4 Mean belief trajectories for each experimental condition for the criminal-sentencing issue. The means and standard deviations at each time are t_1: $M = 4.85$ s, $SD = 3.34$ s; t_2: $M = 9.69$ s, $SD = 6.67$ s; t_3: $M = 14.55$ s, $SD = 10.02$ s; t_4: $M = 19.39$ s, $SD = 13.34$ s; t_5: $M = 24.26$ s, $SD = 16.68$ s; t_6: $M = 29.03$ s, $SD = 19.97$ s; t_7: $M = 33.90$ s, $SD = 23.33$ s; t_8: $M = 38.78$ s, $SD = 26.68$ s; t_9: $M = 43.68$ s, $SD = 30.05$ s; t_f: $M = 48.88$ s, $SD = 33.35$ s.

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discussion within the university and the legislature about the appropriate tuition for the following year. Next, participants received a statement in which a particular tuition increase was advocated; participants were told that this statement was written by a state legislator. After reading the statement, participants were asked to think about the issue and indicate their belief position about the appropriate tuition increase using the computer-mouse technique.

Independent variables. Message discrepancy was manipulated by varying the advocated tuition increase. The levels of discrepancy were a 9% increase (low discrepancy), a 15% increase (moderate discrepancy), and a 22% increase (extreme discrepancy). The ratio of the moderate- to the low-discrepancy position is 1.67, and the ratio of the extreme- to the moderate-discrepancy position is 1.47. Participants' initial positions regarding a tuition increase were measured before they were presented with the message. The mean initial position regarding a tuition increase was 0.00% ($SD = 0.02$).

To manipulate source credibility, the legislator, the hypothetical writer of the statement about the tuition increase, was described as one whose knowledge of the issues and willingness to be fair to students were often questioned (low credibility) or as one who was praised by student groups (high credibility). Manipulation checks showed that credibility was successfully manipulated: fairness: $M = 4.70$, $SD = 0.89$ for the high-credibility source, $M = 3.04$, $SD = 0.86$ for the low-credibility source, $t(93) = 9.18$, $p < .01$, $\eta = .69$; expertise: $M = 4.83$, $SD = 0.97$ for the high-credibility source, $M = 3.00$, $SD = 1.19$ for the low-credibility source, $t(93) = 8.16$, $p < .01$, $\eta = .65$. Messages were the same in all conditions except for message positions (proposed tuition increases) and descriptions of the source.

Dependent variable. The dependent variable was the change from the participant's initial belief position about the appropriate percentage increase in tuition. Beliefs were measured in the same way used for the criminal-sentencing scenario. The scale displayed on the screen allowed participants to choose any increase between zero and 25%. For the trajectories that were generated, the minimum number of time points was 51 (3.93 *s*), the maximum number of time points was 1,964 (151.23 *s*), $M = 629.31$ (48.46 *s*), $SD = 441.31$ (33.98 *s*). The average time for judgment was not significantly different across the different levels of the independent variables: $F(2, 89) = 0.25$, *ns*, for message discrepancy; $F(1, 89) = 0.00$, *ns*, for source credibility; $F(2, 89) = 0.95$, *ns*, for the interaction between message discrepancy and source credibility. Like the criminal-sentencing issue, 10 points in time in addition to the initial time (t_0) were selected for each trajectory. Means and standard deviations of belief change time points are reported in Figure 5.

Individual Differences and Oscillatory Patterns

As noted above, the average time for judgment was not significantly different across the different levels of the independent variables for both the criminal-sentencing issue and the tuition-increase issue. By using ordinal time (i.e., time deciles) rather than actual time from the participant's starting time, any individual differences in the trajectory lengths that were not due to the experimental independent variables were

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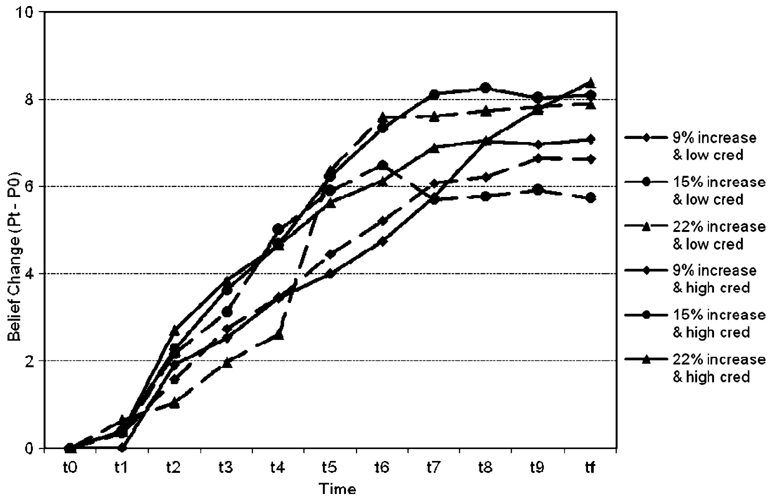

Figure 5 Mean belief trajectories for each experimental condition for the tuition-increase issue. The means and standard deviations at each time are: t_1: $M = 4.85$ s, $SD = 3.40$ s; t_2: $M = 9.69$ s, $SD = 6.80$ s; t_3: $M = 14.55$ s, $SD = 10.20$ s; t_4: $M = 19.38$ s, $SD = 13.59$ s; t_5: $M = 24.25$ s, $SD = 16.99$ s; t_6: $M = 29.01$ s, $SD = 20.35$ s; t_7: $M = 33.89$ s, $SD = 23.76$ s; t_8: $M = 38.77$ s, $SD = 27.18$ s; t_9: $M = 43.65$ s, $SD = 30.61$ s; t_f: $M = 48.46$ s, $SD = 33.98$ s.

controlled. In addition, any oscillatory movement was not likely to be captured with these simplified trajectories based on 11 time points.

Results

The Criminal-Sentencing Issue

Table 1 shows zero-order correlations, the means, and the standard deviations of those variables used for hypothesis testing.

Testing Nonmonotonicity of Belief Change Over Time

Hypothesis 1 and Hypothesis 1_{ALT} present competing predictions as to whether the trajectory of belief change over time is monotonic. $H1_{ALT}$, suggested by the push-with-pullback model, posits that the initial slope relating time and belief change is positive (in the direction of the position in the message) and then the trajectory exhibits a bend and the slope becomes and remains negative, at least for some conditions, suggesting an overall inverted U-shaped pattern of belief trajectories. First, $H1_{ALT}$ was tested: If $H1_{ALT}$ is rejected, the value of coefficient of time in the single-push with friction model (-*b*) will then be estimated and tested.

To test the inverted-U shaped pattern of belief trajectories ($H1_{ALT}$), first, the highest value in the belief-change trajectory is to be compared to the last value in the trajectory. If the last value is not significantly lower than the highest value at an earlier time period, there is no nonmonotonicity in the trajectory of the form predicted by $H1_{ALT}$. If the highest value in the belief-change trajectory is significantly higher than

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Table 1 Zero-Order Correlations among Study Variables, Criminal-Sentencing Data

	D	C	ΔP_{t_1}	ΔP_{t_2}	ΔP_{t_3}	ΔP_{t_4}	ΔP_{t_5}	ΔP_{t_6}	ΔP_{t_7}	ΔP_{t_8}	ΔP_{t_9}	ΔP_{t_f}
Message discrepancy (D)	—											
Source credibility (C)	.04	—										
Belief change at t_1 (ΔP_{t_1})	.07	-.02	—									
Belief change at t_2 (ΔP_{t_2})	.10	.17	.32**	—								
Belief change at t_3 (ΔP_{t_3})	.05	.18	.25*	.84**	—							
Belief change at t_4 (ΔP_{t_4})	.19	.27**	.10	.38**	.46**	—						
Belief change at t_5 (ΔP_{t_5})	.18	.30**	.10	.26*	.33**	.86**	—					
Belief change at t_6 (ΔP_{t_6})	.24*	.29**	.03	.16	.22*	.72**	.81**	—				
Belief change at t_7 (ΔP_{t_7})	.31**	.30**	.06	.19	.25*	.70**	.80**	.95**	—			
Belief change at t_8 (ΔP_{t_8})	.24*	.29**	.06	.23*	.30**	.70**	.79**	.90**	.93**	—		
Belief change at t_9 (ΔP_{t_9})	.25*	.29**	.04	.28*	.32**	.73**	.80**	.88**	.90**	.96**	—	
Belief change at t_f (ΔP_{t_f})	.24*	.33**	.02	.26*	.30**	.72**	.78**	.86**	.87**	.92**	.97**	—
M			0.49	1.78	2.92	4.85	5.93	6.37	6.34	6.97	7.08	7.25
SD			2.19	4.03	4.92	7.53	7.91	8.28	7.87	7.40	7.08	7.13

Note: $N = 95$. Belief change is the difference between belief position at a certain time and the initial position. Values of message discrepancy are 7 years for low discrepancy, 20 years for moderate discrepancy, and 40 years for extreme discrepancy. Source credibility was coded as 0 for low and 1 for high credibility. $^{*}p \leq .05$, two-tailed. $^{**}p \leq .01$, two-tailed.

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the last value in the trajectory, then the significance of the bend (i.e., the nonlinearity) in the trajectory for each condition is to be assessed by a repeated-measures analysis of variance (ANOVA) in which time is the repeated measure and the dependent variable is belief change from the initial position. Because a single bend in the trajectory is being evaluated, this ANOVA would test the quadratic component of change over time.

For the criminal-sentencing data in the high-credibility low-discrepancy condition, the last value was the highest value and thus no further test was required (see Figure 4). For the remaining five conditions, the highest value in the belief-change trajectory was compared to the final (last) value. For all five conditions, the highest value was not significantly different from the last value. Thus, these trajectories did not indicate nonmonotonicity of the form predicted by $H1_{ALT}$. Therefore, $H1_{ALT}$ was rejected.

Testing the Single-Push with Friction Model

Overview. Figure 4 shows the mean belief change trajectory for each of the six experimental conditions. To test this model, message discrepancy and belief change were transformed to a proportional scale in which the maximum message discrepancy, 40 years, becomes 1.000. Following Laroche (1977), the three proportional discrepancy values (discrepancy divided by 40) were .175 for low discrepancy, .500 for moderate discrepancy, and 1.000 for extreme discrepancy.

The data set was a pooled cross-sectional time series. Each case represented the response of a participant at a specific time point. Because belief position was measured 11 times (including the initial position), 11 cross-sectional time-series units appeared for each of the 95 participants (total number of cross-sectional time-series units $= 95 \times 11 = 1{,}045$).

The new model was tested with a nonlinear regression analysis separately for the low-credibility condition and the high-credibility condition. The coefficient for time ($-b$) was expected to be less than zero (Hypothesis 1), and the coefficient for message discrepancy ($-\gamma$) was expected to be less than -1.00 for the low-credibility source (Hypothesis 2a) and between 0 and -1.00 for the high-credibility source (Hypothesis 2b).

Low-credibility condition. The estimated structure for the low-credibility condition was:

$$\hat{y}_t = (D_p e^{-1.64 D_p})(1 - e^{-0.13t}). \tag{8}$$

The standard errors were 0.15 for the coefficient for message discrepancy ($-\gamma$) and 0.02 for the coefficient for time (see Table 2). The model's R equaled .40, $p < .05$. The coefficient for time (-0.13) was statistically significantly less than 0, $t(538) = -6.00$, $p < .05$, which is consistent with H1. The observed coefficient for time ($-b$) indicates that that belief change from initial belief position increases monotonically over time but the rate of change decreases. The observed coefficient for message discrepancy ($-\gamma$) was found to be -1.64, which is significantly less than -1.00 as hypothesized in H2a, $t(538) = -4.26$, $p < .05$. (The t value was obtained by dividing the difference

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Table 2 Parameters (and Standard Errors) for the Single-Push with Friction Model

	Criminal sentencing		Tuition increase	
Parameter	Low source credibility	High source credibility	Low source credibility	High source credibility
From equation number	8	11	13	15
-b (time coefficient)	-0.13 (0.02)	-0.16 (0.03)	-0.19 (0.03)	-0.21 (0.03)
-γ (discrepancy coefficient)	-1.64 (0.15)	-0.81 (0.14)	-0.88 (0.09)	-0.84 (0.09)
R^2	.163	.236	.359	.398
n	49	46	49	46

Note: The analysis used pooled cross-sectional time-series data, so the effective sample size for each nonlinear regression indicated above is 11 × the corresponding *n*.

between the observed value of the coefficient and the target value for the comparison, 1.00 in this case, by the standard error of the coefficient.)

In the reported analysis, observations from the same participants shared certain characteristics and therefore were not fully independent (see Kenny & Judd, 1986, for consequences of violating the independence assumption). To control the effect of this dependence, additional analyses were conducted. Dummy variables were created for individuals and incorporated into the model. The following model was tested:

$$\hat{y}_t = (D_p e^{-\gamma D_p})(1 - e^{-bt}) + \sum_{i=1}^{48} g_i I_i. \quad (9)$$

where g_i is a coefficient for participant i, and I_I represents a dummy variable for that participant. The estimated structure for the low-credibility condition was:

$$\hat{y}_t = (D_p e^{-1.64 D_p})(1 - e^{-0.17t}) + \sum_{i=1}^{48} g_i I_i, \quad (10)$$

The standard errors were 0.15 for the coefficient for message discrepancy and 0.04 for the coefficient for time. The model's R equals .78, $F(50, 489) = 28.2$, $p < .01$, which suggests that the model fits well. As expected, the coefficient for message discrepancy was less than -1.00, and the coefficient for time was less than 0. These results are consistent with the results of the model that did not take the pattern of dependence into account. Thus, the results are supported even when we take within-person dependence into account.

The observed coefficient of message discrepancy indicates that the relationship between message discrepancy and belief change was nonmonotonic in the low-credibility condition. Thus, H1 and H2a were supported in the low-credibility condition for the criminal-sentencing data.

High-credibility condition. For messages from a high-credibility source, the coefficient of message discrepancy (-γ) was expected to be between 0 and -1.00 (Hypothesis 2b). The estimated structure for the high-credibility condition was:

$$\hat{y}_t = (D_p e^{-0.81 D_p})(1 - e^{-0.16t}). \quad (11)$$

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The standard errors were 0.14 for the coefficient for message discrepancy ($-\gamma$) and 0.03 for the coefficient for time ($-b$) (see Table 2). The model's R equaled .49, $p < .01$. Like the low-credibility condition, the coefficient for time (-0.16) was less than 0 and statistically significant, $t(505) = -4.81$, $p < .05$, which is consistent with H1. The observed coefficient of message discrepancy (-0.81) was significantly less than 0, $t(505) = -5.06$, $p < .01$, but not significantly greater than -1.00, $t(505) = 1.23$, *ns*. The results support H2b, which indicates that the relationship between message discrepancy and belief change is monotonic (and positive) for the high-credibility condition.

The estimated structure for the high-credibility condition with individual dummy variables was:

$$\hat{y}_t = (D_p e^{-0.71 D_p})(1 - e^{-0.22t}) + \sum_{i=1}^{45} g_i I_i. \tag{12}$$

The standard errors were 0.09 for the coefficient for message discrepancy and 0.05 for the coefficient for time. The model's R equals .80, $F(47, 459) = 30.39$, $p < .01$, which suggests that the model fits well. As expected, the coefficient for message discrepancy was found to be less than zero but greater than -1.00, and the coefficient for time was less than zero. These results are consistent with the model that did not take the pattern of dependence into account. Thus, the results for H1 and H2b are supported even when we take within-person dependence into account.

Summary. The results of these hypothesis tests show that the effect of message discrepancy on belief change increases over time for a high-credibility source and that the effect of source credibility on belief change increases over time. In addition, across the two levels of source credibility, the coefficients for time differed by less than 1.5 standard errors and were therefore not significantly different. In other words, the deceleration of the trajectories did not differ by source credibility.

Repeated-Measures ANOVA

Discrepancy. The over-time relationship between message discrepancy and belief change for the messages from a purportedly high-credibility source was also tested with a repeated-measures analysis. The repeated-measures analysis of variance test hypotheses that were already tested by the nonlinear regression analyses, but they provide additional evidence regarding the change in the effect of discrepancy on belief change over time. First, belief change was predicted by time (a repeated measure), message discrepancy, and source credibility (see Table 3). Results showed that belief change from the initial belief increased over time with both a significant linear trend, $F(1, 89) = 85.79$, $p < .001$, partial $\eta = .70$, and a significant though smaller quadratic trend, $F(1, 89) = 21.53$, $p < .001$ and partial $\eta = .45$. A statistically significant three-way interaction among time, message discrepancy, and source credibility was found, $F(2, 89) = 3.06$, $p = .05$, and partial $\eta = .24$, which suggests that the interaction between time and message discrepancy differs between high- and low-credibility sources.

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Table 3 Repeated-Measures Analysis of Variance for Belief Change by Time, Message Discrepancy, and Source Credibility, Criminal-Sentencing Data

Source	*df*	*F*	Partial η^2
Between participants			
Source credibility (C)	1	10.87**	.10
Discrepancy (D)	2	3.44	.04
$C \times D$	2	1.47	.03
Between-group error	89	(1,217.65)	
Within participants			
Time (linear, T)	1	85.79**	.49
Time (quadratic, T^2)	1	21.53**	.20
$T \times C$	1	8.14**	.08
$T \times D$	2	3.18*	.07
$T \times C \times D$	2	3.06*	.06
Error (T)	89	(75.75)	

Note: $N = 95$. The parenthesized values represent mean square error.
$^*p \leq .05$, $^{**}p \leq .01$.

To explicate this three-way interaction, a repeated-measures analysis was conduced for high- and low-credibility source conditions separately. In the high-credibility condition, the interaction between message discrepancy and time was statistically significant, $F(2, 43) = 3.84$, $p < .05$, and partial $\eta = .39$. Because the difference in belief change between the extremely discrepant message condition and the low-discrepant message condition was greater at the end of judgment ($M = 4.01$, $SD = 1.88$) than at earlier time points ($M = 0.39$, $SD = 0.49$ at t_1; $M = 0.97$, $SD = 1.01$ at t_2), these results indicated that the effect of message discrepancy on belief change increased over time for the high-credibility condition. On the other hand, in the low-credibility condition, the interaction between message discrepancy and time was not statistically significant, $F(2, 46) = 0.26$, *ns*, and partial $\eta = .10$. In summary, the increase of the effect of message discrepancy on belief change in the high-credibility condition was supported by this repeated-measures analysis as well as by the above nonlinear regression analysis.

Credibility. The over-time relationship between source credibility and belief change was also tested by the same repeated-measures analysis reported above, in which belief change was predicted by time (a repeated measure), message discrepancy, and source credibility (see Table 3). Results of the analysis showed that the interaction between source credibility and time was statistically significant, $F(1, 89) = 8.14$, $p < .01$, and partial $\eta = .28$. Because the difference in belief change between the low-credibility condition and the high-credibility condition was greater at the end of judgment ($M = 4.66$, $SD = 1.38$) than at earlier time points ($M = 0.10$, $SD = 0.45$ at t_1; $M = 1.34$, $SD = 0.82$ at t_2), these results suggested that the effect of source credibility on belief change increased. The increase of the effect of source credibility on belief change was supported by this repeated-measures analysis as well as by the nonlinear regression analysis.

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The Tuition-Increase Issue

Testing Nonmonotonicity of Belief Change Over Time

As for the criminal-sentencing issue, $H1_{ALT}$ was first tested to see whether the trajectory of belief change was nonmonotonic. For the tuition-increase issue, in three conditions (the high-discrepancy and low-credibility condition, the low-discrepancy and high-credibility condition, and high-discrepancy and high-credibility condition), the final (last) value was the highest value; no further test for nonmonotonicity was conducted. For the remaining three conditions the highest value in the belief-change trajectory was compared to the final value to see whether there was nonmonotonicity of the kind predicted by $H1_{ALT}$. For all three conditions, the highest value was not significantly different from the last value. These results indicated that nonmonotonicity in the form predicted was not present in these six trajectories; therefore, $H1_{ALT}$ was rejected.

Testing the Single-Push with Friction Model

Overview. Figure 5 shows the mean belief change trajectories for the tuition-increase topic for each of the six experimental conditions (three levels of message discrepancy by two levels of source credibility). To test the single-push with friction model, message discrepancy and belief change were transformed to a proportional scale in which message discrepancy was divided by the maximum discrepancy employed, 22%. The transformed discrepancies were .409, low discrepancy; .682, moderate discrepancy; and 1.000, extreme discrepancy. The coefficient for time (-b) was expected to be less than zero (Hypothesis 1), and the coefficient for message discrepancy (-γ) was expected to be less than -1.00 for the low-credibility source (Hypothesis 2a) and between 0 and -1.00 for the high-credibility source (Hypothesis 2b).

Low-credibility condition. The estimated structure for the low-credibility condition was:

$$\hat{y}_t = (D_p e^{-0.88D_p})(1 - e^{-0.19t}). \tag{13}$$

The standard errors were 0.09 for the coefficient for message discrepancy (-γ) and 0.03 for the coefficient for time (see Table 2). The model's R equaled .60, $p < .01$. The coefficient for time (-0.19) was significantly less than zero, $t(538) = -6.68$, $p < .01$. This result supports H1, which indicates that belief change from the initial belief position increases monotonically over time but the rate of change decreases. The coefficient for message discrepancy was expected to be less than -1.00, but that was not found to be the case for the estimated coefficient (-0.88). The coefficient (-0.88) was significantly less than zero, $t(1044) = -9.31$, $p < .01$, but it was not significantly greater than -1.00, $t(1044) = 1.33$, *ns*, which is not consistent with H2a.

To control for the dependence among the individual cases, dummy variables were created for each individual and incorporated into the model. The estimated structure for the low-credibility condition was:

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$$\hat{y}_t = (D_p e^{-0.68 D_p})(1 - e^{-0.17t}) + \sum_{i=1}^{48} g_i I_i. \tag{14}$$

The standard errors were 0.10 for the coefficient for message discrepancy and 0.03 for the coefficient for time. The model's R equals .82, $F(50, 489) = 54.75$, $p < .01$, which suggests that the model fits well. These results are consistent with the model that did not take the pattern of dependence into account. Thus, H1 was supported but H2a was not supported in the low-credibility condition for the tuition-increase issue.

High-credibility condition. For messages from the high-credibility source, the coefficient for message discrepancy ($-\gamma$) was expected to be between 0 and -1.00 (Hypothesis 2b). The estimated structure for the high-credibility condition was:

$$\hat{y}_t = (D_p e^{-0.84 D_p})(1 - e^{-0.21t}). \tag{15}$$

The standard errors were 0.09 for the coefficient for message discrepancy ($-\gamma$) and 0.03 for the coefficient for time ($-b$; see Table 2). The model's R equaled .63, $p < .01$. Like the low-credibility condition, the coefficient for time (-.21) was less than 0 and statistically significant, $t(505) = -7.34$, $p < .01$, which was consistent with H1.

The estimated coefficient for message discrepancy (-.84) was found within the expected range: It was significantly less than zero, $t(505) = -8.94$, $p < .01$, but it was not significantly greater than -1.00, $t(505) = 1.69$, *ns*. This result was consistent with H2b, which indicates that that the relationship between message discrepancy and belief change is monotonic (and positive) for high-credibility sources. Finally, for the tuition topic, across the two levels of source credibility, the coefficients for time differed by less than 1.5 standard errors and were therefore not significantly different. In other words, the deceleration of the trajectories did not differ by source credibility.

The estimated structure for the high-credibility condition with individual dummy variables was:

$$\hat{y}_t = (D_p e^{-0.64 D_p})(1 - e^{-0.19t}) + \sum_{i=1}^{45} g_i I_i. \tag{16}$$

The standard errors were 0.08 for the coefficient for message discrepancy and 0.03 for the coefficient for time. The model's R equaled .84, $F(47, 459) = 63.67$, $p < .01$, which suggests that the model fits well. The estimated coefficient was found to be within the expected range, $0 \leq \gamma \leq 1.00$. These results are consistent with the model that did not take the pattern of dependence into account. Thus, both H1 and H2b were supported with the tuition-increase data.

Repeated-Measures ANOVA

Discrepancy. The over-time relationship between message discrepancy and belief change for the messages from a purportedly high-credibility source was also tested with a repeated-measures analysis. First, belief change was predicted by time (a repeated measure), message discrepancy, and source credibility (see Table 5). The results showed that belief change increased linearly over time, $F(1, 89) = 313.07$, $p <$ .001, and partial $\eta = .88$; and quadratically, $F(1, 89) = 29.55$, $p < .001$, partial $\eta = .50$.

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Table 4 Zero-Order Correlations among Study Variables, Tuition-Increase Data

	D	C	ΔP_{t_1}	ΔP_{t_2}	ΔP_{t_3}	ΔP_{t_4}	ΔP_{t_5}	ΔP_{t_6}	ΔP_{t_7}	ΔP_{t_8}	ΔP_{t_9}	ΔP_{t_f}
Message discrepancy (D)	—											
Source credibility (C)	.04	—										
Belief change at t_1 (ΔP_{t_1})	.09	-.06	—									
Belief change at t_2 (ΔP_{t_2})	.02	.11	.56**	—								
Belief change at t_3 (ΔP_{t_3})	.03	.10	.44**	.75**	—							
Belief change at t_4 (ΔP_{t_4})	.02	.08	.33**	.64**	.87**	—						
Belief change at t_5 (ΔP_{t_5})	.20	-.03	.27**	.42**	.61**	.75**	—					
Belief change at t_6 (ΔP_{t_6})	.20*	-.04	.21*	.30**	.49**	.60**	.87**	—				
Belief change at t_7 (ΔP_{t_7})	.15	.06	.18	.17	.40**	.41**	.66**	.86**	—			
Belief change at t_8 (ΔP_{t_8})	.10*	.13	.15	.11	.33**	.34**	.57**	.76**	.92**	—		
Belief change at t_9 (ΔP_{t_9})	.12	.11	.21*	.10	.32**	.33**	.54**	.69**	.87**	.95**	—	
Belief change at t_f (ΔP_{t_f})	.16	.16	.16	.05	.27**	.27**	.47**	.60**	.82**	.90**	.96**	—
M			0.36	1.93	2.96	3.95	5.41	6.23	6.68	6.99	7.19	7.30
SD			1.46	3.25	3.62	3.83	3.71	3.71	3.57	3.44	3.47	3.49

Note: $N = 95$. Belief change is the difference between belief position at a certain time and the initial position. Values of message discrepancy are 9 for low discrepancy, 15 for moderate discrepancy, and 22 for extreme discrepancy. Source credibility was coded as 0 for low and 1 for high credibility.
*$p \leq .05$, two-tailed. **$p \leq .01$, two-tailed.

Table 5 Repeated-Measures Analysis of Variance for Belief Change by Time, Message Discrepancy, and Source Credibility, Tuition-Increase Data

Source	*df*	*F*	Partial η^2
Between participants			
Source credibility (*C*)	1	0.69	.01
Discrepancy (*D*)	2	1.20	.03
$C \times D$	2	0.38	.01
Between-group error	89	(60.24)	
Within participants			
Time (linear, *T*)	1	313.07**	.78
Time (quadratic, T^2)	1	29.55**	.25
$T \times C$	1	0.77	.01
$T \times D$	2	0.91	.02
$T \times C \times D$	2	1.62	.04
Error (*T*)	89	(21.64)	

Note: $N = 95$. The parenthesized values represent mean square error.
$^{**}p \leq .01$.

The results showed that the three-way interaction among time, message discrepancy and source credibility was not statistically significant, $F(2, 89) = 1.62$. A repeated-measures analysis on belief change by time and message discrepancy for the high-credibility condition showed that the interaction between time and message discrepancy was not statistically significant, $F(2, 43) = 0.30$, which indicated that the effect of message discrepancy on belief change did not significantly change over time. The predicted pattern of the increase of the effect of message discrepancy on belief change was not supported by the repeated-measures ANOVA.

Credibility. The over-time relationship between source credibility and belief change was also tested by the same repeated-measures analysis reported above (see Table 5). Results showed that the interaction between source credibility and time was not statistically significant, $F(1, 89) = 0.71$, which indicated the effect of source credibility on belief change did not significantly change over time. Therefore, the predicted increase of the effect of source credibility on belief change was not found in the tuition-increase issue.

Discussion

In previous studies on persuasion, the role of time on the belief change process has not been given adequate attention. The present study investigated the time course of belief change during judgment. The self-generated attitude change model (Tesser, 1978) suggested a shift of beliefs in one direction over time during judgment but did not provide a formal model for this predicted pattern. On the other hand, the single-push with friction model (Kaplowitz et al., 1983) provided a specific functional form for belief change over time. The model suggested that, after message receipt, belief change increases monotonically with a decreasing rate of change. Laroche's (1977) nonlinear mathematical model provided a functional form for the effect of message

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discrepancy and source credibility on belief change. However, Laroche's model did not incorporate change over time; Laroche's model engages in comparative statics focusing on equilibrium values. By incorporating Laroche's model into the single-push with friction model, a new model, combining comparative statics and dynamics, was created. The new model predicts how belief change varies over time as a function of message discrepancy and source credibility. The coefficients for time and message discrepancy in this new model were predicted and tested. For both issues, the coefficient for the rate at which the belief approached its final value did not differ significantly across the two levels of credibility.

Studies of cognitive responses (Brock, 1967; Cook, 1969; Toy, 1982) suggested that messages that are highly discrepant cause beliefs initially to move in one direction and then to move back toward the initial position, thus creating nonmonotonicity of belief change with respect to time. This push-with-pullback model was tested. Because two topics were used, the findings of the present study can be considered not to be topic specific (Jackson, 1992). There was no significant pullback pattern in belief trajectories for either issue.

The single-push with friction model was found to fit modestly well for the criminal-sentencing issue ($R = .40$ for the low-credibility source condition; $R = .49$ for the high-credibility source condition). Furthermore, the coefficients of time and message discrepancy were found to be within the expected range for both low- and high-credibility source conditions. The results showed some dynamic aspects of belief change: a monotonic increase of belief change as a function of time, an increase of the effect of message discrepancy on belief change over time for the high-credibility source, and an increase of the effect of source credibility on belief change over time.

For the tuition-increase issue, the single-push with friction model was found to fit well in some ways. The values of the *R*s (.60 for the low-credibility source condition; .63 for the high-credibility source condition) were quite good. The coefficient of time was found to be within the predicted range, indicating a monotonic increase of belief change over time. On the other hand, the coefficient of message discrepancy was not found to be within the predicted range. Moreover, for the tuition-increase issue, neither the effect of message discrepancy nor the effect of source credibility on belief change changed over time.

Theoretical Implications

The findings of the present study have several significant implications for existing theories of persuasion. First, the findings suggest that the process of belief change occurs over measurable amounts of time and is not instantaneous. After message receipt, beliefs continue to change until a new equilibrium is reached.

The pattern of belief change during judgment was found to be consistent with the self-generated attitude change model (Tesser, 1978) in that beliefs shifted in only one direction. The main proposition of the self-generated attitude change model, greater attitude change with more thinking, can be tested with time-series data. However, the previous tests of that model used data at no more than three points in time, which is not an optimal or effective way to test a dynamic model.

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The single-push with friction model predicts a pattern of belief change consistent with the self-generated attitude change model. However, the single-push with friction model is a mathematical one that is systematically derived from some assumptions and provides a specific functional form for belief change over time. The present study extended the single-push with friction model by incorporating Laroche's (1977) comparative statics of belief change. A functional form of belief change relating these variables was estimated over time. For both the criminal-sentencing and the tuition-increase scenarios, the results suggested that belief change from the initial belief position increases monotonically over time but that the rate of change decreases. In addition, the rate of approach to the final belief position did not differ greatly or significantly between the two levels of source credibility. In the criminal-sentencing data, it was found that (a) the effect of source credibility on belief change increases over time, and (b) the effect of message discrepancy on belief change increases over time for the high-credibility source. In addition, the criminal-sentencing data (but not the tuition data) provided strong support for Laroche's model and the prior findings that the relationship between message discrepancy and belief change is nonmonotonic for low-credibility sources and monotonic (and positive) for high-credibility sources.

The increasing effect of source credibility on belief change over time may be explained by the cognitive response model (see Greenwald, 1968; Petty, Ostrom, et al., 1981). While thinking about the message, recipients may generate a greater number of supportive (and here, positive) thoughts about the message in response to a message from a high-credibility source than in response to a message from a low-credibility source (Cook, 1969). As a result, a positive message from a highly credible source may cause the recipient to develop a greater positive belief position over time. Thus, if the source of the message is highly credible, more positive belief change may be obtained by giving the message recipient more time to think.

This last possibility has practical implications for advertising, marketing, health campaigns, and political campaigns: Message designers can vary the time available for their audience to think about their messages, incorporating what is known about the message source's credibility and the message's discrepancy. The single-push with friction model predicted that, for messages from a high-credibility source, the effect of message discrepancy on beliefs increases over time, and this effect was found. In addition, Laroche's model suggests that when the source of the message is highly credible, a persuader may obtain more belief change by advocating more belief change. The present study proposes that when a credible persuader attempts to obtain more belief change by advocating more belief change, even greater belief change may occur if the message recipient is given more time to think about the message.

The results of the present study are somewhat inconsistent with some studies of cognitive responses to discrepant messages. Both Brock (1967) and Toy (1982) found that as message discrepancy increased, the number of counterarguments increased. Toy (1982) found that as discrepancy increased, the number of supportive arguments decreased. Those counterarguments are expected to pull a belief back toward the

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receiver's initial position. Therefore, Brock (1967) and Toy (1982) implied that the tendency of more discrepant messages to lead to more belief change should decrease over time. However, no such pullback was observed in the present study.

Hypotheses about the dynamic effect of message discrepancy and source credibility on belief change were supported by the data from the criminal-sentencing issue but not fully supported by the data from the tuition-increase issue. For the tuition-increase issue, the time courses predicted by the single-push with friction model were found; however, no significant differences in belief change were found among different levels of message discrepancy and source credibility. Different effects of message discrepancy and source credibility on belief change between the two issues may be explained by the level of ego involvement associated with the two topics that were used. Laroche's model suggests that as the level of ego involvement increases, the relationship between message discrepancy and belief change changes from monotonic to nonmonotonic. If the relationship were already nonmonotonic, a further increase in involvement tends to flatten the curve relating discrepancy and belief change. Thus, if an issue is highly ego-involving, there will be not much difference in belief change among different levels of message discrepancy (see Figure 1). The tuition-increase issue had significant consequences on students' personal lives (high outcome-dependent involvement), and the initial belief that the students had was probably held very strongly.

Limitations

In the present study, belief positions at 11 time points were selected to be analyzed. As a result, some information in the belief trajectories was not employed. Kaplowitz et al. (1983) proposed a spatial-linkage model of cognitive forces that predicts an oscillatory pattern of belief change during judgment. Because of the methods employed in the present study, any oscillatory component of the belief-change pattern was not analyzed. Different analytic methods are needed to test not only the average trajectory in each condition but the dynamics of each individual's belief-change trajectory, including its oscillatory motion.

The present study examined the static and dynamic effects of message discrepancy and source credibility on belief change with two different issues. The two issues differed with regard to their level of personal involvement: The criminal-sentencing issue is low on personal involvement, whereas the tuition-increase issue is high on personal involvement. For the low personal-involvement issue, message discrepancy and source credibility had both static and dynamic effects on belief change, and the amount of belief change over time increased at a decreasing rate. For the high personal-involvement issue, the amount of belief change over time increased at a decreasing rate just as for the low personal-involvement issue. However, in the ANOVA neither message discrepancy nor source credibility had significant effects.

According to the elaboration likelihood model (ELM), the amount and the depth of information processing differ depending on personal involvement: For high personal-involvement issues, in which a greater amount and depth of information processing is expected, argument-related variables are more effective; for low

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personal-involvement issues, in which a smaller amount and depth of information processing is expected, cue-related variables are more effective. Source credibility is often used as a peripheral cue in ELM studies. In the present study, source credibility was found to have an effect on belief change for the low personal-involvement issue but not for the high personal-involvement issue, which is consistent with the ELM. However, in the present study, the level of personal involvement was not manipulated; therefore, the difference in belief change between two issues cannot be unequivocally attributed to the level of personal involvement. In a future study, this ELM prediction can be tested by manipulating personal involvement.

One mechanism that may help explain belief change during judgment could be the generation of cognitive responses. If cognitive responses were effectively measured, the relationship between cognitive responses and belief trajectories could be examined. In future research, this relationship should be investigated.

In the present study, the time course of the single-push with friction model was contrasted with the nonmonotonic (with respect to time) trajectory of the push-with-pullback model. However, another curve that has some theoretical justification is an *S*-shaped curve (see Kaplowitz & Fink, 1982, pp. 371, 376). The S-shaped curve is similar to the model tested here in that both level off toward the end of the belief change period. However, unlike the single-push with friction model, the S-shaped curve accelerates at the beginning of belief change. Future research should examine the theoretical basis and the empirical evidence for such other possible functional forms for belief change over time.

Conclusion

There are two main contributions of the present study: (a) The pattern of belief change over time and its comparative statics were modeled by a predicted functional form; and (b) the proposed model was tested with belief trajectories. The Haldane (1927) epigraph suggested that a model be evaluated for its power of prediction and that judgments of a model's simplicity and fruitfulness are aesthetic judgments. The mathematical model proposed and tested here was fruitful and predictive: The model predicts the over-time trajectories and the comparative statics of beliefs due to message discrepancy and source credibility. Even though the model was somewhat limited (e.g., oscillations were not investigated) and even though the measurements were somewhat limited (e.g., only 11 time points were used), the present study made vague notions of the process of belief change (in the epigraph, "it oozes") more precise and more fruitful so far as prediction of belief change is concerned.

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