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Oscillation in Beliefs and Decisions

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John Dewey, in his classic *How We Think,* stated that thinking "involves a jump, a leap, a going beyond what is surely known to something else accepted on its warrant. . . . The very inevitableness of the jump, the leap, to something unknown only emphasizes the necessity of attention to the conditions under which it occurs" (Dewey, 1991, p. 26). Our research on attitude and belief change and decision making has attempted to explicate the cognitive forces at work as individuals think, consider alternatives, and resolve issues.

All of us can recall when our decisions have come about after vacillation, wavering, or oscillation. We believe that such oscillation is an important phenomenon. This chapter reviews our most recent research about oscillation of beliefs. It also suggests a possible new direction for research by examining chaos-based measures to understand these oscillations.

Lorenz (1977) posited that "any self-regulating process in whose mechanisms inertia plays a role tends toward oscillation" (p. 237). Because there is evidence that cognition has such an inertial principle (see, e.g., Saltiel & Woelfel, 1975), it is reasonable to expect oscillatory dynamics for cognition.

With a few exceptions (e.g., Lewin, 1951), until the late 1970s, the theory and research on attitudes and decisions focused on the outcome of the process rather than on its dynamics. For example, a review of the decision-making literature (Abelson & Levi, 1985) focused on models predicting decisions based on the probability of and utility of various outcomes. In attitude research, the major emphasis during this time has been on how

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source, message, and receiver characteristics influence an attitude, typically measured only once after an experimental treatment. Thus, those investigating decision making and attitude change have generally failed to measure the time course of variables associated with the underlying psychological dynamics.

However, understanding dynamics in general and cognitive oscillations in particular is critically important. First, understanding the time course of attitude and belief change may add considerably to our understanding of the forces causing this change, thereby allowing the creation of a model that governs the process.

Second, because beliefs are typically measured at one point in time, the existence of oscillations can introduce what appears to be unreliability into the measurement of beliefs. In other words, *systematic* change, in the form of oscillation, can be mistaken for the *random* disturbances in a measurement, which we usually think of as unreliability. Determining the time parameters of such oscillations may allow us to separate unreliability from instability in the measurement of an attitude or a belief (see, e.g., Heise, 1969). It also may tell us how long we need to wait for the attitude to reach equilibrium or “settle down.”

Both attitude and decision researchers have recently begun paying more attention to process and dynamics. In the attitude area, not only have thoughts been considered an important intervening variable (see, e.g., Chaiken, Liberman, & Eagly, 1989; Petty & Cacioppo, 1986), but a number of studies (Liberman & Chaiken, 1991; Millar & Tesser, 1986) suggest that thinking is sufficient to bring about attitude change. Thus, McGuire (1989) stated that those who study attitudes increasingly view them as an interacting dynamic system. The decision-making literature has also shown increasing concern with the dynamics of the process (see, e.g., Janis & Mann, 1977; Tversky & Shafir, 1992).

COGNITIVE OSCILLATION: INDIRECT EVIDENCE

From studying post-decisional attitudes, Walster (1964) and Brehm and Brehm (1981) have found that people often initially regret a choice that they have just made. Only later do they reduce their post-decisional dissonance with that choice (see also Landman, 1993). The regret-dissonance reduction process may, in fact, be one cycle of oscillation in beliefs; dissonance researchers did not measure attitudes with sufficient frequency in any experiment to know whether attitudinal oscillation might continue.

Gilbert, Krull, and Malone (1990) showed that an idea must first be entertained as true before it can be rejected as false. If correct, this idea suggests that an individual’s beliefs must change at least once in the process of rejecting a proposition. Moreover, Latané and Darley (1970) stated that bystanders experiencing the stress of an emergency can “cycle back and forth” between beliefs such as “the building’s on fire—I should do something” and “I wonder if the building’s really on fire” (p. 122). For other evidence relevant to the possibility of cognitive oscillations, see Poole and Hunter (1979, 1980) and Wegner (1989, pp. 34, 113).

How have cognitive oscillations been explained? Lewin (1951) posited that as we approach a goal, both the attractive and repulsive forces associated with the goal get stronger, but the repulsive forces increase more rapidly than the attracting ones. Thus, whereas at great distances the net force is attractive, as the goal is approached, the net force becomes repulsive (see Lewin, 1951, p. 264). Similarly, in Brehm and Brehm’s (1981) analysis of reactance, moving toward one choice alternative threatens the freedom to choose another choice alternative. This process causes the previously rejected alternative to become more attractive. Both of these approaches suggest an oscillatory decision trajectory.

A SPATIAL-SPRING MODEL OF COGNITIVE FORCES

A spatial-spring model of attitude change and decision making has two basic components. First is a *geometry* of cognition in which similarity in the meaning of concepts is indicated by their distance from each other (see Woelfel & Fink, 1980) and in which the degree to which a concept is positively evaluated is indicated by how close it is to some other concept (e.g., "things I like") indicating positive evaluation (see Neuendorf, Kaplowitz, Fink, & Armstrong. 1986).

Second, cognitive oscillation suggests the existence of restoring (negative feedback) *forces*. Such restoring forces are built into this model by assuming that there are associative linkages between concepts and that these linkages are spring-like (see Fink & Kaplowitz, 1993; Fink, Monahan, & Kaplowitz, 1989; Kaplowitz & Fink, 1982, 1988, 1992, 1996; Kaplowitz, Fink, & Bauer, 1983; for earlier treatments, see Barnett & Kincaid, 1983; Kincaid, Yum, Woelfel, & Barnett, 1983; Woelfel & Fink, 1980, esp. pp. 158-159). Consistent with the operation of a mechanical spring, we assume that the forces attracting one *toward* an alternative increase in strength as the individual cognitively moves *away* from that alternative.

We found the spring imagery especially attractive for two reasons. First, a spring system fits our geometric model in making the forces dependent on the instantaneous distances among concepts. Second, as discussed more fully in what follows, a spring analogy helps to make sense of the tension people feel when experiencing opposing forces.

A model incorporating spring-like forces assumes that a linkage between two concepts, A and B, creates a force satisfying the following equation:

$$F_{\mathrm{A,B}} = K_{\mathrm{A,B}}[d_{\mathrm{Eq}}(A,B) - d(A,B)], \qquad (1)$$

where $F_{\mathrm{A,B}}$ is the force between the concepts, $d_{\mathrm{Eq}}(A,B)$ is the equilibrium distance of the linkage, $d(A,B)$ is the distance between those concepts in the receiver's cognitive space, and $K_{\mathrm{A,B}}$ is the restoring coefficient of the linkage. This model posits that on either side of the equilibrium location, the net force is directed toward the equilibrium location.

People often see a choice alternative as consisting of both attractive and unattractive features (cf. value conflict as discussed in Liberman & Chaiken, 1991). In this choice situation, there should be spring-like linkages pulling in opposite directions. The equilibrium of the system is that point at which the opposing forces balance; the relevant restoring coefficient is the sum of the effects of all the individual linkages.

We now consider the motion of a system consistent with Equation (1). From Newton's laws of force and motion, acceleration is proportional to the product of the distance of a concept from its equilibrium location and K, the net restoring coefficient computed from all linkages on a concept. If K is constant over time, then this equation leads to a sinusoidal trajectory of *undamped oscillations* (i.e., with a constant amplitude and a constant period of oscillation). Moreover, the period of oscillation is a decreasing function of the restoring coefficient.

Sometimes people manifest no perceptible cognitive oscillation. Furthermore, even when they do oscillate, it appears that such oscillations usually die out. Just as mechanical systems have friction, which serves to damp oscillations, we assume a *cognitive damping* process whose force is proportional to, and in the opposite direction from, the velocity of the concept in motion. Whether the system exhibits oscillation depends on the size of the damping coefficient as compared to the restoring coefficient.

Like Lewin (1951), we see the forces on a person's decision as depending on the cognitive distance from an alternative. The spatial-spring model, however, explains Lewin's ad hoc assumption that as one approaches a goal, the repulsive force increases more rapidly than the attractive force. In addition, the spatial-spring model's explicit equations of force and motion enable us to predict the time course of change more precisely.

THE PSYCHOLOGICAL MEANING OF THE MODEL

Equilibrium Length

The equilibrium length of a linkage is the distance between concepts that the linkage implies when one ignores the effect of other linkages. The equilibrium length of the linkage between an attribute and an evaluative concept represents the evaluation of the attribute, again ignoring the effect of other linkages. Thus, for most people the linkage between *good pay* and *jobs I want* has a small equilibrium length, whereas the linkage between *long hours* and *jobs I want* has a large equilibrium length.

We extend the model to persuasion by assuming that a message linking concepts A and B establishes a linkage between them, whose equilibrium length, $d_{\mathrm{Eq}}(A,B)$, is the dissimilarity between A and B specified in the message. Thus, the equilibrium length is the position advocated by the message.

Restoring Coefficient

The restoring coefficient reflects the importance of the attribute in the decision calculus. Attributes that are more important have greater restoring coefficients. The cognition and memory literature (e.g., Anderson, 1983) suggests that more frequent associations between concepts cause stronger linkages and that the lack of recent co-occurrence causes these linkages to weaken. Thus, we see the restoring coefficient as related to co-occurrence (for exceptions, see, e.g., Bornstein & Pittman, 1992).

Although messages are assumed to establish spring-like linkages between concepts, they do not fully determine the receiver's new view. The force created by a new message linkage is opposed by and ultimately in balance with the preexisting forces from the network of other linkages in the receiver's cognitive system. These *anchoring* linkages represent the strength of the receiver's initial view and are the result of prior messages.

Thus, our model posits two distinct spring-like linkages. One is called the *message* linkage and is represented by the symbol $K_{\mathrm{A,B}}$. The other is called the *anchoring* linkage and is represented by K_{R}. Given Equation (1), we find that when the system is in equilibrium, attitude change can be predicted by the following equation:

$$\Delta P = \frac{K_{A,B} Dp}{K_R} + K_{A,B}, \qquad (2)$$

where Dp is the discrepancy (between the position advocated by the message and the initial position of the receiver.

$K_{\mathrm{A,B}}$ should be an increasing function of factors that enhance attitude change such as source credibility and argument strength. However, because various studies (e.g., Aronson, Turner, & Carlsmith, 1963) have shown that as discrepancy increases, attitude change becomes a smaller proportion of the discrepancy, $K_{\mathrm{A,B}}$ should be a decreasing function of message discrepancy.

The strength of the anchoring linkage K_{R} is expected to be an increasing function of premessage factors that inhibit attitude change such as the strength of the initial attitude (or value-relevant involvement [see Johnson & Eagly, 1990]).

We have stated that all linkages are assumed to decay over time (see Ebbinghaus, 1964); however, new messages or self-generated thoughts may have the effect of strengthening these linkages.

Frequency and Amplitude of Oscillation

The frequency of oscillation of a spring is an increasing function of its restoring coefficient. Because the total restoring coefficient is the sum of the coefficients of the message linkage and the anchoring linkages, we can derive some interesting hypotheses based on the preceding discussion of these factors:

Hypothesis 1: Other things being equal, the frequency of oscillation is an increasing function of (a) source credibility, (b) argument strength, and (c) strength of initial opinion.

Hypothesis 2: Other things being equal, the frequency of oscillation is a decreasing function of message discrepancy.

We now examine determinants of the amplitude of oscillation. The spatial-linkage model predicts sinusoidal trajectories that are symmetric about the equilibrium location and that have amplitudes that are greatest at the start of the cognitive trajectory. Thus, the maximum possible amplitude is the distance between (a) the equilibrium location of a concept after persuasion and (b) the concept's original location. By definition, this distance is the final attitude change. Thus, we have the following hypothesis:

Hypothesis 3: The greater the attitude change, the greater the amplitude of oscillation (cf. Kaplowitz & Fink, 1982).

As indicated previously, attitude change is predicted to be an increasing function of source credibility and argument strength and (usually) of discrepancy, and it is predicted to be a decreasing function of the strength of the receiver's initial belief. Combining these with Hypothesis 3 leads us to the following hypothesis:

Hypothesis 4: The amplitude of oscillation is an *increasing* function of (a) source credibility, (b) argument strength, and (usually) (c) discrepancy, and it is a *decreasing* function of (d) the strength of the receiver's initial belief.

TESTING THE PREDICTIONS OF THIS MODEL

To summarize, the spatial-linkage model has very elegant and clear predictions. It predicts oscillatory trajectories with constant frequencies, which are either damped (getting steadily smaller in amplitude) or totally undamped (staying the same in amplitude). Moreover, the amplitude and frequency should be functions of the persuasion variables discussed previously.

Our first study to examine oscillations (Kaplowitz et al., 1983) used more than 1,000 participants, each of whose attitude was measured only once. However, their attitudes were measured at different times from the receipt of the persuasive message. We then treated the mean response of all participants who received the same experimental treatment and who responded at the same time after the message as if it were a point on the trajectory of a single individual. We treated the within-cell variance as measurement error.

We found modest but significant support for the existence of oscillations; however, there was no evidence of damping.

Aside from time until measurement, our other independent variable in that study was message discrepancy. Consistent with Hypothesis 4, the message with the greatest discrepancy not only induced the most attitude change but also induced the trajectory with the greatest amplitude. But inconsistent with Hypothesis 2, no relationship between discrepancy and the frequency of oscillation was found.

Obviously, the technique used in the Kaplowitz et al. (1983) study has serious drawbacks, and we have since developed better ways to measure oscillation. The technique we have used most often requires participants to think about an issue and use a computer mouse to indicate their instantaneous opinions about the issue. Mouse position is recorded at least every 18 milliseconds, thereby giving us trajectories of individual attitudes or decisions. When participants determine that they have made a final decision, they press the mouse button, and this signal indicates the end of the trajectory.

We tested Hypotheses 1 through 4 with a study that had 99 participants. We provided a message that manipulated discrepancy and source credibility and then had the participants use the mouse while thinking about the issue. We measured attitude trajectories for two separate issues. One issue was the appropriate sentence for a convicted armed robber (a scenario used in Kaplowitz & Fink, 1991). The other issue was the appropriate increase in tuition at the students' university (a scenario used in Fink, Kaplowitz, & Bauer, 1983).

There were some very striking qualitative findings that came from examining the nearly 200 trajectories generated by this study. The first is that oscillatory trajectories, in which participants' mouse motion reverses direction, are quite common. In both scenarios, more than half of the participants changed direction at least once. This finding has been confirmed with other decision problems as well (see Table 2.1).

However, the oscillatory trajectories do not look like the trajectories predicted by the simple version of the spatial-spring model discussed earlier. That model predicted constant periods and amplitudes that either remained constant or got steadily smaller (i.e., were damped). None of the oscillatory trajectories found showed constant periods. Moreover, some amplitudes suddenly got larger, and oscillations abruptly ended with no gradual damping (see Figure 2.1).

Because we did not have regular trajectories, we could not measure frequency and amplitude in the usual way. Our analogue to amplitude became the *pseudo-amplitude* (half of the difference between the maximum and minimum values of the decision trajectory). We created two analogues to the frequency. One was the *total number of changes of direction* the participant made. The other was the *pseudo-frequency* (the number of changes of direction divided by the decision time).

In determining the number of changes of direction, we wanted to distinguish mouse motion that reflected attitude change from unintentional motion. Thus, any change had to be at least 4% of the range of the scale for us to consider it a true change of direction. In addition, spike-like changes, in which the participant, on reaching a position, *immediately* moved in the opposite direction, were also interpreted as unreliable motion. We assumed that the participant, having overshot a "true" position, was hastening to correct it.

Although credibility was successfully manipulated, contrary to Hypothesis 1a, it had virtually no effect on number of changes of direction. For both scenarios, the Pearson correlation between credibility and number of changes was less than .08. Contrary to Hy-

TABLE 2.1 Statistics From Online Oscillation Studies

		Criminal Sentencing	*Tuition*	*College Admission (Wang Experiment 2)*[a]		*College Admission (McGreevy)*[b]	
		Continuous Discreteness	*Continuous Discreteness*	*Dichotomous Discreteness*		*Dichotomous Discreteness*	
				Easy	*Difficult*	*Easy*	*Difficult*
Sample size		99	91	31	36	50-51	47-51
Percentage changing direction at least once		72.7	59.3	77.4	97.2	64.7	76.5
Number of changes of direction	Adjusted geometric mean[c]	1.33	0.91	1.66	5.04	0.89	1.60
	25th percentile	0	0	1	3	0	1
	Median	1	1	2	5.5	1	2
	75th percentile	2	2	3	9	3	4
	Maximum[d]	7	11	14	14	12	18
Decision time (seconds)	Adjusted geometric mean[c]	26.59	26.60	17.20	38.81	6.38	45.05
	25th percentile	15.60	15.93	8.01	23.96	1.00	4.00
	Median	27.67	26.85	18.02	40.98	6.50	58.00
	75th percentile	42.40	45.37	35.98	57.75	40.50	103.00
	Minimum	4.84	4.89	3.00	9.00	0.00	0.00

a. Wang Experiment 2 is the experiment described in this chapter.
b. For McGreevy, the results reported in the table are only from the post-message phase.
c. Let log($x + c$) be the transformation used to create a functional form whose skew was approximately zero, where x is the variable of interest and c is a constant. Adjusted geometric mean xxx (antilog of the mean of transformed variable) – c. If c were zero, the adjusted geometric mean would equal the geometric mean.
d. For this variable, the minimum was zero in all experiments.

pothesis 3, for both scenarios, the Pearson correlation between discrepancy and number of changes was slightly positive, but it was not significantly different from zero in either scenario. We also found our independent variables to have no significant effect on pseudo-frequency.

Hypothesis 4a predicts that the greater the attitude change, the greater the amplitude. Using the pseudo-amplitude (and counting the

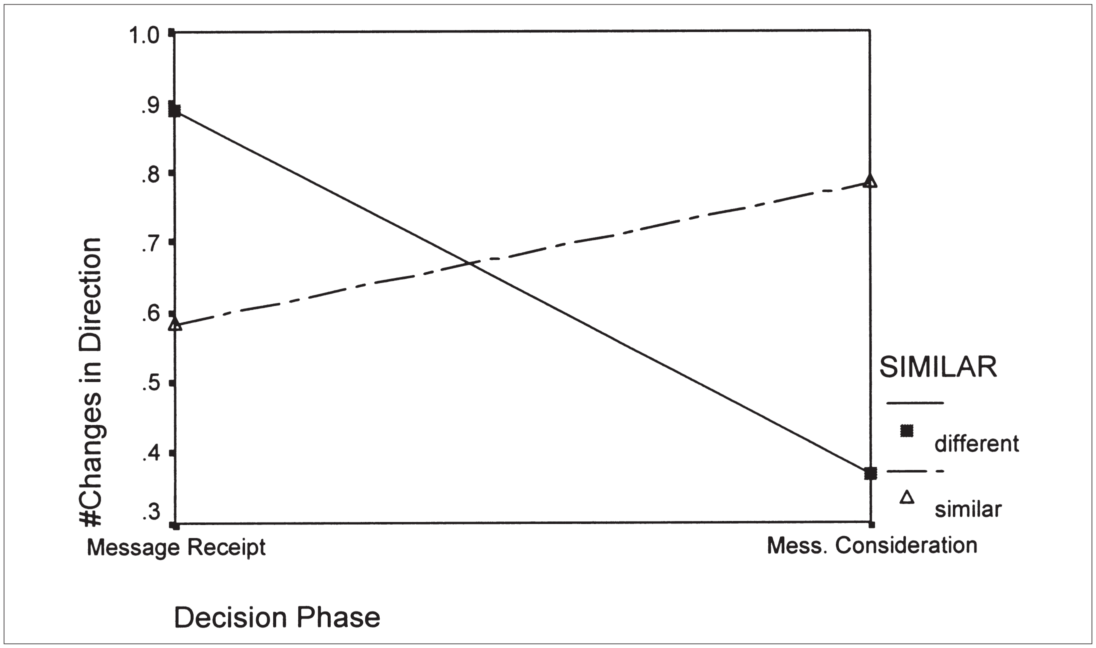

Figure 2.1. Mean Number of Changes in Direction, by Phase and by Object Similarity

amplitude as missing when there were no changes in direction), strong support for this hypothesis was found, but only for the sentencing scenario. For the criminal sentencing scenario, the Pearson correlation between amplitude and final attitude change was .45 ($p < .01$). However, for the tuition scenario, the Pearson correlation between these variables was only .08 (*ns*).

Although several of our findings disconfirmed our hypotheses, other evidence by Vallacher, Nowak, and Kaufman (1994) was consistent with the spatial-spring model. In that study, participants evaluated a stimulus person as they thought about that person and used a computer mouse to record their instantaneous judgments. Consistent with our spring model, they found in their Experiment 1 that the further someone's attitude is from its equilibrium position, the greater the acceleration.

To summarize, we have some support for the idea that people oscillate, but not for the more specific predictions of the spatial-spring model. One obvious explanation of this outcome comes from the logic of the model itself. We have assumed that every message a participant receives creates a new linkage. But as is well-known, as people process an external message, they often send themselves messages (i.e., cognitive responses) (see, e.g., Petty & Cacioppo, 1986; Petty, Ostrom, & Brock, 1981). If these self-generated messages create new linkages and affect the receiver's attitude, they will lead to trajectories that are far more complex and chaotic than those implied by the simple model. We now consider other variables that may affect the trajectories.

AMBIVALENCE, ELABORATION, DISTRACTION, AND NEED FOR COGNITION

Janis and Mann (1977) predicted that "vacillation" occurs when the conflict felt by the decision maker involves a "serious risk from the current course of action" or a "serious risk from a new course of action" and when "a better solution may be found" (p. 78). Similarly, Bruss (1975) attributed "a wavering in the process of deliberation" to

> an unclear ranking of preferences or incommensurable preferences, vague or uncertain beliefs about how well an object or act will satisfy a preference, what the available alternatives are and the relative probabilities of attaining each, and unresolved notions of the risk that is warranted or tolerable if a chosen alternative fails. (pp. 557-558)

Katz (1981) also argued that ambivalent attitudes tend to be unstable—a finding supported by Bargh, Chaiken, Govender, and Pratto (1992).

Situations in which people are ambivalent tend to be experienced as situations involving a great deal of tension. In these situations, people often are said to feel torn, pulled apart, or strained by conflicting demands of competing roles (see, e.g., Goode, 1960) as well as by the difficulty of making some decisions (see, e.g., Festinger, 1957; Heider, 1958). Such situations are clearly ones of great tension or stress. Thus, we predict the following:

> *Hypothesis 5:* Oscillation is more likely for issues on which the respondent is ambivalent (i.e., most likely to have conflicting feelings) and for which a decision is difficult.

Those studying cognitive responses to persuasion (see, e.g., Petty & Cacioppo, 1986; Petty et al., 1981) have shown that such cognitive responses have a strong relationship to attitude change. This idea suggests the following:

> *Hypothesis 6:* The number of cognitive responses should be positively correlated with the number of changes of direction.

If oscillation requires cognitive elaboration, it is more likely when people have the ability and motivation to elaborate (see Petty & Cacioppo, 1986). The *ability* to elaborate should be related to the availability and accessibility of the decider's thoughts (see Fazio, 1989; on the availability heuristic, see also Tversky & Kahneman, 1974) and should be more likely when the decider has a detailed or complex schema for understanding the issue (see, e.g., Tetlock, 1983a, 1983b). It should also be more likely when the decider is not distracted from concentration (see, e.g., Petty, Wells, & Brock, 1976).

Based on the Elaboration Likelihood Model, the motivation to elaborate should also be a function of the individual's need for cognition and of the importance of the issue to the decider. If thoughts have the effects we expect, then the number of changes of direction will be related to the number of cognitive responses. Thus, we have the following hypotheses:

> *Hypothesis 7:* Oscillation is more likely for issues the respondent considers important.

> *Hypothesis 8:* Oscillation is more likely for those who are high in need for cognition.

> *Hypothesis 9:* Distraction will cause fewer oscillations.

Our study employing criminal sentencing and tuition increases as the topics for consideration by the participants provides some evidence in support of Hypothesis 5. Respondents clearly regarded the tuition issue as more important to themselves, and a significantly greater percentage (47%) showed oscillation in this scenario than in the sentencing scenario (35%).

The results dealing with ambivalence are more extensive. We did a self-report study (see Fink & Kaplowitz, 1993, p. 261) in which participants were given a set of hypothetical decision problems (scenarios) and asked for paper-and-pencil responses to them. Consistent with Hypothesis 5, those who reported the decision to be difficult were more likely to also report having oscillated.

Similarly, Vallacher et al. (1994) provided other evidence that ambivalence contributes to oscillations. In their studies, participants received information about a stimulus person that was either positive, negative, or mixed (ambivalent) and then indicated how their instantaneous evaluations of the stimulus changed. Although participants in all conditions were likely to oscillate initially, the amplitude and frequency of oscillation of those receiving the positive or negative information declined, whereas the oscillations of the ambivalent participants did not.

Several of our online studies (i.e., those in which the participant employs a computer mouse to encode the trajectory of thoughts while thinking) have also examined the effect of ambivalence on oscillation. In the criminal sentencing and tuition attitude study, we measured ambivalence in two ways. One was by asking participants to list their thoughts about the sentence and the tuition. The other was by a set of closed-ended questions asking the participants' views on these issues.

Ambivalent participants were those who agreed with the arguments on both sides of the issue. For example, the following statement indicates a belief system that might oppose severe punishment for criminals: "Two wrongs do not make a right. Even though the criminal has behaved badly, this does not justify society violating the criminal's human rights." By contrast, the statement, " 'An eye for an eye' is an appropriate principle of justice," indicates a belief system that might favor severe punishment. Ambivalent participants were those who might agree with both of these positions.

In the study described previously, ambivalence had no significant relationship with the number of changes of direction in the attitude trajectory. Moreover, contrary to Hypothesis 6, the Pearson correlation between number of thoughts and number of changes of direction was less than .10 (*ns*) in each scenario.

We have also experimentally manipulated ambivalence by varying the difficulty of the decision the respondents are asked to make. In these studies, participants were asked to choose which of two fictitious candidates should be admitted to their university. In one case, the information was designed so that participants would find it to be a difficult decision. In the other case, the information was designed to make it likely that the participants would see one candidate as more suitable. As participants thought about the admissions decision, they used a computer mouse to indicate their instantaneous opinions as to which applicant should be admitted. At one end of the scale (from 0 to 100) was *definitely admit* [*Candidate A*]; the other end was *definitely admit* [*Candidate B*]. At intermediate points on the scale, the respondents could indicate leaning toward one candidate without total certainty.

In the first of these studies (Wang, 1993), one of the candidates for admission was Black and the other was White. To vary the decision difficulty, the hypothetical Black applicant was described either in an *individuated* way (i.e., in ways that the participants considered atypical of Black applicants) or in a *stereotypical* way. Note that in neither condition were evaluatively negative terms or beliefs used to describe either applicant. From the literature on racial attitudes, (e.g., Bobo & Kluegel, 1991; Jackman & Senter, 1983) and on individuation (see, e.g., Wilder, 1978, 1981), we expected White participants to have a more positive attitude toward the Black applicant when the Black applicant was individuated than when he was stereotypical. Consequently, we expected participants to find the admissions decision to be more difficult (i.e., more ambivalent) when the Black applicant was individuated than when he was stereotypical. Thus, we expected a greater amplitude and a greater number of changes in direction in the decision trajectory of the individuated than in the stereotype-consistent condition.

In this study, we also manipulated distraction. In the *high distraction* condition, there was distracting noise on the tape-recorded instructions, and the experimenter rustled papers and snacked on crunchy foods. In the *no distraction* condition, neither of these things happened. Manipulation checks showed that both independent variables were manipulated successfully. We also measured need for cognition using Petty and Cacioppo's (1986) scale.

Of the 67 participants, 59 (88%) had at least one change of direction. Moreover, the individuation manipulation created significantly greater self-reported decision difficulty. Individuation also had positive and significant (at $p < .01$) linear correlations with (a) the number of direction changes in the participant's decision trajectory ($r = .541$), (b) decision time ($r = .460$), and (c) pseudo-amplitude ($r = .401$). The linear correlations with self-reported decision difficulty were less strong (perhaps because of unreliability of the manipulation check of decision difficulty). Although individuation and decision difficulty were significantly correlated with each other ($r = .372$, $p < .01$), neither individuation nor decision difficulty was significantly correlated with pseudo-frequency (for individuation, $r = .003$; for decision difficulty, $r = .086$). In short, the more difficult decision involved more changes of direction, but these changes had the same frequency in both the easy and hard decisions. Thus, whether decision difficulty increases oscillation depends on whether one is using the total number of changes or their rate as the dependent measure.

Consistent with Hypotheses 5 and 6, individuation produced more thoughts ($r = .368$, $p < .01$), and the number of thoughts was positively correlated with the number of changes of direction ($r = .411$, $p < .01$). These results also contained some surprises. First, the need for cognition scale had a near zero correlation with the number of thoughts and a surprisingly small correlation with the number of changes of direction ($r = -.262$, $p < .05$). Second, contrary to our expectations, distraction had a positive correlation ($r = .221$, *ns*) with the number of thoughts and a significant and a positive correlation ($r = .420$, $p < .01$) with the number of changes in direction.

Thus, decisional conflict increases the tendency to change one's mind, which apparently made the decision process take longer. This conflict did not, however, increase the rate of the oscillation. Contrary to the findings of previous studies (e.g., Petty et al., 1976), distraction did not reduce thought production. Rather, it made the thinking process take longer.

McGreevy's (1996) study ($N = 102$) used a similar methodology to Wang's (1993) study and examined the effect of both decision difficulty and distraction. In the *difficult* decision, both college applicants were *similar* in that both were appropriate for admission into college. In the *easy* decision, only one candidate was appropriate for admission into college. The difficulty manipulation in this study was successful.

The results generally replicated those just reported. For cognitive processing *after reading the message*, participants again showed significantly more oscillation for the difficult decision than for the easy one. They also took significantly more time in the condition in which they were distracted. (As explained later, McGreevy, 1996, also measured the trajectory as the participants read the message.)

NEED FOR CLOSURE AND DECISION PHASE

Kruglanski's (1989, 1990) theory of lay epistemics suggests that people differ in their *need for closure*. Need for closure is defined as "the desire for a definite answer on some topic, any answer as opposed to confusion and ambiguity" (Kruglanski, 1989, p. 14). On the other hand, *need to avoid closure* occurs in situations "where judgmental noncommitment is valued or desired" (p. 18). Kruglanski (1989, 1990) claimed that need for closure can result in an "epistemic freezing" (Kruglanski, 1989, p. 14), in which participants are not motivated to process information and have a strong desire to come to a quick conclusion. We hypothesize that individuals who experience a *high need for closure* are unwilling to expend the cognitive effort required to make a decision. Therefore, we have the following hypothesis:

> *Hypothesis 9:* Need for closure correlates negatively with (a) the time to make a decision and (b) the number of changes of direction.

There is evidence that different kinds of cognitive processing may occur during different phases of the decision-making process (see Bassili, 1989; Hastie & Park, 1986; Hastie & Pennington, 1989). Hastie and Pennington (1989) have found differences in cognitive processing between social inference tasks that were made online ("during the process of perception, when the other person is present to the senses") and social inference tasks that were memory based ("when we think about a person in their absence") (p. 1).

Research on online cognition suggests that a great deal of cognitive processing can occur while an individual receives a message. This cognitive processing may be different from the type of processing that occurs once the message has been received and while an individual thinks about the information contained in the message in order to make a decision. To explore this possibility, we divided the attitude trajectory into two phases: (a) the *message receipt phase*, which occurs as an individual is receiving the attitude message; and (b) the *post-message phase*, which occurs after the message has been received and while the individual is considering the information in the message.

In addition to examining the effect of decision difficulty and distraction, McGreevy's (1996) study examined the effect of need for closure and decision phase on the attitude trajectory. Need for closure was manipulated by varying environmental noise (Kruglanski & Webster, 1994). In the *high need for closure* condition, a loud humming noise was piped into the experimental room. In the *low need for closure* condition, participants were warned that the noise might occur; however, no noise was actually used. There was also one individual difference variable, *trait* need for closure, which was measured by Webster and Kruglanski's (1994) need for closure scale.

Manipulation checks showed that individuals who heard the noise reported the environment to be significantly more distracting and also reported a significantly greater motivation to complete the task quickly than did those who did not hear the noise. Thus, this manipulation both increased the participants' need for closure and made them feel more distracted. They did not, however, report that their cognitive capacity was affected by the noise.

This study measured the attitude trajectory using the same computer mouse technique described earlier, with one important change. The previous studies had participants use the mouse only after reading the message. In this study, participants started indicating their instantaneous preferences with the mouse *while they read the information about the candidates.* Participants were further instructed to push the left mouse button when they finished reading the information. Then, as in previous studies, they were to continue to move the mouse as they thought about the issue until they made a final choice as to whom they preferred. At this point, they were to push the left mouse button a second time. This procedure allowed each participant's decision trajectory to be divided into two parts: (a) the *message receipt phase* (i.e., while the participant was receiving the message) and (b) the *post-message phase* (i.e., while the participant was thinking about the message and deciding between the candidates).

Overall Trajectory

Those with a high need for closure were expected to take less time on the decision-making process (Hypothesis 9a) and have decision trajectories that exhibit fewer oscillations (i.e., fewer changes in direction) (Hypothesis 9b) than those with low need for closure. We first examine these results for the overall trajectory over two decision-making phases and then examine the phases separately.

As expected, participants with a difficult decision took significantly more time to decide between the candidates ($p = .001$) than did those with an easy decision. But contrary to Hypothesis 6, the number of changes of direction exhibited by the mouse had no significant relation to the difficulty of the decision. However, a *self-report* measure of changes in cognitive direction produced results consistent with Hypothesis 6. In what follows, we examine this finding.

A statistically significant interaction between manipulated need for closure and the candidates' similarity (decision difficulty) on decision time was also found. Consistent with Hypothesis 9a, when participants faced the more difficult decision, the higher the need for closure, the less time participants took to make their decision. But when participants dealt with the easy decision, contrary to Hypothesis 9a, the greater the manipulated need for closure, the more time the participants took.

We found a somewhat similar interaction effect when the number of changes of direction was our dependent variable. Consistent with Hypothesis 9b, when the decision was rated as difficult by the participants, those in the high need for closure condition had fewer changes in direction than did those in the low need for closure condition. However, when the decision was rated as less difficult, those in the high need for closure condition exhibited more changes in direction than those in the low need for closure condition.

The results that are contrary to Hypothesis 9a or 9b can be better understood when we remember that the need for closure manipulation was a distraction. Wang (1993) found that those who experienced a distraction took longer to come to a final decision than did those who did not experience a distraction. And it is also possible that the distraction not only increased the time spent but also caused people to reconsider their decision, resulting in additional oscillations. However, the reason that this effect was found only in the easy decision scenario is not clear.

Separate Decision Phases

In the post-message phase, we found mixed results for both hypotheses. Consistent with Hypothesis 9b, the need for closure scale had a significantly negative linear correlation with the number of changes in direction. But contrary to Hypothesis 9a, it had a near zero

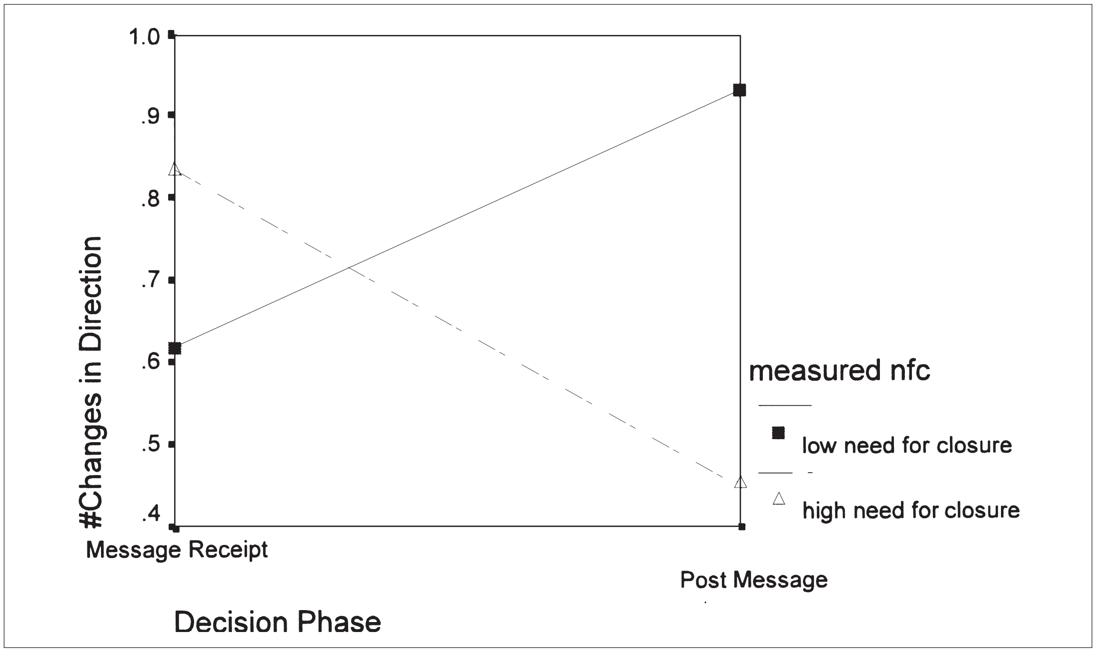

Figure 2.2. Mean Number of Changes in Direction, by Phase and by Measured Need for Closure

linear correlation with the decision time. Consistent with Hypothesis 9a, manipulated need for closure had a negative (but nonsignificant) linear correlation with decision time. But contrary to Hypothesis 9b, it had a near zero linear correlation with number of changes in direction.

Examination of trajectories showed that the independent variables had different relations to the trajectories in the two different phases. As indicated previously, for the post-message phase, those with a difficult decision showed more changes in direction than did those asked to choose between different candidates. For the message receipt phase, however, the results were in the opposite direction and the interaction was significant (see Figure 2.1).

We also found a significant interaction between decision phase and measured (trait) need for closure (see Figure 2.2). As indicated previously, the post-message phase shows the expected results. Those measuring high in need for closure exhibited fewer oscillations than did those measuring low in need for closure. For the message receipt phase, however, the results were in the opposite direction.

These results suggest that different kinds of cognitive processing occur at different points in the attitude change process. Those with a high need for closure do most of their oscillating (and perhaps most of their cognitive processing) while receiving the message. Evidence of oscillation while receiving a message is consistent with current research about online cognition (Bassili, 1989). But consistent with Kruglanski (1989), those with low need for closure are more likely to oscillate after the message has been received.

Let us now return to the findings relating number of changes of direction to difficulty of decision (similarity of candidates). We have found that (a) the overall trajectory shows no significant effect of difficulty, (b) there is a significant effect of difficulty on the self-reported oscillations, and (c) the effect of decision difficulty on the number of observed changes is as predicted in the post-message phase but is in the opposite direction in the message receipt phase. Taken together, these findings may suggest that the observed trajectory is a more accurate reflection of the cognitive process in the post-message phase than in the message receipt phase. In the message receipt phase, participants were asked to read the message and record their preferences as they were having them. In this phase, it is possible that when they were asked to choose between two similar candidates, they were concentrating so hard that they forgot to move the cursor in conjunction with their thoughts. When asked to recall the number of times they changed their minds between candidates, however, they were able to recall changing their minds more often for the difficult decision scenarios. Further research is needed to clarify this issue.

DEGREE OF RANDOMNESS AND CHAOS

As indicated previously, we started with a model that predicted periodic trajectories. We found this prediction to be disconfirmed. Furthermore, we proposed that cognitive responses create trajectories that are chaotic. Indeed, such chaos is suggested by the Dewey quote that begins this chapter.

The (most positive) Lyapunov exponent is a statistic that permits us to examine the degree of pattern in a trajectory. This statistic is "a measure of the rate at which nearby trajectories in a phase space diverge" (Sprott & Rowlands, 1992, p. 19; see also Casti & Karlqvist, 1991). Periodic orbits have Lyapunov exponents that are near zero, chaotic orbits have at least one positive Lyapunov exponent, and random orbits have still larger Lyapunov exponents. In other words, the higher the Lyapunov exponent, the more unpredictable the future trajectory is based on its past values.

We find that in McGreevy's (1996) study, out of 102 trajectories, only 1 has a negative Lyapunov exponent and 1 more has a value less than 0.10. Fully 75% of the trajectories have Lyapunov exponents that are 0.24 or greater. The median value for the Lyapunov exponents of these trajectories is 0.30 (range: –0.10 to 1.66). This result suggests that the trajectories are chaotic.

A reexamination of the attitude trajectories in Wang's experiment (see Fink, Kaplowitz, & Wang, 1994) showed that whereas greater oscillation occurred when the decision was difficult than when the decision was easy, those in the difficult decision conditions exhibited attitude trajectories that were less patterned (having higher Lyapunov exponents) than the attitude trajectories of those in the easy decision conditions.

The results from the McGreevy (1996) experiment were different. These results showed no significant effects of any of our independent variables on the Lyapunov exponents of the attitude trajectories. However, when we enter the participants' assessments of how careful they were as a covariate and also have it interact with our independent variables, several highly significant ($p < .01$) effects are found. The trajectories of those with high manipulated need for closure have higher Lyapunov exponents than do those with low manipulated need for closure. There is a significant interaction between decision difficulty and manipulated need for closure, such that the trajectories of those with an easy decision but low manipulated need for closure have relatively low Lyapunov exponents, whereas those with an easy decision but high manipulated need for closure have relatively high Lyapunov exponents. There are also several significant interactions that are not easily interpreted.

CONTINUOUS VERSUS DICHOTOMOUS DECISIONS

Some decisions require a choice between two opposing alternatives (e.g., which of two candidates to choose), whereas others allow for the possibility of a compromise between them. Some decisions, in fact, allow for a nearly continuous range of possible outcomes (e.g., the amount of money to contribute to an organization). This distinction, the *discreteness* of the decision outcome, may affect oscillations.

Suppose that the balance of attitudinal forces causes the decider to be uncomfortable with either end point of the set of decisional choice alternatives and to prefer some compromise. If the decision is continuous, this equilibrium location is a viable decision. However, if the decision is dichotomous, any such compromise is an impossibility. Thus, with dichotomous decisions, for oscillations to die down, it is not sufficient that the individual settle down at the position where the cognitive forces balance. It may also be necessary that the strength of these forces be *altered* so that one decisional end point can become the equilibrium location. The preceding discussion suggests the following hypothesis:

> *Hypothesis 10:* Difficult dichotomous decisions are likely to sustain more oscillations and take longer than are continuous decisions.

This prediction may be investigated by employing the data summarized in Table 2.1. We have identified two independent variables that should affect oscillation. One is the importance of the decision to the respondent; the other is the difficulty of the decision. Among all of the oscillation studies, the one in which the decision is probably most important to the respondents is the tuition study. This issue affects the respondents in a way that none of the others affects them. On the other hand, the most difficult decisions were probably those admissions decisions that were designed to be difficult. In these decisions, the respondents truly were pulled in both directions. The tuition study allows a continuous outcome, whereas the admission decisions requires a dichotomous choice.

In Table 2.1, we see that the continuous decisions have a smaller mean time of decision and fewer changes than do the difficult dichotomous ones. But we also see that the continuous decisions and the easy dichotomous ones do not differ in the number of oscillations. The two easy dichotomous decisions, however, took less time than the continuous ones. Moreover, because the discreteness of the decisions is confounded with decision difficulty, we cannot reach any conclusions about whether continuous decisions produce fewer oscillations than dichotomous ones.

LENGTH OF DECISION AND RELIABILITY

At the beginning of this chapter, we said that studying oscillations might tell us how long we need to wait for the attitude to reach equilibrium. At equilibrium, an attitude should be stable and its measurement should be reliable. Table 2.1 provides some useful information on this issue. Looking at decision time, across all studies it seems that even in the easiest decision, if we want at least 75% of the respondents to reach a decision that they consider complete, we need to wait at least 36 seconds. This time period is a slight overestimate of how long the participants oscillate because participants usually waited several seconds after reaching their final position before declaring themselves done. However, it indicates that when people are creating an attitude response online (rather than retrieving a rating stored in memory), it takes more time to do so than an attitude survey typically allows.

CONCLUSION AND FUTURE RESEARCH

Clearly, oscillation occurs (especially for difficult decisions) and exhibits a systematic relation to theoretically relevant independent and dependent variables. Evidence indicates that attitude trajectories are not simple sinusoids. This finding suggests that we need to supplement our oscillation model with theory based on consideration of conscious cognition. Results also suggest that the attitude change process is more complex than current models imply.

Conclusions from our online investigations are based on two assumptions. First, the motion of the computer mouse represents true cognitive motion (i.e., attitude or belief change). Second, the attitudinal position indicated by the mouse is the position the respondent would take if required to make a final decision at that moment.

We have seen evidence that the first assumption is not always met. Trajectories sometimes contain vibrations and spikes that look like random motion. However, we have corrected for this apparent noise by not counting these motions as true change. We also have seen that our independent variables have a different effect on the trajectories created while people are reading a message as compared to their post-reading trajectories. We suggest that people may sometimes forget to move the mouse while they are reading. If so, the trajectory of mouse movement that is created while reading does not fully reflect the cognitive changes. This point merits further research.

At first glance, it might appear that if the first assumption (i.e., that the recorded motion of the mouse is true change) is valid, then the second one (i.e., that the position at any instant represents the decision at that instant) must also be valid. However, rather than being what the participant would choose if forced to decide, the mouse motion may be the cognitive equivalent of “trying on” a position or decision to see whether it “fits.”

To resolve this question, we propose the following experiment. One could, at a predetermined time, interrupt the participants while they are thinking and moving the mouse. (Participants would be randomly assigned to different interruption times.) One could then ask for a paper-and-pencil response, allowing the participants different amounts of time to think before responding. A finding that the correlation between the final mouse position and the paper-and-pencil rating is much higher when participants are required to respond immediately than when they are is given more time to think would support our assumption that the mouse position is, in fact, the choice the participant would make at that point.

Future research should also focus on a deeper understanding of the relationship among the many variables responsible for oscillation in attitudes and beliefs. In addition, we want to resolve some confusing findings regarding distraction. Distraction sometimes slows cognitive processing, and at other times it apparently creates a need to finish more quickly, speeding up the decision process and reducing oscillation. Future research should further examine the relationship among variables such as decision time, the number of thoughts, the number of changes in direction, and the amplitude of the oscillation. Results from our research provide exciting evidence regarding differences in the types of cognitive processing that occur (a) while individuals receive a message and (b) while individuals consider the information contained in the message. A closer examination of these subprocesses, including how the different types of processing affect the outcome of persuasive messages, will lead to a clearer understanding of the entire attitude change process.

A second set of issues relates to interactions involving the message receipt phase of cognitive processing. McGreevy (1996) found that in the post-message phase, those faced with a difficult decision oscillated more than did those faced with an easy decision. She also found that those with a low need for closure oscillated more than did those with a high need for closure. Neither of those findings was surprising. What was surprising, however, was that while reading the message, both of these findings were reversed. We have suggested that perhaps those dealing with the difficult decision were so absorbed in reading that they forgot to move the mouse. But why did they show this effect only in the message-reading phase and not in the post-message phase? Research and theory are needed to investigate this question.

Furthermore, why does need for closure play such a different role in the two phases? Recall that during the message receipt phase, individuals with a high need for closure have greater oscillation. What is the link between need for closure, speed of message processing, and oscillation? Do those with a high need for closure process messages more thoroughly? What are the characteristics of the message on which oscillation and speed of processing depend?

The Lyapunov exponent indicates that attitude trajectories that we observed are rather chaotic, suggesting that Dewey (1991) may be correct. We found some very interesting interactions involving the Lyapunov exponents. But although several experimental variables clearly have a substantial effect on these exponents, we currently lack a theory that can make sense of these results.

We should be engaged in theory building from several directions. First, it appears that the process of decision making and attitude change may be best described by the mathematics of nonlinear dynamics and chaos. Understanding this mathematics offers the possibility of making explicit the links between the psychological forces and the attitudinal trajectory.

Second, we should improve our understanding of how various features of the trajectory lead to higher versus lower Lyapunov exponents. Does the total number of changes of directions have an effect? Does the speed at which the changes in direction take place make a difference? How do changes in the amplitude and frequency affect the Lyapunov exponent?

Once we investigate these issues, we may be better able to understand how various psychological and communication variables influence the decision trajectory. If we can use this information to predict the effects of certain theoretically relevant independent variables, we will be better able to understand and explain the cognitive processes at work.

NOTES

1. The equilibrium predictions of this model are isomorphic with those of an information integration model we have used (see Fink, Kaplowitz, & Bauer, 1983; Kaplowitz, Fink, Armstrong, & Bauer, 1986; Kaplowitz & Fink, 1991). These models, in turn, have been based on earlier ones proposed by Anderson (1981), Anderson and Hovland (1957), and Saltiel and Woelfel (1975). In the Information Integration Model, the weight of the initial attitude is analogous to the anchoring linkage, and the weight of the message position is analogous to the message linkage. Equation (2) is actually a special case of a more general equation proposed by Kaplowitz and Fink (1992, p. 353).

2. An alternative would be to consider the amplitude to be zero in those cases without any changes in direction. However, if this were done, the Pearson correlation between amplitude and the number of changes would exceed .80, and it would

then not be possible to disentangle the effects of our predictors on amplitude and frequency.

3. Subsequent analysis of the data suggests that distraction led to thoughts that were more concrete and sequential.

4. Statistical analysis within the linear model requires that residuals be normal and homoscedastic. Although these methods are robust with respect to modest violations of these assumptions, in many cases our data indicated gross violations (e.g., large positive skews). Where this was the case, the dependent variable was logarithmically transformed prior to analysis.

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