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From Consistency Theories to Constraint Satisfaction**  
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## Structural Dynamics of Cognition: From Consistency Theories to Constraint Satisfaction

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*We first offer a brief review of the history of cognitive consistency theories in social psychology. After promising beginnings as an outgrowth of Gestalt theory, early consistency theories failed to yield a general account of the mechanisms by which attitudes are formed and decisions are made. However, over the past decade the principles underlying consistency theories have been revived in the form of connectionist models of constraint satisfaction. We then review experimental work on complex legal decision making that illustrates how constraint satisfaction mechanisms can cause coherence shifts, thereby transforming ambiguous inputs into coherent decisions.*

Half a century ago, in an exciting period in the history of social psychology, a cluster of theories were proposed that became known as theories of cognitive consistency. Balance theory (Heider, 1946, 1958), cognitive dissonance (Festinger, 1957), congruity theory (Osgood & Tannenbaum, 1955), and symmetry theory (Newcomb, 1953) shared the same Gestaltian origins (Zajonc, 1960a), and they seemed also to share a common mission of uncovering the structural-dynamic character of human cognition (Abelson et al., 1968; Heider, 1960; Zajonc, 1968; Zajonc & Markus, 1985). For example, McGuire highlighted the expectation that consistency theories would provide the basis for a general psychology of inference:

The end was a description of how people think in the broadest sense of the term. By using the assumed psychological necessity for maintaining a highly structured, highly consistent belief system, I hoped to do no less than construct and test a psychology of inference, that is, a depiction of the manner and extent to which one idea leads to another psychologically (McGuire, 1968, pp. 140-141).

A principal characteristic of structural dynamics was the phenomenon of mutual interdependency among the

elements of thought, forming states of “order and coherence” (Heider, 1946, p. 175). Heider explained:

These conceptions, symmetry, consonance, balance, and simplicity, are, of course, implied in that idea with which Gestalt theory started and which always was central to it, namely, the idea of a “good” figure. ... This model implies a number of different entities with certain properties and standing in certain relations, which make up a constellation of factors tending toward a standard state. (1960, p. 168)

Heider argued that elements that “go together” tend to form stable structures, whereas inconsistent elements generate forces that operate towards the reinstatement of stability (Heider, 1960).

Among the consistency theories, one variant—cognitive dissonance theory—soon became dominant. Dissonance research revealed that not only could people be manipulated into telling lies (Festinger & Carlsmith, 1959), insulting other people (Davis & Jones, 1960), and eating grasshoppers (Zimbardo, Weisenberg, Firestone & Levy, 1965), but that they would subsequently change their attitudes to believe the lie they told, to derogate the victim of their insult, and to develop a liking for the taste of grasshoppers. As this “forced compliance” paradigm came to dominate dissonance research, cognitive dissonance became the flagship of social psychology, recognized as “the most single important development in social psychology to date” (Jones, 1976, p. x).

However, the burgeoning program of research on cognitive dissonance in some ways undercut the broader

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goals of consistency theories. As the cognitive dissonance research program progressed, it began to rely less on Heider's balance theory (Festinger, 1957, pp. 7-8) and its Gestaltian underpinnings, and more on hypotheses related to self-maintenance. Cognitive dissonance theory was first reformulated to state that it makes its strongest and clearest predictions when the dissonance pertains to violation of one's self-concept as consistent, stable, competent, and moral (Aronson, 1968). In a similar vein, subsequent reformulations emphasized other self-related conditions, including the freedom in choosing the behavior (Davis & Jones, 1960), public commitment (Brehm & Cohen, 1962; Carlsmith, Collins, & Helmreich, 1966), aversive consequences (Cooper & Fazio, 1984; Scher & Cooper, 1989; cf. Harmon-Jones, Brehm, Greenberg, L. Simon, & Nelson, 1996; Thibodeau & Aronson, 1992), personal responsibility (Cooper & Fazio, 1984), foreseeability of consequences (Wicklund & Brehm, 1976), and irreversibility of consequences (Lepper, Zanna & Abelson, 1970). Aronson (1992) and others claimed that cognitive dissonance is capable of encompassing a range of self-maintenance theories, including self-affirmation (Steele, 1988), symbolic self-completion (Wicklund & Gollwitzer, 1981), self-evaluation maintenance (Tesser, 1988), self-discrepancy (Higgins, 1989), action-identification (Vallacher & Wegner, 1987), self-verification (Swann, 1984), and self-regulation (Scheier & Carver, 1988). Indeed, cognitive dissonance theory came to be interpreted as a rival to some other theories of self-maintenance (Schlenker, 1982; Tedeschi & Rosenfeld, 1981).

The conclusion that cognitive dissonance had become an ego-defense theory seems beyond dispute (Berkowitz & Devine, 1989; Greenwald & Ronis, 1978; Simon, 1997). One consequence was that some of the early supporters of cognitive dissonance theory, and proponents of other variants of consistency theory, grew disenchanted. By 1968, McGuire noted that he was "rather disappointed and regretful" about the tendency of consistency researchers to emphasize flagrant behavioral situations while sidestepping the more important mission of utilizing consistency tendency to explore the structure and functioning of the cognitive system (McGuire, 1968, p. 141). In an address entitled "Whatever became of consistency theory?" Abelson (1983) lamented the fate of consistency theories, noting that cognitive dissonance theory had been reduced to explaining how people "recover from experimentally engineered major embarrassments." Abelson insisted that the behavior of people who have been forced to make "damned fools of the themselves" is a distraction from the broader potential applications of structural dynamics (Abelson, 1983, p. 43; see also Berkowitz & Devine, 1989).

But there was more than the focus on ego-protection that prevented consistency theories—especially cognitive dissonance—from providing an encompassing the-

oretical framework for the understanding of human reasoning more generally (For a discussion, see Simon, 1997). Dissonance was confined to dyadic cognitive structures only, and the situations in which the cognitive elements are directly opposed to one another (Festinger, 1957, p. 13). Dissonance theory's emphasis on people's reactions to undesirable states did not offer much in the way of analysis of the mental processing that leads them into those situations. In the forced-compliance paradigm, dissonance is assumed to arise only following engagement in counter-attitudinal conduct. The theory says nothing about the conditions that affect the compliant counter-attitudinal behavior, nor about how anticipation of arousal of dissonance might affect behavior. Similarly, in the decision-making paradigm, Festinger and his colleagues insisted that dissonance is aroused only after the decision has been completed. Prior to that point, they claimed, the processing is best characterized by the "impartiality of information seeking and the absence of any systematic, biasing re-evaluation of alternatives" (Festinger, 1964, p. 153). Jerome Bruner criticized Festinger on the grounds that "the most interesting aspects of cognition are those that *precede* the making of decisions rather than those that *follow* [it]." Bruner commented that cognitive dissonance theory amounted to a "rather autistic tradition" (Bruner, 1957, p. 152, italics in original).

Following Bruner (1957), dissonance has been criticized for being excessively responsive in nature (Rosenberg & Hovland, 1960), and for having turned, in effect, into an inconsistency theory (Singer, 1966). As Heider (1979) later suggested, the tendency towards consistency should not be deemed as merely repairing disturbances of coherence; rather, it implies reaching out to bring the various pieces of the cognitive field into consonance. Similarly, McGuire (1968) emphasized the significance of consistency maximization.

Prominent consistency researchers argued that consistency attainment should be deemed as proactively making sense of the world. Heider (1979) argued that the tendency toward balanced states is based on the desire "to have our cognitive food prepared so that it is easy to swallow, to assimilate" (p. 16). Abelson (1968) described the cognitive function as motivated by the need to "organize the information stored by the individual in a way that is likely to be useful to him, directly or indirectly, for affective or behavioral purposes" (p. 133). Pepitone (1966) claimed that the pressures to reduce inconsistency follow from the fact that consistent structures "are simpler to maintain than distinctions, discrepancies and contradictions" (p. 270). Back (1968) emphasized the effectiveness of cognitive processing as a necessary means for survival: "Consistency makes it possible for the organism to structure the world in an economical way to react to facts which are con-

nected in a consistent way” (p. 315). Tannenbaum (1968) summarized the position as follows:

“...The reasoning behind [the consistency position] relates to the organism’s presumed need to apprehend and comprehend things and events about him. In monitoring, processing, and interpreting information from the environment, some degree of consistency and equilibrium is seen as essential for reasons of parsimony and economy of effort, as well as to allow for the predictability of, and hence adaptability to, subsequent encounters. ...most assume a universal value for the organism in his having a stable predictable view of his environment” (p. 346).

Looking back from our current vantage point, other early variants of consistency theory seem to have provided a stronger basis for models of cognitive change. Foundations for a general approach to human reasoning can be found in Abelson and Rosenberg’s theory of Symbolic Psycho-Logic (1958; Rosenberg & Abelson, 1960), an offshoot of Heider’s balance theory. The model carves out what is called a conceptual arena, comprised of the relationships among the elements that constitute the attitudinal structure, including abstract concepts and complex propositions. The myriad of relationships generate a variety of positive, negative or neutral values that ultimately drift towards balanced states. The model posits that a person experiencing attitudinal imbalance will try to redress the cognitive state by altering the relations, modifying the elements, or avoiding the issue altogether. A related model is McGuire’s (1960) image of a “loose-link” network comprising chains of reasoning. Consistency-driven forces spread gradually through the related links to the system’s remote elements, gradually changing the network’s activation towards a higher state of coherence. McGuire’s (1960) research on the “Socratic Method” showed that the elicitation of a person’s beliefs on complex issues reveals the extant inconsistencies among them, which then causes a change in those beliefs in the direction of greater consistency.

### Connectionist Models of Constraint Satisfaction

In the 1990s, consistency theories were reformulated with the advent of connectionist theories of cognition, and in particular, constraint satisfaction mechanisms. In models of this type, complex tasks are performed by networks in which the decision variables are interconnected by excitatory and inhibitory links representing positive and negative relations among the variables. Constraint satisfaction models operate by applying a relaxation algorithm that settles the network into a stable state in which the asymptotic activation

levels of the units define a set of highly activated variables. Bidirectional activations enable units that mutually support each other via excitatory connections (i.e., those that “go together”) to become highly active, and collectively inhibit their rivals. The bidirectional influences between related units play a critical role in allowing the system to impose a coherent interpretation on the overall situation.

Connectionist constraint-satisfaction models were first applied to lower-level cognitive processes, notably letter and word perception (McClelland & Rumelhart, 1981). Models based on similar algorithms were later applied to a variety of higher-level cognitive processes, including analogical mapping (the ACME model of Holyoak & Thagard, 1989; Spellman & Holyoak, 1992), evaluation of competing explanations (the ECHO model of Thagard, 1989, 1992; see also Read & Marcus-Newhall, 1993), and decision making (the DECO model of Thagard & Millgram, 1995).

Read and Miller (1994; Read, Vanman, & Miller, 1997) proposed the application of constraint satisfaction mechanisms to the questions left unresolved by consistency theorists. As Read and Miller pointed out, the capability of connectionist representations to capture rich and large conceptual structures and to relate them to the person’s background knowledge constituted important progress over the restrictive dyads and triads of yesteryear. Furthermore, interactive constraint-satisfaction algorithms provide a more realistic and nuanced means of resolving consistency than the crude mathematical rules used by consistency theorists.<sup>1</sup> Read and Miller (1994) used constraint satisfaction simulations to model the restoration of consistency to states of imbalance and dissonance. Similarly,

<sup>1</sup>A rich and prescient description of both the structural and the dynamic aspects of constraint satisfaction mechanisms was offered by Milton Rosenberg:

Let us imagine a finite but vast space called the ‘attitudinal cognitorium.’ Within it are located hundreds (thousands?) of object-concepts, each of these being a verbal (or other symbolic) representation of a person, institution, policy, place, event, value standard, or other ‘thing’ which, when psychologically encountered, elicits some fairly stable magnitude of either positive or negative evaluative affect. Represent each of the object-concepts as a little metal disk. Between these disks run strings which tie them together, two at a time. Red strings indicate a negative or ‘disjunctive’ relationship of the sort that might be conveyed by the terms ‘opposes,’ ‘prevents,’ ‘dislikes,’ ‘stays away from,’ etc. Green strings indicate a positive or ‘conjunctive’ relationship of the sort conveyed by terms such as ‘supports,’ ‘facilitates,’ ‘likes,’ ‘helps,’ ‘is part of,’ etc.

Any given object disk is tied by red strings to some, and by green strings to other, object disks. But it is not directly connected to all other disks in the attitudinal cognitorium. [strings can be of varying degrees of thickness] ...

Compound such a structure a few hundredfold (or many thousandfold...) and one has an analog representation of an individuals’ attitudinal cognitorium. Now lay all the disks, with the connecting strings on some vast floor. Peering from

Schultz and Lepper (1996) used a constraint-satisfaction model to simulate various findings of dissonance research; and Spellman, Ullman and Holyoak (1993) tested attitudes in a semi-naturalistic setting and showed consistency effects across a fairly large attitudinal structure.

### **Coherence Shifts in Legal Decision Making**

In our own joint research (Holyoak & Simon, 1999; Simon, Pham, Le & Holyoak, 2001), we have addressed the issue of whether processes that generate coherence among inferences and beliefs could play a direct role in complex decision making. In contrast to earlier work in the tradition of dissonance theory, our research focuses on the cognitive mechanisms involved in reaching decisions in large and complex tasks. Our guiding hypothesis has been that decisions based on complex but ambiguous information follow a function of maximal coherence among the underlying inferences; and that the process of achieving coherence is based on constraint satisfaction, which depends on bidirectional links.

We performed a series of experiments in which college students acted as judges in a simulation of judicial reasoning. Our major aims were to demonstrate (1) that coherence can in fact be achieved in the face of extreme ambiguity; (2) that the pressure to achieve coherence guides the decision-making process itself, rather than simply providing post hoc rationalizations; and (3) that the impact of "spreading coherence" can extend through a chain of intermediate inferences to produce remote changes.

To address the first question, we examined whether people faced with a decision fraught with ambiguity shift their beliefs so as to increase their coherence with

one another and with the eventual decision. Participants in all our experiments were asked to evaluate a set of arguments that share no apparent relationship, first in isolation, and later in the context of a legal case. In the latter instance, the inferences were phrased in the form of legal arguments, half of which were made by the plaintiff and half by the defendant. Correspondingly, half of the arguments supported one decision and the other half supported the opposite outcome. If decisions are based on bidirectional constraints between inferences, then we would expect assessments of the individual arguments to shift so as to lend stronger support for the final verdict. In addition, we would expect to observe a shift from zero or weak correlations among the argument evaluations in the preliminary assessments to robust positive correlations on the post-decision assessment.

In some experiments we also addressed the second question—when do coherence shifts occur?—by examining whether a shift in coherence precedes the generation of a verdict, or only occurs post-verdict. If coherence among argument evaluations emerges prior to the decision, this result would support the claim that development of internal consistency within a coherent position plays a causal role in reaching decisions, rather than arising as the result of post-decision changes (contrary to the position advocated by Festinger, 1957, 1964).

The materials in all of our experiments consisted of a legal case and sets of opposing arguments offered by the plaintiff and the defendant. The case was called "Caught in the Net", and involved a civil action triggered by a statement that was posted on an Internet bulletin board. The dispute centered on a lawsuit launched by Quest, a software company, against Jack Smith, an investor in the company. The facts, which were not in dispute, were that Quest's financial situation had deteriorated and its management was having difficulty in coping with the problems facing the company. Smith, a dissatisfied shareholder, posted a negative message about Quest's prospects on an electronic bulletin board directed at investors. Shortly thereafter Quest's stock price plummeted and the company went bankrupt. It was later revealed that (unbeknownst to Smith) Quest had been secretly developing a new product that might have saved the company. Quest was now suing Smith for libel, claiming that his message caused the collapse of the company.

Each side made six arguments in favor of its position. The arguments formed opposing pairs, or points of dispute. The first three points of dispute involved matters of fact, and the second three involved matters of law or social policy. (1) Truth: Quest argued that Smith's negative message was unfounded, whereas Smith claimed it was well founded. (2) Cause: Quest asserted that the message caused the company's downfall, whereas Smith claimed that mismanagement was the cause. (3) Motive: Quest claimed that Smith's ac-

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above at the total array or at some sector of it, we note that green strings connect like-signed objects and red strings connect opposite signed objects (consistency by Heiderian or psycho-logic definition!) far more often than do green strings connect opposite-signed objects and red strings same-signed objects (inconsistency).

After capturing the essence of representational structures, Rosenberg offers a metaphoric depiction of dynamic nature of settling constraints within a cognitive space. Again, the similarity to constraint satisfaction mechanisms is remarkable:

To get at the full attitude one must lean over, grab the particular disk, and pull it into the third dimension. The other disks that come off the floor shortly thereafter, because they are directly attached by red or green strings to the object that has been made central by our pulling it, are the other objects that, together with the central one, comprise an intraattitudinal structure.

It is noteworthy that with no theoretical tools or empirical findings to support these insights, Rosenberg apologetically portrayed this presentation as a "fanciful metaphor." (Rosenberg, 1968, pp. 78-80).

tion was motivated by vindictiveness, whereas Smith claimed he only aimed to protect other innocent investors. (4) Regulation: Quest claimed that in posting his message, Smith had violated a company bylaw requiring prior notification of management; Smith maintained that he had complied with the bylaw. (5) Speech: Quest argued that as a matter of public policy, it is in society's interest to regulate speech over the Internet, whereas Smith argued that society would benefit from free speech over the Internet. (6) Analogy: Quest likened the Internet to a newspaper, which is subject to libel law, whereas Smith drew an analogy to a telephone system, which is immune from libel law.

Two instruments were constructed to assess participants' opinions about each point of dispute. The first instrument was a pretest that was presented before participants were told about the Quest case. A series of questions were constructed, each presented with a brief context that was intended to correspond to the part of the Quest case relevant to that particular question. Each question was introduced as an independent query about "factual situations, public policy, business situations and legal affairs." Participants were told they were not expected to have any expert knowledge, but were simply to use common sense in making their ratings. Each question's context introduced a distinct company or individual, or else a general policy issue. For example, separate questions probed participants' assessment of the degree to which the Internet resembled a newspaper, and to which it resembled a telephone system. All assessments were made by giving a rating on an 11-point scale, ranging from -5 (*strongly disagree*) to +5 (*strongly agree*), with a rating of 0 indicating neutrality.

The second instrument elicited participants' assessments of the parallel arguments in the context of the Quest case. These questions had the same form and wording as those used in the pretest, except that they were now embedded in the Quest case, and formulated as arguments made by the two opposing parties.

In our initial experiment (Holyoak & Simon, 1999, Experiment 1), participants were assigned to one of two conditions. Those in the 2-phase condition first completed the pretest. After this booklet was collected, participants spent a few minutes completing an unrelated reasoning task. They then received a booklet that provided the factual summary and arguments for the Quest case. They were allowed to look back at the case as they went on to indicate a verdict, and to provide a rating on a 5-point scale of their confidence that they had made the best possible verdict. Participants then completed the final posttest evaluation of the arguments.

Participants in the 3-phase condition completed essentially the same procedure as did those in the 2-phase condition, except that in the initial instructions for the Quest case, 3-phase participants were told that before reaching a verdict they should wait to hear the verdict of another judge in a related case, as the other verdict

would provide important additional information highly relevant to their decision in the case at hand. In the meantime, they were to read the Quest case and think about it. These 3-phase participants were then asked to state their "preliminary leaning" toward either Quest or Smith, rating their confidence on a 5-point scale. The second assessment instrument eliciting their evaluations of the arguments was then administered. After their response forms were collected, participants were then told that the other judge was not going to deliver a verdict after all, and that they should proceed to reach a final verdict by themselves based on the facts and arguments they had read. After stating their verdict, they completed the second assessment instrument again (with a different random order of the arguments). Relative to those in the 2-phase condition, participants in the 3-phase condition thus provided an additional interim assessment of the points of dispute, after reading the Quest case but prior to being asked for a firm verdict. If a shift toward greater coherence was observed from the pretest to the interim test for the 3-phase participants, this would provide initial evidence that the coherence shift preceded the announcement of a decision (and hence may have guided the process of reaching it), rather than simply following in its aftermath.

### Can Coherence Arise Out of Ambiguity?

Our first concern was to establish that participants were able to reach clear verdicts despite the inherent ambiguity created by the conflicting arguments. The distribution of verdicts did not differ significantly between the 2-phase and 3-phase conditions; accordingly, we will describe the aggregate results. Participants were about evenly divided in their verdicts, with 26 deciding in favor of the plaintiff, Quest, and 22 deciding in favor of the defendant, Smith. Yet despite the apparent ambiguity of the case, individual participants were generally very confident that they had reached the best possible decision. Seventy-five percent of participants indicated that they had *maximal* (5) or *next-to-maximal* (4) confidence in their verdicts; conversely, only five percent indicated they had *minimal* (1) or *next-to-minimal* (2) confidence. This combination of ambiguity and high individual confidence in decisions is consistent with constraint-satisfaction models of decision making, which will tend to resolve ambiguous situations by allowing one coherent set of beliefs to become highly activated, inhibiting the rival set.

The next question we addressed concerned whether the process of reaching a verdict was accompanied by shifts in participants' assessments of the six points of dispute between the plaintiff and the defendant. Constraint-satisfaction models of decision making predict that an emerging decision will be accompanied by a general shift toward a coherent position across all the

points of dispute. To measure participants' positions on each disputed point, the ratings obtained for each assessment instrument (pretest, interim test for 3-phase condition only, and posttest for both conditions) were converted to values we termed "Q-scores," which provide an index of agreement with the position of the plaintiff, Quest. The Q-score for each point of dispute was computed by taking an average of the ratings for questions that assessed that point, reversing the scale for those questions for which positive values indicated support for Smith's position. For example, the Q-score for Analogy was the mean of the rating in support of the newspaper analogy (Quest's position) and the negation of the rating in support of the telephone analogy (Smith's position). All Q-scores therefore range from -5 (*minimal support for Quest's position*) to +5 (*maximal support for Quest's position*), with 0 indicating neutrality. Mean Q-scores were calculated by averaging the Q-scores for the individual points of dispute.

Figure 1 presents the mean Q-score on each assessment, plotted separately for participants who decided in favor of Quest versus those who decided in favor of Smith. It is clear from inspection of Figure 1 that the two groups had similar Q-scores on the pretest. However, the Q-scores for the two groups sharply diverged in the direction of the verdict on the interim test (3-phase condition only) and on the posttest (both conditions). Q-scores for each of the six individual points shifted in the direction that cohered with the verdict.

Although the above analyses revealed a clear shift in participants' assessments of the six points of dispute

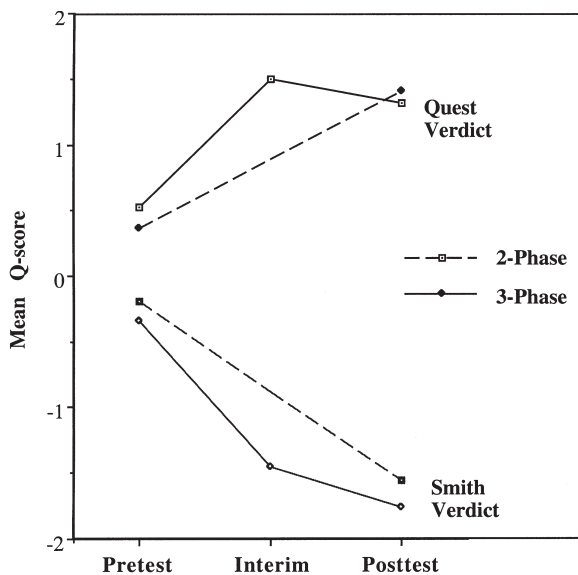


Figure 1. Shifts in Q-scores (favorability to Quest's position) across tests as a function of eventual verdict for Quest versus Smith (Holyoak & Simon, 1999, Experiment 1). From "Bidirectional reasoning in decision making by constraint satisfaction," by K. J. Holyoak and D. Simon, 1999, *Journal of Experimental Psychology—General*, 128, p. 3–31. Copyright 1999 by APA. Reprinted with permission.

in the direction of their verdict, they do not suffice to establish that individual participants reached a broadly coherent position across the disputed points. It remains possible, for example, that each participant was eventually persuaded by some single argument for one side in the case, with the particular critical argument varying from one person to the next. However, if a constraint-satisfaction process was used to reach a decision, then individual participants would be expected to shift their assessments of most or all of the disputed points in the direction of their eventual verdict.

Such a general increase in coherence could be revealed by a correlational analysis. On the pretest, participants' assessments of the six positions would not constrain one another, and hence would tend to be uncorrelated. Once the points are presented in the context of the case, however, a constraint network would be created, the effect of which will be to generate positive correlations among the disputed points, and between each point and the verdict. This is the pattern we observed. On the pretest, only two of the 21 correlations among the disputed points and verdict were significantly positive, and several were negative. This further demonstrates that the materials created a genuine sense of complexity and ambiguity. In contrast, on the posttest all but one of the correlations were significantly positive, including all six correlations between disputed points and the verdict; the non-significant correlation was also positive. We have since replicated this pattern of coherence shifts many times, and thus can conclude with confidence that coherent decisions can arise out of initial ambiguity.

### Do Coherence Shifts Drive Decisions?

The second major issue we addressed, beginning in our initial experiment, was whether coherence shifts occurred prior to reaching some sort of real commitment to a decision, or whether they only occurred subsequent to reaching a firm decision (as a form of dissonance reduction). As is apparent in Figure 1, the coherence shift in Q-scores for the 3-phase condition occurred mainly at the interim test, prior to reporting a firm decision. Similarly, the increase in correlations for the 3-phase condition occurred from the pretest to the interim test, with only small additional increases in the correlations between the interim test and the posttest. These results provided initial evidence that the emergence of a coherent position on the disputed points led, rather than followed, participants' arrival at a firm decision.

To verify and further explore these initial results, we performed another set of experiments designed to identify the sufficient conditions for coherence shifts (Simon, Pham, et al., 2001). It might be argued that in our initial experiment the request for a "preliminary leaning" initiated the decision process, and that the participants felt somewhat committed to those decisions (e.g.,

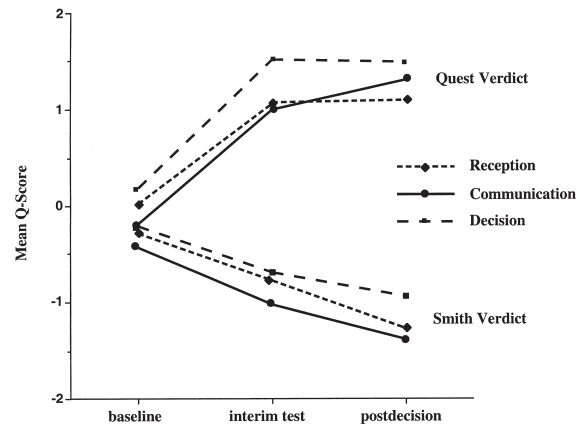
Cialdini, Cacioppo, Bassett, & Miller, 1978). If that were the case, then the reported “interim” evaluations were more akin to post-decision evaluations. Accordingly, Simon, Pham, et al. (2001, Experiment 1) replicated the basic design used by Holyoak and Simon (1999), but explicitly varied whether participants assessed the arguments before or after they were asked to report their preliminary leaning. We found that the placement of the request for a preliminary leaning made no difference to the pattern of results: Coherence shifts occurred even when the interim test preceded the request for a leaning.

It might be argued that even in the absence of an elicitation of a decision or a preliminary leaning, participants’ evaluations were affected by their knowledge that they were playing the role of a judge who would eventually have to make the decision. Accordingly, further experiments were designed to test how participants process the information in contexts that do not present the participants with a decision task at all. When a person does not anticipate having to making a decision, it seems implausible to hold that formation of a preference could form a commitment to a decision (cf. Kielser, 1971).

The first non-decisional processing set we examined was memorization. A basic finding in work on text comprehension and memory is that people actively impose organization on texts (e.g., Bartlett, 1932; Bransford & Johnson, 1973). Accordingly, we hypothesized that coherence would emerge in the course of processing the case for the sake of comprehending or memorizing it, in the absence of any requirement to ever reach a decision. Indeed, memorization instructions proved sufficient to trigger a shift in the evaluations towards coherence (Simon, Pham, et al., 2001, Experiment 2) on the interim test. Only a modest additional increase in coherence was observed on the final test, after participants were actually instructed to decide the case.

A further experiment investigated other non-decisional sets that might yield coherence shifts. We introduced two additional processing sets: preliminary processing under the expectation that more information would be received later (Reception condition), and processing under the expectation that the participants would later have to communicate the information to someone else (Communication condition). These two tasks were modeled after the “receiver” and “transmitter” sets used by Zajonc (1960b). For comparison, the standard decision task (role-playing a judge) was also included in the experimental design.

Figure 2 presents the mean Q-scores on each assessment, plotted separately for participants who decided in favor of Quest versus those who decided in favor of Smith, for each of the three conditions. As in the previous experiments, Q-scores diverged across the three assessments as a function of the eventual verdict that was reached. The shift in Q-scores across tests was sta-



**Figure 2.** Shifts in Q-scores (favorability to Quest’s position) across tests as a function of eventual verdict for Quest versus Smith, for decision, reception, and communication conditions (Simon et al., 2001, Experiment 3). From “The emergence of coherence over the course of decision making” by D. Simon, L. Pham, Q. A. Le, & K. J. Holyoak, 2001, *Journal of Experimental Psychology—Learning, Memory and Cognition*, 27, pp. 1250–1260. Copyright 2001 by APA. Reprinted with permission.

tistically identical for both the Decision group, in which participants expected from the start to eventually have to make a decision, and in the Reception and Communication groups, where the interim test was completed without any instructions about an eventual decision or role-playing a judge. Similarly, comparable strong increases in correlations among arguments and the eventual verdict were observed in all three conditions. These coherence shifts resemble findings by Tesser (1978; Tesser, Martin & Mendolia, 1995) of thought-induced polarization of attitudes.

The common feature of the various incidental processing conditions examined by Simon et al. (2001) is that they all encouraged participants to process the materials for some purpose or another, which most likely entailed an attempt on their behalf to comprehend the case. Our findings were that every one of these processing sets was accompanied by coherence shifts. When faced with tasks of high ambiguity, conflict and complexity—conditions that might otherwise be experienced as insurmountable—the increase of coherence in support for one of the decision alternatives enables and facilitates the making of confident decisions.

### Does Coherence Spread?

Our final major aim (Holyoak & Simon, 1999, Experiment 3) was to determine whether spreading coherence could bias inferences and decisions in a subsequent transfer case. We have argued that in the course of reaching a decision by constraint satisfaction, people will change their assessments of the points of dispute. People’s final assessments could then influence the constraint network for a subse-



quent problem in which some of the same arguments are again relevant. Analogy is a particularly plausible candidate for generating such transfer effects. In Thagard's (1989, 1992) ECHO model of evaluating competing explanations, for example, analogy is one source of constraints. The nature of analogical reasoning is to use knowledge of the source analog to generate parallel inferences about the target. If the source analog is a rich one, there are an indefinite number of plausible analogical inferences that might be generated if they are contextually relevant to a new target problem.

One of the key points of dispute in the Quest case concerns whether the better source analog for the Internet is a newspaper or a telephone system. Suppose, following the example used previously, that a person decides for Quest and in doing so comes to believe that the Internet is basically an electronic newspaper. If a different case is then presented—even one that has little overlap with the issues involved in the Quest case—in which the choice of source analog for the Internet is relevant, the person may be predisposed to again favor the newspaper source analog over the telephone alternative. If so, the favored analogy may provide a bridge that allows coherence to spread from the Quest case to the transfer case, thereby triggering additional inferences and decisions in the latter case that will tend to cohere with the person's final position on the Quest case.

The materials for the Quest case were based on those used in all the other legal decision-making experiments we have described. The only change was in the factual summary, for which two new variants were written, the "Good Smith" and "Bad Smith" versions. "Good Smith" had a history of constructive criticism of companies in which he invested, whereas "Bad Smith" had a history of harming and libeling them. Our goal was to manipulate participants's verdicts by introducing a rational basis for deciding whether Smith's motives were benign or self-serving. And indeed, the majority of subjects decided the Quest case in the direction consistent with Smith's stated character. The effectiveness of this experimental manipulation of coherence provides further evidence that generating coherence is a key component of decision making.

A second case, "The Bonus Dispute at Infoscience," served as a transfer problem. This case involved a contract dispute between a company that runs a bulletin board on the Internet and its employees with regard to how high a bonus should be paid to employees. The contract specified that the bonus should be related to two factors: the bonus paid at similar information-service firms located in the vicinity, and the extent to which the company's profits could be attributed to the employees's efforts. The arguments by the two sides focused on these two points of dispute. The first, Anal-

ogy, concerned whether the most similar company to Infoscience was the local newspaper or the local telephone company. Which side cited which analogy was counterbalanced (with the analogy cited by Infoscience always supporting a lower bonus than that cited by the employees). The two sides gave legalistic definitions of "newspaper" and "telephone system" that were identical to those used in the Quest case. Thus Analogy was a shared point of dispute that served as a bridge between the Quest and Infoscience cases.

The second point of dispute, Credit, was specific to the Infoscience case. This point concerned whether the company's profits were mainly attributable to installation of a new computer system (the position of Infoscience) or to the efforts of the employees (the position of the employees). The Infoscience materials had the same overall structure as the Quest materials: opening instructions, factual summary, opposing arguments, elicitation of a verdict, and a posttest concerning its two points of dispute.

To assess the adequacy of the overall coherence model as a description of the causal connections among the manipulation of Smith's character, the assessments of arguments, and the verdicts, the model was formulated as a structural equation model. The EQS program (Bentler, 1995) was used to estimate the model's parameters, test their significance, and assess the global fit and parsimony of the model. Figure 3 provides a graphical display of the initial and final coherence models that were tested. Directed arrows connect predictor variables to their outcomes. The arrows follow the major predicted flow of influence from the experimentally manipulated variable, Smith's character. The direct predictive links are from Smith's character to Motive; to the Quest verdict; to each of the other Quest arguments, including Analogy; from Analogy in Quest to Analogy in Infoscience; to the Infoscience verdict; to Credit (a total of six inference steps). Each argument variable was represented by its Q-score. The parameter values on the direct links in Figure 3 are standardized values representing the predicted shift in the outcome variable in standard deviation units as a function of a one standard deviation shift in the predictor variable (controlling for the influence of any other predictors). All direct links between predictor and outcome variables (as well as the undirected link between the residual errors for Cause and Truth) were statistically reliable. The main question of interest concerned how extensive were the coherence effects triggered by Smith's character. The results were clear: all the indirect effects of Smith's history (indeed, all indirect effects in the entire model) were statistically significant, including the most remote, 6-step indirect influence of Smith's history on Credit in the Infoscience case. Structural equation modeling thus provided support for the claim that our experimental manipulation of Smith's character generated coherence shifts that extended throughout both the Quest and the Infoscience cases.

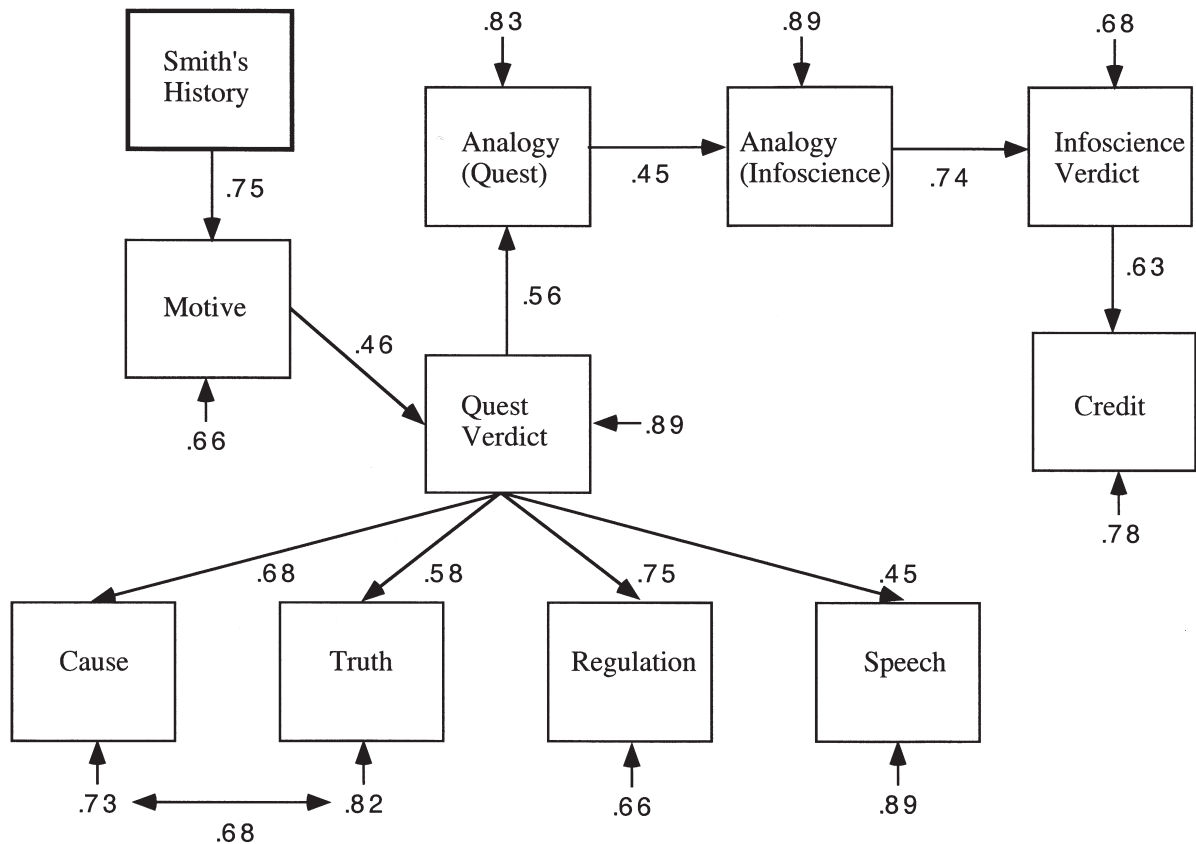


Figure 3. Graphical summary of the final model of coherence shifts among the experimental manipulation of Smith's character, verdicts, and points of dispute in the Quest and Infoscience cases (Holyoak & Simon, 1999, Experiment 3), with parameter estimates and error terms derived from EQS. From "Bidirectional reasoning in decision making by constraint satisfaction," by K. J. Holyoak and D. Simon, 1999, *Journal of Experimental Psychology: General*, 128. Copyright 1999 by APA. Reprinted with permission.

### General Discussion

In the experiments reviewed above, we found that coherence emerged not only when the participants were asked to make a decision, but also when they memorized the case and when they prepared themselves for communicating it to someone else or for receiving more information about it. Together with findings of coherence in the formation of impressions (Asch, 1940, 1946; Thorndike, 1920), construction of explanations (Hastie & Pennington, 2000; Pennington & Hastie, 1986, 1992; Thagard, 1989), and maintenance of attitudinal structures (Spellman et al., 1993), our findings lend support to the possibility that coherence-driven mechanisms of constraint satisfaction play a general role in the way people interact with their social and physical environments.

Although we have emphasized activation changes as the way by which coherence is generated, additional and more specific mechanisms may play important roles (see e.g., Abelson & Rosenberg, 1958; Kelman & Baron, 1968; Tesser, 1978). It should also be noted that in the experiments reviewed here people tended to achieve global coherence, accepting one set of argu-

ments in their totality while rejecting the rival set. In more complex situations, the pressure for coherence may result in a differentiated structure, with clusters of locally coherent elements (Nowak, Szamrej & Latane, 1990; Nowak, Vallacher, Tesser & Borkowski, 2000).

As suggested by Read and Miller (1994; Read et al., 1997), connectionist-based models of thought based on constraint satisfaction offer a conceptual framework that overcomes the limitations that hobbled cognitive consistency theories, most notably, the difficulty of generalizing such theories to achieve coherence among large networks of beliefs. The experiments and simulation modeling reported by Holyoak and Simon (1999) and Simon, Pham, et al. (2001), recently extended by experiments investigating multi-attribute decision making (Simon, Krawczyk & Holyoak, 2000) and integration of factual evidence (Simon, Read, Snow, & Brownstein, 2001), lend support to that suggestion. These experiments captured the crucial elements of structural dynamics in a task that involves many more components than the dyadic structures of cognitive dissonance theory or the triads of balance theory. The experiments also demonstrate that for inconsistency to arise, it is sufficient that inferences have implications

for competing alternatives; there is no need for diametrically opposed relationships (cf. Festinger, 1957, 1964). Perhaps most importantly, the experiments underscore the ability of constraint-satisfaction models to accommodate semantically-rich knowledge structures (cf. Abelson & Rosenberg, 1958; Heider, 1946, 1958) as well as broad range of types of inferences. For example, our decision task included the making of a causal and a motivational attribution, an assessment of the truthfulness of a statement, making of an analogy to a previous case, and the application of a general rule and a public policy to a particular instance. It is possible, then, that embedded in a connectionist framework of constraint satisfaction mechanisms, cognitive consistency theories may yet return back from the state of disarray lamented by Abelson (1983), and realize their potential to provide a framework for a general “psychology of inference” (McGuire, 1968, p. 140).

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