

A Coherence Model of Cognitive Consistency: Dynamics of Attitude Change During the Persian Gulf War

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We describe Co3 (Coherence Model of Cognitive Consistency), a computational model that we used to simulate attitudinal shifts toward various factors related to the Persian Gulf War. Co3 is based on "parallel constraint satisfaction," a mechanism that revises a set of attitudes so as to maximize overall coherence, with each attitude simultaneously influencing every other related attitude. The Gulf War provided a naturalistic case study for examining the dynamics of attitude change. A survey of attitudes toward U.S. military involvement was administered to 129 students at the University of California, Los Angeles, first during the initial two days of the war, and again two weeks later. At each time, support for U.S. military action was highly correlated (either positively or negatively) with factors indicative of attitudes toward pacifism, the legitimacy of U.S. intervention, isolationism, and President Saddam Hussein of Iraq. A within-subject analysis revealed that shifts in support for the war were correlated with consistent shifts in all four of the major predictors, including those (e.g., pacifism) that would not seem to have been directly affected by events over the intervening time period. This pattern of attitude change demonstrates cognitive consistency. Co3 was used to model how a shift in one attitude due to external inputs (e.g., media reports) can trigger correlated shifts in related attitudes. Computational methods of the sort exemplified by Co3 may be useful in modeling various social psychological phenomena.

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The intense interest of the American public in the events of the Persian Gulf crisis, and the extensive debates that took place about the advisability of military intervention by the United States and its allies, afforded a valuable opportunity for naturalistic research on the dynamics of attitude change. Peoples' attitudes toward intervention were shaped by both external and internal forces, including the actual unfolding of events, arguments based on analogies to previous conflicts such as World War II and the Vietnam War (Spellman & Holyoak, 1992; Voss, Kennet, Wiley, & Schooler, 1992), personal values such as belief in pacifism, personal political opinions about the degree to which the United States should be involved in overseas conflicts, and so on. During the course of the war, opinion polls showed a general shift toward greater support for the military action (e.g., "Changing Expectations," 1991; "Mixed Feelings," 1991).¹ Theories of attitudinal consistency (e.g., McGuire, 1960; Wyer & Goldberg, 1970; for the classic review of the various consistency theories, see Abelson et al., 1968) suggest that shifts in certain attitudes, perhaps triggered by external events reported in the media, may be accompanied by shifts in related attitudes. For example, reports that Iraq had fired missiles on Israel might diminish a person's belief that the United States had no business being involved in the crisis. Such an attitudinal shift might directly result in increased support for military intervention, and more indirectly (in order to maintain consistency) reduce the person's tendency toward pacifism.

In this article we describe Co3 (*Coherence Model of Cognitive Consistency*), a computational model that we used to simulate attitudinal shifts toward various factors related to the Persian Gulf War. Computer simulations have become an increasingly popular tool in social psychological research. In 1988, the *Journal of Experimental Social Psychology* (Ostrom, 1988a) devoted an entire issue to simulation models in social psychology. As Ostrom (1988b, p. 381) remarked in his lead-off article, in which he describes what he considers to be the value of such simulations, "Computer simulation is finally coming of age in social psychology."

Since then, phenomena in many areas of psychology have been modeled using simulations based on "parallel constraint satisfaction." In this kind of simulation, a network structure is set up that represents informational elements (e.g., beliefs, concepts, or hypotheses), relations of support or conflict between the elements, the intensity of those relations. The process of constraint satisfaction allows each element to simultaneously influence and be influenced by the

¹On January 10–11, 1991, the Gallup organization phoned a national sample of 751 adults and asked, "Should U.S. forces engage in combat with Iraq if Iraq refuses to leave Kuwait and restore its former government?"; 62 percent said "Yes" ("Mixed Feelings," 1991, p. 18). On January 24–25, 1991 a similar sample was asked, "Do you approve or disapprove of the way President Bush is handling the situation in the Persian Gulf region?"; 86 percent approved ("Changing Expectations," 1991, p. 25). The margin of error for each poll was plus or minus 4%.

elements to which it is connected (either directly or via longer paths through the network). Typically, such simulations will eventually reach a stable asymptotic state of "balance" that maximizes the overall consistency of the network of information. We believe that computational models that use such parallel constraint satisfaction mechanisms are particularly well suited for simulating the types of complex interactions characteristic of various phenomena in social psychology. (For a discussion of the relative merits and weaknesses of different types of computational models, see Holyoak & Spellman, 1993).

Co3 takes a set of related attitudes and uses a parallel constraint satisfaction algorithm to maximize consistency. Co3 is an adaptation of the ECHO model of explanatory coherence (Thagard, 1989; see Read & Marcus-Newhall, 1993, for an application in social psychology). Although the details of the simulations differ, Co3 is based on the same general principles as those embodied in other constraint-satisfaction simulation models of dissonance reduction (Gabrys, 1989; Read & Miller, in press; Shultz & Lepper, 1992). Structurally, a Co3 network resembles the signed graphs used by Cartwright and Harary (1956) in their formalization of structural balance theory. Cartwright and Harary's goals were to mathematically formalize the definition of balance and, among other things, to generalize Heider's (1946) balance theory to situations involving more than three entities. In their graphical representation, points represent entities and lines connecting the points represent the existence of relations between those entities. Structural balance theory can give a global evaluation of the balance in a graph; however, it has several limitations. Most importantly, although the relations between entities can be positive or negative, structural balance theory provides no way to represent variations in their intensity or strength—relations are simply present or absent.²

Functionally, Co3 simulates the dynamics of one of the methods of dissonance reduction proposed by Festinger (1957). Co3 operates on a network consisting of units, which represent entities or concepts toward which one may have an attitude (e.g., a person, an object, an action, or a philosophy), and links connecting the units, which represent the "support" or "implication" relations between the units they connect. Each unit has an activation value, which can be positive or negative, representing the strength of the attitude toward (or against) the entity represented by the unit. Links each have a weight, which also may be positive or negative, indicating the strength of the implication relation. Thus

²Superficially, Co3 also seems to share certain structural similarities with the model proposed by Judd and Krosnick (1989), which embeds Heider's balance theory (1958) in a semantic network model like that of Anderson's (1983) ACT*. There are, however, many important differences between the models with respect to the meaning of the activations of nodes and the weight of links. Most fundamentally, whereas the Judd and Krosnick model simply suggests a way of measuring domainwide attitude consistency, Co3's parallel constraint satisfaction algorithm shows how changes can be made in attitudes to maximize such consistency.

implication relations can be a matter of degree, rather than all or none. Co3 is initiated by specifying a network structure that indicates which units are connected to which, weights on the links between units, and initial activation values for the units. The model can then be "run" to find the pattern of attitudes that maximizes overall consistency; later, revisions can be made to the model as information (which may create new dissonance) is accrued from external sources.

Festinger (1957) describes three ways in which dissonance may be reduced: "1. By changing one or more of the elements involved in dissonant relations. 2. By adding new cognitive elements that are consonant with already existing cognitions. 3. By decreasing the importance of the elements involved in the dissonant relations" (p. 264). Co3 simulates the first technique—changing the elements involved in dissonant relations—which is naturally modeled by the parallel constraint satisfaction algorithm. However, Co3 does not change only a single dissonant attitude. Because (a) dissonance is a property of an entire attitude structure, (b) the strength of attitudes may vary in a continuous fashion, and (c) all attitudes may affect all other attitudes (either directly or indirectly), the model is highly interactive. Co3 changes not only the dissonant attitude to some degree, but the other attitudes as well, in order to reach a new optimum consistency.

Although the model could in principle be applied to a wide range of experimental phenomena involving dissonance reduction (see Gabrys, 1989; Read & Miller, in press; Shultz & Lepper, 1992), we wished to test its applicability to patterns of attitudes and attitude changes based on a complex naturalistic situation. A repeated survey of students' attitudes toward the issues involved in the Gulf War provided a suitable opportunity for such a test.

Survey

In order to assess attitudinal change and consistency, we administered a questionnaire to subjects at the beginning of the Persian Gulf War and again two weeks later. During that intervening time, Iraq had begun missile attacks on Israel, had reportedly mistreated American prisoners of war, and had dumped Kuwaiti oil into the Persian Gulf. The questionnaire measured six major attitudinal factors: overall support for the United States' action in the war, pacifism, perceived legitimacy of United States intervention, isolationism, perceived evil of President Saddam Hussein, and anticipation of terrorism in response to the United States' military action.

Method

Subjects. Subjects were 129 undergraduate students (85 female, 44 male) who were enrolled in an undergraduate psychology course on research methods at the University of California, Los Angeles. The students ranged in age from 19

to 34 years ($M = 22$, Mode = 21). Of the 81% of the student who reported ethnicity, 63% were white, 10% were African American, 15% were Asian American, and 12% were Latino. Sixty percent of the students reported that their political affiliation was Democratic, 31% Republican, and 9% other. Reported religious affiliations were Christian (69%); Jewish (15%); Buddhist, Hindu, or Islamic (6%); and other or no religion (9%).

Materials and procedure. Both surveys were administered during the subjects' regular laboratory section time (in classes of about 15 students) as part of a classroom exercise on survey research methods. On each occasion, subjects were told that the surveys would be anonymous and that participation was voluntary.

The first survey took place on January 17 and 18, 1991 (the first two days after the Allied forces commenced bombing Baghdad). Each subject was given a numbered survey and told to keep a written record of that number for later reference. The first survey contained 32 opinion statements relating to the Persian Gulf crisis. Under each statement was a 9-point scale with three points on the scale labeled as follows: (1) *strongly disagree*, (5) *neutral*, and (9) *strongly agree*. Subjects were instructed to circle a number on the scale below each statement to indicate their agreement or disagreement with that statement. They were instructed to try to use the entire range of the scale, but to feel free to use any rating as often as they felt it was appropriate. After the opinion statements was a section containing 8 demographic questions. The last page of the survey contained an analogical mapping task, asking the subjects to compare the Persian Gulf crisis to World War II and the Vietnam War. The results of this task are reported elsewhere (Spellman & Holyoak, 1992). One hundred eighty-six subjects completed the first survey.

The second survey took place on January 31 and February 1, 1991 (two weeks after the first survey). Each subject was given a new survey and asked to write down the number of his or her original survey. The second survey contained the same 32 opinion statements as the first survey with the same response scale, but contained no demographic questions. Of the 133 students who completed the second survey, 129 were subjects whose second survey could be matched to their first survey. Results are based on the analysis of data from these 129 subjects.

Results and Discussion

Identification of attitudinal constructs. A confirmatory factor analysis was used to validate six constructs associated with attitudes toward different concerns related to the war. Table 1 presents each of these constructs along with the specific questions that served as indicators for each. No questions had a loading of greater than .40 on more than one construct. For each subject, a summary

Table 1. Construct Indicators and Construct Reliability for Six Constructs ($N = 129$)

General support (GEN): Time 1 $\alpha = .82$, Time 2 $\alpha = .83$	
GEN1	The US and its allies were justified in launching a military strike against Iraq.
GEN2	I agree with the way George Bush has handled the Iraqi situation so far.
GEN3 ^a	George Bush is a greater threat to world peace than Saddam Hussein.
Pacifism (PAC): Time 1 $\alpha = .81$, Time 2 $\alpha = .77$	
PAC1	Under no circumstances should the US and its allies have initiated military action against Iraq.
PAC2	War is never justified.
PAC3	Please answer the following question hypothetically—that is, assume it could happen. If I were drafted by the US to serve in the military in the Middle East, I would attempt to seek a deferment on moral/ethical grounds.
Legitimacy (LEG): Time 1 $\alpha = .81$, Time 2 $\alpha = .81$	
LEG1	The fact that a UN resolution authorizes the use of force against Iraq made the use of force a legitimate option for the US and its allies.
LEG2	The US is acting to stop aggression and defend principles of international law and sovereignty.
LEG3 ^a	The US has often failed to follow international law in the past, and therefore had no right to attack Iraq now.
LEG4	The US is committed to defending freedom for people in all countries.
Isolationism (ISO): Time 1 $\alpha = .71$, Time 2 $\alpha = .72$	
ISO1	The US should not get involved in regional politics.
ISO2	The attack by the US and its allies against Iraq will result in great damage to western relations with the entire Arab world, which will last for years to come.
ISO3	The situation in the Persian Gulf is a regional rather than an international conflict.
Saddam Hussein (SAD): Time 1 $\alpha = .70$, Time 2 $\alpha = .78$	
SAD1	If he is not stopped now, Saddam Hussein will develop nuclear and/or chemical weapons and will be more dangerous and difficult to stop in the future.
SAD2	Saddam Hussein is similar to Adolf Hitler.
SAD3	If he is not stopped now, Saddam Hussein will eventually attack other countries in addition to Kuwait.
SAD4 ^a	Iraq has legitimate reasons to occupy Kuwait.
Terrorism (TER): Time 1 $\alpha = .68$, Time 2 $\alpha = .58$	
TER1	Terrorist attacks against US interests will be triggered all around the world.
TER2	Los Angeles is at high risk for terrorist attacks related to the Persian Gulf situation.

Note. Time 1 is January 17 or 18, 1991; Time 2 is January 31 or February 1, 1991.

^aSubjects scores on these questions were reflected to maintain the same direction as the other questions in the construct.

value for each construct was created by averaging the values for the questions used as indicators for that construct (reversing the scale for questions for which high agreement indicated a low value for the construct).³ Less than 3% of the data on any single question were missing; accordingly, regression methods were used to estimate missing data, using the BMDP AM computer program.

³Two of the questions (ISO2, LEG3) were worded in such a way that subjects may have had to consider more than one issue in answering them. The confirmatory factor analysis indicated that these questions loaded only on their respective constructs. Therefore, although subjects may have had to consider more than one issue in answering these questions, it seems that subjects did not need to consider issues represented by other constructs.

A construct representing general support for the United States' military action (GEN) was created using 3 questions that probed general attitudes toward the war, such as "The US and its allies were justified in launching a military strike against Iraq" (GEN1). High scores on this construct indicate agreement with the United States' action in going to war. The remaining five constructs were selected as possible predictors of general support. Attitudes toward pacifism (PAC) were assessed with 3 questions that probed different facets of pacifism, for example, "War is never justified" (PAC2). High scores on this construct indicate a high degree of pacifism. Attitudes concerning the moral and legal legitimacy of the war (LEG) were assessed with 4 questions, such as "The US is committed to defending freedom for people in all countries" (LEG4). High scores indicate agreement that the war was legitimate. Three questions assessed attitudes regarding whether the United States should be isolationist (ISO), such as "The US should not get involved in regional politics" (ISO1). High scores on this construct indicate the belief that the Persian Gulf crisis should not be a United States concern. Attitudes toward Saddam Hussein (SAD) were measured with 4 questions, for example, "Saddam Hussein is similar to Adolf Hitler" (SAD2). High scores on this construct indicate *negative* attitudes toward Saddam Hussein. A sixth construct representing expectations about terrorism (TER) was assessed with 2 questions, including "Terrorist attacks against US interests will be triggered all around the world" (TER1). The belief that terrorism would increase is indicated by high scores on this construct.

The reliability (i.e., degree of internal consistency) of the constructs was assessed using Cronbach alpha reliability indicators calculated for Time 1 (January 17 or 18, 1991) and Time 2 (January 31 or February 1, 1991). The reliability of the TER construct was rather low, especially at Time 2; however, measures of reliability for all other constructs were in the acceptable range (the lowest was $\alpha = .70$, highest was $\alpha = .83$). The reliabilities are presented in Table 1.

Relations between attitudes within each survey time. The strength of the relations between the six constructs were assessed for Time 1 and Time 2 using Pearson product moment correlations. In addition, partial correlations were calculated in which the variance due to GEN was removed. Because of the large number of correlations evaluated, a Bonferroni adjustment was made and the correlations were evaluated at $\alpha = .005$. The correlations obtained for Time 1 and for Time 2 are reported in Tables 2 and 3, respectively. At both times, strong correlations (ranging from .61 to .83) were observed between GEN and 4 of the 5 predictor variables: PAC, LEG, ISO, and SAD. The relations between these pairs of constructs were in the expected direction for all cases (e.g., high PAC correlated negatively with GEN). Furthermore, these four predictor constructs were significantly intercorrelated with each other. The partial correlations were low and generally nonsignificant, however, indicating that most of the variance

Table 2. Pearson Product Moment Correlations Between Six Constructs at Time 1 (January 17 or 18, 1991)

Construct	GEN	PAC	LEG	ISO	SAD	TER
PAC	-.82*		-.19	.01	.01	.20
LEG	.81*	-.73*		-.19	.13	.04
ISO	-.78*	.64*	-.70*		-.04	.21
SAD	.61*	-.50*	.56*	-.50*		.09
TER	-.20	.28*	-.19	.29*	-.06	

Note. Lower triangle shows bivariate correlations. Upper triangle shows partial correlations controlling for general support (GEN) at Time 1. GEN: general support; PAC: pacifism; LEG: legitimacy; ISO: isolationism; SAD: Saddam Hussein; TER: terrorism. For both sets of correlations, $N = 129$. * $p < .005$.

shared by pairs of predictor variables was attributable to their common relation to GEN. Unlike the other predictors, TER was not significantly related to GEN at either Time 1 or Time 2, nor did this construct correlate strongly with the other predictor variables.

Relations between attitudes across survey times. In order to examine the changes in construct values from Time 1 to Time 2, a one-way within-subjects multivariate analysis of variance was performed on the six attitudinal constructs as a function of survey time. The assumptions of multivariate normality, homogeneity of variance-covariance matrices and regression, and linearity were satisfactorily met (Tabachnick & Fidell, 1989). Through the use of Mahalanobis distance, with a criterion for which $p = .001$, one multivariate outlier was identified and deleted; accordingly, the analysis was conducted using data from 128 subjects.

The Wilks's lambda criterion detected a significant change in the combined multivariate dependent variable between the two time periods, $F(6, 122) = 4.18$,

Table 3. Pearson Product Moment Correlations Between Six Constructs at Time 2 (January 31 or February 1, 1991)

Construct	GEN	PAC	LEG	ISO	SAD	TER
PAC	-.77*		-.20	.14	-.02	-.05
LEG	.83*	-.71*		-.28*	.19	-.06
ISO	-.72*	.61*	-.70*		-.12	.25*
SAD	.70*	-.54*	.66*	-.56*		.15
TER	-.17	.09	-.17	.29*	-.01	

Note. Lower triangle shows bivariate correlations. Upper triangle shows partial correlations controlling for general support (GEN) at Time 2. GEN: general support; PAC: pacifism; LEG: legitimacy; ISO: isolationism; SAD: Saddam Hussein; TER: terrorism. For both sets of correlations, $N = 129$. * $p < .005$.

$p = .001$, $\eta^2 = .17$. To examine the effect of time on each of the constructs, both univariate and stepdown analyses were performed. Stepdown analyses of the constructs are analogous to performing a series of analyses of covariance controlling for each successive construct. This technique eliminates the problem of performing multiple analyses on data with overlapping variance. Our constructs were correlated; the correlation between constructs is reflected in the differences between the univariate and stepdown F ratios. For the stepdown analysis, GEN was entered first, followed by ISO, PAC, LEG, SAD, and TER. The means for each construct at each time, and the univariate and stepdown F ratios, are presented in Table 4. Following a Bonferroni adjustment, the univariate and stepdown analyses were evaluated at $\alpha = .008$. As indicated by the significant univariate F ratio, GEN increased in the two-week period (mean = 5.88 at Time 1, 6.15 at Time 2). After adjusting for GEN, attitudes became slightly but significantly more isolationist (mean = 4.50 at Time 1, 4.76 at Time 2). No other significant overall changes in constructs were observed over the two survey times.

The analyses of central interest for testing a model of attitudinal consistency involve the relations between changes in the various attitudes. In order to assess the degree to which attitudes changed together across the two test sessions, correlations were calculated between the difference scores for each construct. The difference scores were created by subtracting the Time 2 construct value from the Time 1 construct value. In addition to the overall correlations between difference scores, partial correlations were calculated with the variance attribut-

Table 4. Means, Standard Deviations, Univariate and Stepdown F Ratios for Six Constructs ($N = 128$)

Construct	Time 1 mean (SD)	Time 2 mean (SD)	Univariate F	Stepdown F
GEN	5.88 (2.20)	6.15 (2.01)	7.22*	7.22*
ISO	4.50 (1.91)	4.76 (1.88)	4.02	9.23*
PAC	4.08 (2.38)	3.83 (2.20)	4.62	3.36
LEG	5.61 (1.97)	5.91 (1.93)	.06	.07
SAD	6.88 (1.38)	6.98 (1.43)	1.20	.29
TER	6.44 (1.50)	6.19 (1.36)	4.58	4.00

Note. High scores indicate more agreement. Range 1–9. GEN: general support; PAC: pacifism; LEG: legitimacy; ISO: isolationism; SAD: Saddam Hussein; TER: terrorism. Time 1 is January 17 or 18, 1991; Time 2 is January 31 or February 1, 1991.

* $p < .008$.

Table 5. Pearson Product Moment Correlations Between Difference Scores on Constructs

Construct	GEN	PAC	LEG	ISO	SAD	TER
PAC	-.36*		-.13	.27*	.31*	.08
LEG	.37*	-.14		-.34*	.31*	.08
ISO	-.41*	.30*	-.35*		-.26*	.09
SAD	.30*	-.30*	.31*	-.25*		.01
TER	-.11	.11	.07	.12	.02	

Note. Lower triangle shows bivariate correlations. Upper triangle shows partial correlations controlling for general support (GEN) difference score. GEN: general support; PAC: pacifism; LEG: legitimacy; ISO: isolationism; SAD: Saddam Hussein; TER: terrorism. For both sets of correlations, $N = 129$. * $p < .005$.

able to the change in GEN removed. The correlations between difference scores are presented in Table 5. The correlations were generally lower than those obtained within each time (Tables 2 and 3), as would be expected given that error variance is necessarily larger for difference scores. However, the qualitative pattern of intercorrelations between difference scores was similar to that observed within each survey time. Shifts in each of the four predictor constructs PAC, LEG, ISO, and SAD were significantly correlated with each other (except for the correlation between PAC and LEG) and with shifts in GEN. This pattern was maintained for the partial correlations that removed variance attributable to GEN. In contrast, changes in TER did not correlate significantly with changes in any other construct.

Assessment of consistency. The results indicate that attitudinal consistency was maintained as opinions about factors relevant to evaluating United States military intervention in the Persian Gulf shifted over the first two weeks of the war. An increase in general support for the war was correlated with increases in evaluation of moral/legal legitimacy and negative evaluations of Saddam Hussein, and by decreases in pacifism and support for United States isolationism. Even though for subjects as a group both general support for the war and isolationism increased over the two-week period, the degree of increase in general support for individual subjects was correlated negatively with the shift in isolationism. Although expectations of terrorism declined over the period between surveys, this construct did not have any strong relations with other factors, including general support. The lack of any correlation with the terrorism construct may indicate that subjects did not view the threat of terrorism as a reason to oppose intervention; however, it is also possible that the low reliability of our measure of expectation of terrorism attenuated this relation.

Given the observational nature of the present study, we are unable to draw conclusions about the causal basis for the observed pattern of attitude shifts. It

seems reasonable to suppose, however, that the pattern reflects a mixture of "external" influences—reactions to reports of events that occurred over the first two weeks of the war—and "internal" pressures to maintain cognitive consistency. Of the four factors that predict degree of general support (GEN) for the war, two seem likely to have been more directly influenced by external events. News reports concerning the behavior of Saddam Hussein and the Iraqis (e.g., the missile attacks on Israel, reports of mistreatment suffered by prisoners of war, and dumping oil into the Persian Gulf) might have triggered increases in negativity to Saddam Hussein (SAD) and decreases in isolationism (ISO) for some subjects. The failure of any significant Gulf-related terrorism to materialize would also decrease their expectation of terrorism (TER). It is less apparent that external events would have so directly influenced the other two factors, pacifism (PAC) and moral/legal legitimacy (LEG). Pacifism would seem to be a more deep-rooted attitude that would not be expected to change in reaction to specific events of the war. The LEG factor was measured by questions that would seem to be based on events that occurred prior to the onset of the United States' intervention: the authorizing United Nations' resolution (LEG1), general principles of international law presumably violated by Iraq's invasion of Kuwait (LEG2), the past behavior of the United States (LEG3), and its stated commitment to defending freedom (LEG4). Even if one argues that some intervening events (e.g., the attacks on Israel) might have directly altered attitudes toward PAC and LEG for some people, the overall degree of direct external influence would almost certainly be different for the different constructs. If this premise is accepted, then we need to explain how externally generated shifts in a subset of the predictor constructs might trigger correlated shifts not only in GEN, but also in the other factors related to GEN.

From the perspective of consistency theories, the maintenance of cognitive consistency requires that shifts in attitudes regarding one factor be accompanied by shifts in attitudes regarding other relevant factors. One possibility is that people actually have direct connections between each pair of factors. It does not seem obvious, however, that every person would have formed a direct connection between his or her attitude toward Saddam Hussein and, for example, his or her degree of pacifism. A more subtle possibility, suggested by our data, is that consistency is maintained on the basis of indirect linkages between attitudes. Suppose, for example, that each predictive construct has a bidirectional influence on the value of general support for war, but that there are no direct connections between the various predictors, thus creating a cognitive structure with a high degree of "organization" (Zajonc, 1960) or "centralization" (Scott, 1969). A shift in attitude on any one factor would then produce a shift in support for the war, which would in turn trigger shifts in attitudes on the other factors in the direction that maintains consistency.

The Coherence Model of Cognitive Consistency

The kind of consistency model described above can be formalized in a computational model such as Co3, which uses a simple connectionist network that is capable of finding a maximally consistent (or coherent) set of attitudes. Co3 can be used to model both direct and indirect attitude shifts like those that may have been involved in the dynamics of opinion change during the Persian Gulf War. Figure 1 sketches a hypothetical network of attitudinal relations that

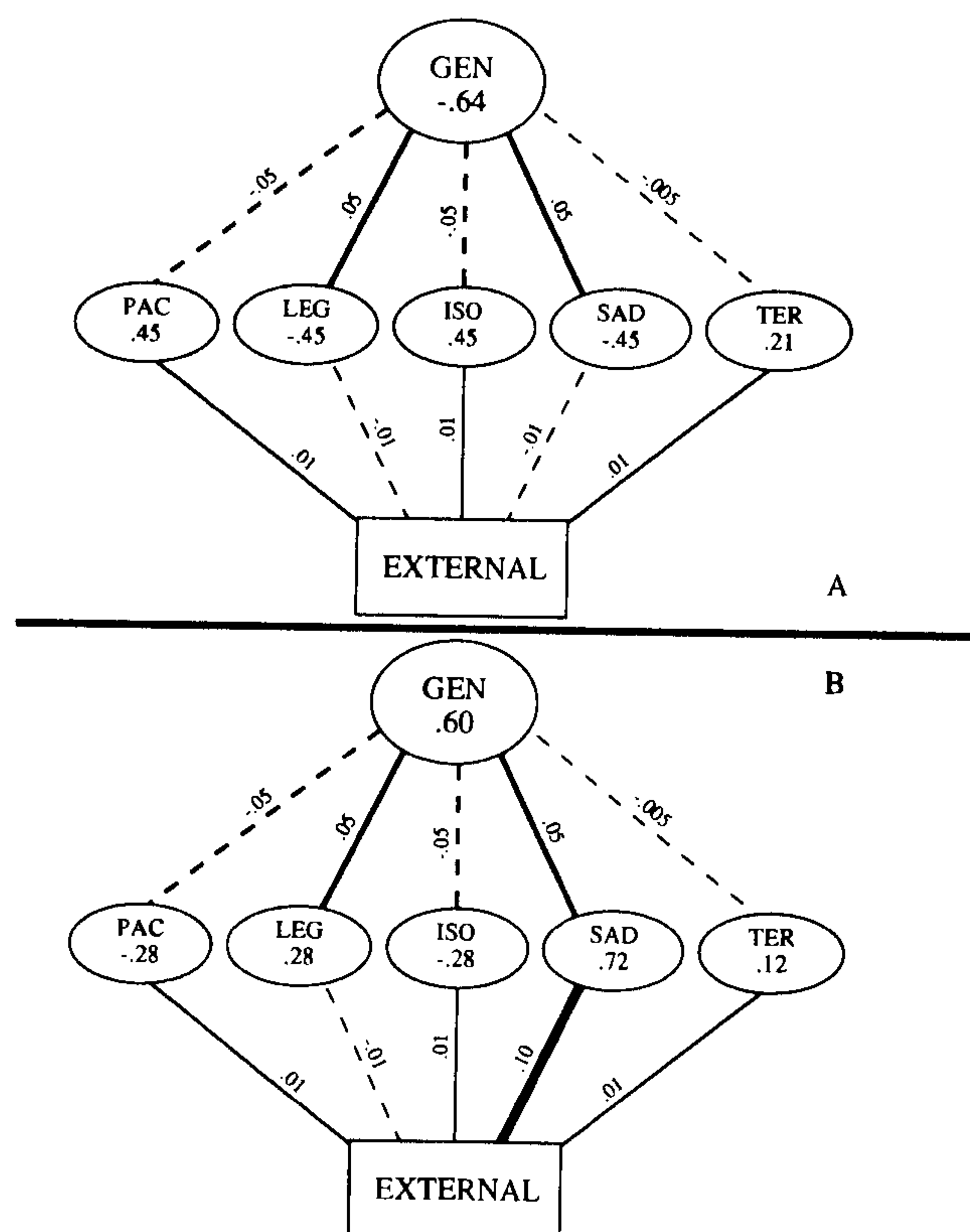


Fig. 1. Network showing Co3 units and links representing the relations between attitudes about the six constructs related to the Persian Gulf War. Panel A shows original weights on links and activations of units after 100 cycles. Panel B shows activations of units after the weight on the link from EXTERNAL to SAD is changed from $-.01$ to $+.10$ and network has run for 1000 cycles. Solid lines are excitatory links; dotted lines are inhibitory links; thickness of the lines indicates the weight on the link. GEN: general support; PAC: pacifism; LEG: legitimacy; ISO: isolationism; SAD: Saddam Hussein; TER: terrorism. EXTERNAL represents external influences on each of the constructs.

we created based on the data reported above. Each node or "unit" (circle) in this network represents one of the six constructs we measured. At any time, the "activation" value of a unit (the number in the circle) represents the person's attitude toward the corresponding construct. These values are scaled to range from -1 (maximally negative) through 0 (neutral) to $+1$ (maximally positive). Note that in the figure the units representing the predictor factors each have a link to the unit representing general support (GEN) but that, as suggested by our data, the predictor factors have no links among themselves. The links represent the implication relation between the units, and they have "weight" values ranging from -1 (maximal negative implication) through 0 (no relation) to $+1$ (maximal positive implication). That is, negative weights imply that the connected units should have activations of opposite signs, whereas positive weights imply that the connected units should have activations of the same sign. Links allow the activation of a factor to directly influence the activation of a connected factor; the weight on each link modulates the strength and direction of that influence. Although in principle the weights on links might be asymmetrical, the current version of Co3 treats all links as symmetrical.

The structure of the network in Panel A of Fig. 1 represents the qualitative configuration of interrelated attitudes that, based on our data, it appears our subjects had at Time 1. We assume LEG and SAD have strong *excitatory* connections (set at $.05$) to GEN (i.e., as the value of one factor increases, the value of the connected factor should also increase), PAC and ISO have strong *inhibitory* connections (set at $-.05$) to GEN (i.e., as the value of one factor increases, the value of the connected factor should decrease), and TER has a weak inhibitory connection to GEN (set at $-.005$). The EXTERNAL unit is a special unit, with activation fixed at $+1$, that represents external influences on the values of each of the predictor constructs. External support can be interpreted as reflecting either preexisting attitudes or knowledge of current events that support an attitude.

We were particularly interested in whether Co3 could simulate how an individual might switch from an anti-war to pro-war opinion. First, we set parameter values for a hypothetical subject. Panel A shows the initial weights we imposed on the links from the EXTERNAL unit, which support some modest positive value for PAC, ISO, and TER (weight = $.01$ for each), indicating mild external support for pacifism, isolationism, and an expectation of terrorism; and which support a modest negative value for LEG and SAD (weight = $-.01$), indicating mild external support for believing that Saddam Hussein was not too evil and that the United States might be acting slightly illegitimately. Note that the external factors described above should lead one to be against United States involvement in the Gulf War.

Co3 attempts to find the most coherent set of attitudes by using a parallel constraint satisfaction algorithm to "settle" the activations of all units into a state

that maximizes a mathematical "harmony" function (see Thagard, 1989). To run the simulation, the activations of all units (except EXTERNAL) are initialized at 0. The simulation then runs through cycles of updating; during each cycle the activation of each unit changes as a function of the activation values of all of the units linked to it, with the contributions being modulated by the weights on the relevant links. The equations governing constraint satisfaction, which are based on those originally introduced in McClelland and Rumelhart's (1981) interactive-activation model of word perception, are presented in the Appendix.

Given the assumed weights, and starting the activation of all units (except EXTERNAL) at 0, we ran Co3 through 100 cycles of updating. The activations for the construct units in Panel A show that after those cycles the network settles into a state in which GEN is negative, values of PAC, ISO, and TER are each positive (although less positive for TER than the other factors because of the relatively weak link between TER and GEN), and values of LEG and SAD are negative. In other words, the network in Panel A reflects a consistent set of attitudes indicative of an anti-war position.

Now suppose that intervening events provide external evidence that Saddam Hussein is a more reprehensible menace than the person had initially believed. We can model this external influence on the person's attitudes by replacing the weak negative connection from EXTERNAL to SAD with a strong positive connection (.10). (Note that this intervention does not represent a direct change in the strength of an attitude; rather, it represents a change in the support that outside evidence gives to an attitude.) If we now allow the network to resettle, beginning with the activations in Panel A and continuing until a total of 1000 cycles of updating have taken place, we obtain the new attitudinal equilibrium depicted in Panel B.⁴ The person's value on SAD has now increased dramatically, from $-.45$ (moderately favorable attitude to Saddam Hussein) to $.72$ (very unfavorable attitude). As a consequence of the direct excitatory connection between SAD and GEN, the activation of the latter unit has been increased from $-.64$ (anti-war) to $.60$ (pro-war). Furthermore, because of the links between GEN and the other predictor constructs, each of the latter has undergone a smaller but considerable shift as an indirect result of the change in SAD. For example, the value of PAC has gone from $.45$ (moderately pacifistic) to $-.28$ (modestly nonpacifistic). (This qualitative aspect of the model, in which a change in the activation of a unit will have the greatest impact on the activations

⁴The LISP program used to dynamically alter the network by changing weights from the EXTERNAL unit and then to continue the settling process was adapted from code provided by Patricia Schank (see Schank & Ranney, 1991).

of the units to which it is directly connected, and a lesser impact on units with more indirect connections via intermediary units, is consistent with the metaphor of "spatial inertia" proposed by McGuire, 1981, to describe the "remote ramifications" of an altered attitude.)

We then reexamined our data to see whether subjects exhibited the pattern of attitude change suggested by the model. We divided the subjects into three distinct groups: those whose rating on the SAD factor was higher by at least 1.0 at Time 2 than at Time 1 (i.e., those who became more negative toward Saddam), those whose rating on SAD showed no change (defined as a difference of .30 or less in either direction between the two tests), and those whose rating on SAD was lower by at least 1.0 at Time 2 than at Time 1 (i.e., those who became more positive toward Saddam). A total of 95 subjects could be categorized into one of these three groups. Table 6 presents the standardized change in values of GEN, PAC, LEG, and ISO from Time 1 to Time 2 for subjects in each group. For each of these constructs, the amount of change was monotonic in the direction consistent with change in SAD (e.g., subjects who became more negative toward Saddam showed the greatest increase in general support for the war, the greatest decrease in pacifism, the greatest increase in perceived legitimacy, and the greatest decrease in isolationism). When the standardized difference scores for GEN, PAC, LEG, and ISO were aligned in the direction consistent with the change in SAD, the three SAD groups showed a significant linear trend with a Scheffé adjustment used to adjust for post hoc testing, $F_s(1, 94) = 12.64, p < .05$. The observed pattern of attitudinal shifts reported in Table 6 is consistent with the qualitative pattern of activation changes obtained in the Co3 simulation described above.

Table 6. Standardized Changes in Attitudes from Time 1 to Time 2 Toward the General Support, Pacificism, Legitimacy, and Isolationism Constructs as a Function of Changes in Attitude Toward the Saddam Construct

Change in SAD	Construct				
	N	GEN	PAC	LEG	ISO
		Time 2 score—Time 1 score			
SAD more negative	26	.47	-.36	.43	-.36
SAD unchanged	55	-.11	.09	-.06	.02
SAD more positive	14	-.23	.43	-.18	.67

Note. SAD more negative: subjects whose rating on the Saddam construct was higher by at least 1.0 at Time 2 than at Time 1; SAD unchanged: subjects whose rating on the Saddam construct differed by .30 or less in either direction from Time 1 to Time 2; SAD more positive: subjects whose rating on the Saddam construct was lower by at least 1.0 at Time 2 than at Time 1; GEN: general support; PAC: pacifism; LEG: legitimacy; ISO: isolationism; SAD: Saddam Hussein.

General Discussion

We have shown that a parallel constraint satisfaction model can qualitatively capture the maintenance of cognitive consistency in a simple attitude structure. We believe that the ability of constraint-satisfaction models to capture attitudinal dynamics may make them a useful tool not only for modeling experimental results, but also for increasing the specificity and clarity of predictions derived both from the various consistency theories and theories intended to replace them. (See Abelson, 1983, for a discussion of the demise and reemergence of consistency theories.) For example, Gabrys's (1989) simulations using his HEIDER constraint-satisfaction model contain a node labeled SELF, which is always set at 1.0, indicating that the hypothetical person being modeled feels good about himself or herself. Different explanations of various empirical phenomena (e.g., dissonance reduction, impression management, and self-esteem theories) might be modeled by alternative properties of such a SELF node. Various competing predictions could be derived once those models were specified in greater detail. A simulation by Shultz and Lepper (1992) based on a classic experiment from the free-choice paradigm reported by Brehm (1956) demonstrates how models can lead to greater predictive precision. Their constraint-satisfaction model predicted Brehm's results more precisely than did dissonance theory—in part because the computational model, by its nature, had to provide a more specific model of the structure of the experimental situation. Parallel constraint satisfaction models could also easily be set up to simulate cognitive structures that vary along the dimensions of structure postulated by Zajonc (1960) and Scott (1969). Such simulations could provide predictions about the comparative behavior of differently parameterized cognitive structures.

Elsewhere we have described how parallel constraint satisfaction can be used to model how people drew analogies between the main characters involved in the Persian Gulf War and those involved in World War II (Spellman & Holyoak, 1992). We argued that establishing coherence might be an iterative process that involves finding the maximally coherent pattern, revising the network by generating new elements and relations, finding the maximally coherent pattern in the revised network, and so on. In both that simulation and the present one, our models relied only on finding the maximally coherent pattern, without generation of new elements and relations. However, the latter type of procedure could also be brought into play within a general constraint-satisfaction model of attitude and belief revision.

In 1983, Zajonc, commenting on a talk by Abelson (1983) entitled "Whatever Happened to Consistency Theory?" suggested that the era of cold cognition and cold computer models had inhibited work on structural dynamics, the progenitor of dissonance theories. Zajonc described structural dynamics as "the idea that the structural arrangements of elements and of parts depend on the distribu-

tion of the forces among them, and that conversely, these forces derive from the relationships of the elements to each other" (p. 55). He complained that the existing structural theories and models could not capture dynamics; they could "not include the notion of forces or vectors that endow a structure with a potential for movement and change and that explain and determine its stability" (p. 56). We suggest that parallel constraint satisfaction models can capture that interplay. The present naturalistic study provides encouragement for further exploration of computational models of cognitive consistency and the dynamics of attitude change.

Appendix

Activations of all units (except EXTERNAL) are initialized at 0. The activation of a unit j may range from -1 to 1 and is computed using the following equation:

$$a_j(t+1) = a_j(t)(1-\theta) + \begin{cases} \text{net}_j[\max - a_j(t)] & \text{if } \text{net}_j > 0 \\ \text{net}_j[a_j(t) - \min] & \text{if } \text{net}_j < 0 \end{cases}$$

where $a_j(t)$ is the activation of unit j on cycle t , θ is a decay parameter that decrements the activation of each unit on every cycle, $\max$ and $\min$ are respectively maximum (1) and minimum (-1) activations, and net_j is the net input to a unit, defined as

$$\text{net}_j = \sum_i w_{ij} a_i(t)$$

For the simulation reported here, we used a value of .05 for θ .

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