

## If Saddam Is Hitler Then Who Is George Bush? Analogical Mapping Between Systems of Social Roles

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The analogy between World War II and the 1991 Persian Gulf crisis led people to construct a coherent system of roles for the participants in the Gulf crisis. The Analogical Constraint Mapping Engine (ACME), a model of analogical mapping by constraint satisfaction (Holyoak & Thagard, 1989), makes predictions about the types of correspondences people are likely to draw between the people and countries in these analogs. Both a survey (Experiment 1) and an experimental study (Experiment 2) revealed clear evidence that people have a strong tendency to generate mappings that honor certain basic coherence constraints. In Experiment 3, with science-fiction materials, further evidence for the generality of these constraints was obtained. Computer simulations of Experiments 2 and 3 using ACME yielded mappings similar to those generated by Ss. General models of analogical reasoning may have implications for everyday understanding of complex systems of social roles.

The importance of analogical reasoning in everyday life was dramatically illustrated in the context of events surrounding the 1991 Persian Gulf War. Indeed, from published reports of decision making by Western leaders, it would not be a great exaggeration to say that the United States went to war over an analogy. The prelude to the war engendered widespread use of analogy as a tool of argument and persuasion. As has been typical in all debates about American military intervention since the 1970s (Gilovich, 1981), two antithetical positions were advanced, each based on a historical analogy. Hawks insisted that Saddam Hussein was an emerging Hitler, who had to be stopped before he swallowed other countries, developed new weapons, and became yet more dangerous to Western interests; doves warned that the Persian Gulf was a trap like Vietnam, conjuring images of an unpopular and drawn-out war in which the United States did not belong. President George Bush was able to convince most of the American public, as well as members of Congress and leaders of other Western nations, that the World War II analogy was sound. The pragmatic impact of this analogical transfer was war.

The intense public interest in the analogies to the Gulf situation afforded a unique research opportunity for a naturalistic

investigation of analogical reasoning. Almost all research on analogical transfer has used laboratory paradigms in which subjects are provided with a relatively simple source analog, after which transfer to a novel target analog is studied (e.g., Gentner & Toupin, 1986; Gick & Holyoak, 1980, 1983; Holyoak & Koh, 1987; Novick & Holyoak, 1991). Such experiments allow control over subjects' knowledge of the analogs; however, it is unclear whether laboratory experiments capture the richness and complexity of naturalistic analogical reasoning. By investigating people's understanding of a complex situational analogy with clear pragmatic importance, we can provide a valuable test of whether theories of analogical reasoning developed largely on the basis of laboratory studies are able to account for reasoning about naturalistic analogies.

Furthermore, as we argue later in this article, it is possible that analogical mapping may be a major cognitive mechanism involved in social cognition, particularly in guiding human understanding of social roles. In addition, a model of analogical mapping may suggest a framework for the development of formal models of cognitive coherence. Accordingly, Experiments 1 and 2 of the present study were focused on college students' understanding of the analogy between the Gulf War and World War II. These experiments were performed during and immediately after the Gulf War, a period when this analogy was a focus of attention of the U.S. media and a matter of considerable interest to our subjects. We first review previous work on analogical transfer as it relates to the current project and then report the results of two experiments that assessed subjects' mappings between the people and nations involved in the two conflicts. We then describe a computer simulation of the mapping process. The simulation is used to model the mappings obtained for the war analogies used in Experiment 2, and also to model the results of Experiment 3, in which science-fiction-style materials were used to clarify some of the residual questions raised by the results of the experiments with naturalistic materials. Finally, we discuss the broader implications of analogical mapping for understanding social roles and cognitive coherence.

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### Component Processes in Analogical Transfer

Analogical transfer typically involves using knowledge about a relatively well-understood *source* analog to make inferences about a poorly understood *target* analog. It is useful to distinguish different component processes in analogical transfer (e.g., Gentner, 1989; Gick & Holyoak, 1980; Keane, 1988; Novick & Holyoak, 1991). Successful transfer requires (a) the retrieval of a potentially useful source; (b) finding a *mapping*, or set of appropriate correspondences between the elements of the source and target; (c) using the mapping, together with knowledge of the source, to construct inferences about the target; and (d) evaluating and possibly adapting the inferences in light of what is actually known about the target. In addition, as a consequence of analogical transfer, the analogist may generalize the two analogs to form a more abstract schema for a class of situations (Gick & Holyoak, 1983; Novick & Holyoak, 1991).

A variety of empirical findings support the usefulness of these distinctions among component processes. In particular, a great deal of evidence suggests that the retrieval and mapping processes are differentially sensitive to various types of similarity relations. Initial access to a source analog stored in memory is heavily dependent on salient surface similarities between the source and target; once a source has been accessed, however, the mapping process is more sensitive to the underlying structural correspondences (often involving causal connections) between the analogs (Gick & Holyoak, 1980; Gilovich, 1981; Holyoak & Koh, 1987; Keane, 1988; Ratterman & Gentner, 1987; Ross, 1987, 1989). This separation of similarity effects is not complete, as structural correspondences can influence retrieval (Holyoak & Koh, 1987; Read & Cesa, 1991), and surface features can influence mapping (Gentner & Toupin, 1986; Ross, 1989). However, the relative impact of different types of similarity varies between retrieval and mapping. The importance of surface features as retrieval cues implies that salient but causally irrelevant features may influence which source analog is accessed in memory and hence indirectly alter the inferences made about the target (e.g., Gilovich, 1981). Once a particular source analog has been accessed, however, people are readily able to compare the source with the target in terms of their structural correspondences, disregarding superficial similarities and differences that do not seem causally relevant and deriving pragmatically useful predictions about the target.

During the Gulf crisis, both the World War II and Vietnam analogs were widely discussed in the media as possibly relevant cases, so that the need for retrieval of the analogs was effectively eliminated. In fact, source analogs are often explicitly presented in the contexts of teaching and argumentation. In such cases, it is the mapping process that is most crucial to analogical transfer. People's understanding of analogies involving the Gulf situation presumably depended to a large extent on their assessment of structural similarities and differences between the source and target (e.g., why each war was or was not justified, and why it was or was not winnable). Because our subjects were virtually certain to have had their attention called to the possible analogy between the Gulf situation and World War II before serving in our experiments, the present study was focused solely on the nature of analogical mapping, leaving aside issues related to premapping access and postmapping infer-

ence, evaluation, and schema induction. Because analogical transfer depends on the correspondences drawn between the source and target situations, there is good reason to believe that the mapping process is in fact crucial.

### Analogical Mapping by Constraint Satisfaction

The theoretical problem of describing how people are able to map the participants in complex social situations, such as the Gulf conflict, provides an interesting example of the general problem of specifying constraints that govern human analogical mapping. Perhaps the most central theoretical idea shared by all major theories of analogical reasoning is that people strive to achieve some sort of coherence in the mapping they establish between the elements of the source and target analogs. That is, mapping decisions are interdependent, so that the preferred mapping will consist of a set of correspondences that collectively "make sense." The intuitive notion of coherence has been formalized in various ways. The present study was guided by the constraint-satisfaction theory of analogical coherence proposed by Holyoak and Thagard (1989) and instantiated in a computer simulation of the mapping process, Analogical Constraint Mapping Engine (ACME). Here we describe the general theory and the qualitative predictions it generates for the present study; the ACME system is described in more detail in a later section when we apply it to simulate the results of Experiment 2.

The ACME model, like most previous models of mapping that have been applied to complex analogs (e.g., Gentner, 1983; Winston, 1980), operates on representations of source and target analogs that consist of structural descriptions. The elements of a structural description consist of (a) objects (e.g., *Iraq* or *supplies*), (b) predicates (including one-place predicates such as *person* that can apply to an individual object, multi-place predicates or relations such as *attack* that interrelate multiple objects, and higher order relations such as *cause* that interrelate propositions), and (c) propositions, which bind predicates to arguments, where arguments may be either objects (e.g., *Iraq attacked Kuwait*, where the relation *attack* is bound to the objects *Iraq* and *Kuwait*) or more elementary propositions (e.g., *Iraq's attack on Kuwait caused the United States to attack Iraq*, where the higher order relation *cause* links two propositions).

The central theoretical claim of the ACME model is that analogical coherence emerges from the interaction of three fundamental constraints:

1. The structural constraint of *isomorphism* implies that mappings should be (a) one-to-one and (b) structurally consistent. Structural consistency requires that if a target proposition maps to a certain source proposition, then the predicate and argument(s) of the former should also map to the respective predicate and argument(s) of the latter. For example, if *Iraq attacked Kuwait* maps to *Germany attacked Poland*, then *Iraq* should map to *Germany*, *Kuwait* should map to *Poland*, and *attack* should map to *attack*.
2. The constraint of *semantic similarity* yields a preference for mappings between predicates that are similar in meaning (e.g., identical, or sharing a common superordinate).
3. Finally, *pragmatic centrality* yields a preference for corre-

spondences that are assumed before the mapping process or that link especially important elements.

ACME treats all of these constraints as pressures (Hofstadter, 1984), rather than as strict requirements. Thus, the constraints may sometimes conflict with each other, and they may be only imperfectly satisfied by the resultant mapping. The interactions among the constraints are governed by a mechanism that performs parallel constraint satisfaction, using a connectionist relaxation algorithm (e.g., McClelland & Rumelhart, 1981). In essence, the overall task of deriving a mapping is broken into the subproblems of finding a corresponding element for each constituent element in the source and target; then these subproblems are solved simultaneously and incrementally, with continuous communication of partial results. The model eventually "settles" on a set of correspondences that collectively provide the best compromise to satisfy the constraints that govern analogical coherence. If the analogs are not entirely isomorphic, some elements may simply be left unmapped. Holyoak and Thagard (1989) and Holyoak, Novick, and Melz (in press) have shown that the ACME model can provide a good account of a number of psychological findings concerning human mapping performance, including robustness in the face of analogs that are less than isomorphic.

### Overview and Predictions

The present study tested a number of qualitative predictions of the ACME model as it applies to mapping between subjects' knowledge of World War II and the Persian Gulf War. We performed two studies, conducted in the United States during and immediately after the Gulf War, in which college students were asked to assume that Saddam Hussein mapped to Hitler and then to provide mappings for George Bush and for the main countries involved in the Gulf War. No simple isomorphism exists between the Gulf situation and that in World War II; accordingly, ACME predicts that finding a mapping requires resolving conflicting pressures. One might argue that the United States of 1991 (US-'91) maps to Great Britain of World War II, and Bush maps to Churchill (because Bush, like Churchill, led his nation and the Western allies in early opposition to Saddam-Hitler). Nonetheless, other conflicting pressures could yield alternative mappings. The United States of the World-War-II era (US-WW2) did not, of course, go to war until it was bombed by Japan—well after Hitler had marched through Europe. However, simple semantic similarity supports mapping US-'91 to US-WW2, which in turn favors mapping Bush to Franklin Delano Roosevelt (FDR). Such a mapping is certainly not entirely superficial, because (at least according to American textbooks) the US-WW2 under FDR's leadership played a major role in winning World War II by supplying most of the Allied arms and equipment, just as the US-'91 was to do in the Persian Gulf War.

Leaders and countries are closely entwined by a complex web of relations; for example, Churchill was not simply "the leader of Britain," but also the person who inspired the British people, led the drive for the country's military buildup, and so on. It follows that the constraint of structural consistency will generate pressures such that if Bush is mapped to Churchill, then the US-'91 will tend to be mapped to Britain; whereas if Bush is

mapped to FDR, then the US-'91 will tend to be mapped to the US-WW2. The ACME model predicts that either of the above consistent mappings is possible; furthermore, either will be preferred to a crossed mapping, such as Bush to FDR coupled with the US-'91 to Britain, which would involve violation of structural consistency. In general, ACME predicts that subjects will be much more likely to produce correspondences in which the leader and his nation in the target analog "stay together" when mapped to the source. However, like all the constraints postulated by the model, the pressures that favor consistent mappings of leaders and their countries are not absolute. In our report of Experiment 3, we provide evidence that when faced with strong opposing pressures, people sometimes crossed mappings for leaders and their countries.

The other constituent of ACME's isomorphism constraint, in addition to structural consistency, is the pressure toward one-to-one (target-to-source) mappings. This pressure may have various manifestations but generally leads to the prediction that people will tend to produce unique mappings. Thus, although different subjects may map Bush onto either Churchill or FDR, any single subject should tend to select one or the other. However, because ACME (unlike, for example, the Structure Mapping Engine model of Falkenhainer, Forbus, & Gentner, 1989) does not treat one-to-one mapping as a strict requirement, the model predicts that subjects may occasionally give multiple correspondences to a single target element. One-to-many mappings are most likely to be generated when (a) strong positive pressures support each of the alternatives and (b) no other target element maps strongly to any of the source elements involved in the one-to-many mapping.

A number of elements of the Gulf situation seem to be plausible candidates to generate occasional one-to-many mappings. Kuwait (at least once the war began) seems to map best onto Poland (because the German invasion of Poland triggered a military response by the Allies). However, the invasion of Poland was preceded by the German annexation of Austria and part of Czechoslovakia; hence, one could argue that Kuwait maps to one or both of these. Saudi Arabia also seems to be somewhat ambiguous in its mapping, arguably playing roles in various ways parallel to those of Britain or France (at least) in World War II. If the constraint of one-to-one correspondence is a pressure rather than a strict requirement, people will sometimes provide one-to-many mappings for the leaders and countries involved in the Gulf War.

### Experiment 1

Experiment 1 consisted of a naturalistic survey of students' opinions about the correspondences between the Gulf situation and World War II. These data were collected on January 17 and 18, 1991 (the 2 days immediately after the start of the war).

### Method

*Subjects.* Subjects were 122 students enrolled in a lower division required psychology course at the University of California, Los Angeles (UCLA).

*Materials and procedure.* The mapping task was administered immediately after subjects had completed a 5-page survey containing demographic questions and statements about the Persian Gulf crisis, for

which the students were asked to give their opinions on a rating scale. The last page of the survey, which is the sole focus of the present report, contained the following analogy mapping problem:

Many people have drawn an analogy between the Gulf situation and the situation in Europe prior to World War II. Regardless of whether or not you think this analogy is appropriate, we would like to know what you think the analogy really means. Suppose someone says, "Hussein is analogous to Hitler." For each of the people or countries listed below that are involved in the Gulf crisis, please write down the most natural match in the World War II situation (from the point of view of someone who thinks Hussein is analogous to Hitler). If you think there is no good match, write "none."

Subjects were then asked to generate mappings for Iraq, the United States, Kuwait, Saudi Arabia, and George Bush (in that order). Although the initial survey was administered to a total of 196 subjects, because of time limitations only 122 of these attempted the analogical mapping task.

### Results and Discussion

We focused our analyses on subjects who demonstrated basic knowledge of the participants in World War II. Of the 122 subjects, 15 did not map Iraq to Germany, 17 gave no mapping for Kuwait, and 41 failed to provide a mapping for either the United States or Bush, or both. (All but 2 of these 41 provided no mapping for Bush.) For purposes of our primary analyses, we also excluded 7 other subjects who mapped Bush to someone other than Churchill or FDR, or mapped the US-91 onto a country or set (usually the Allies) other than Britain or the US-WW2. Excluding these 80 subjects, we were left with 42 subjects who satisfied all of the following criteria: Each mapped Iraq to Germany; mapped Bush to either FDR or Churchill, or to "the leader of the United States (or Britain) at that time"; mapped the US-91 to either the US-WW2 or Britain; and provided some mapping for Kuwait.

To test the ACME model's prediction that people would tend to make mappings that were structurally consistent for the leader and his nation, we examined the frequency of the alternative mappings provided for Bush and the US-91. The data in Table 1 provide a cross-tabulation of the frequencies with which Bush was mapped to FDR or Churchill and the US-91 was mapped to the US-WW2 or Britain. These data demonstrate a strong effect of structural consistency. Subjects who matched the US-91 to the US-WW2 were more likely to match Bush to FDR; subjects who matched the US-91 to Britain were more

likely to match Bush to Churchill,  $\chi^2(1, N = 42) = 16.16, p < .01$ . Note that although individual subjects tended to choose one or the other of the two possible consistent mappings, a significant number of subjects in fact chose each. These results thus suggest that this subset of the elements of the Gulf situation, the United States and its president, generates a bistable mapping based on two coherent but mutually incompatible sets of correspondences. This mapping ambiguity is reminiscent of the well-known perceptual ambiguity of the Necker cube, in which the sets of four points that define the front or back plane of the cube always seem to shift together into one of the two stable interpretations of that figure. The ACME model explains the bistability of the war analogy using essentially the same constraint-satisfaction mechanisms that have been applied to explain the ambiguous interpretations of the Necker cube (Rumelhart, Smolensky, McClelland, & Hinton, 1986).

The interdependency of the mappings extended beyond those provided for Bush and the US-91. For subjects who mapped the US-91 to the US-WW2, 8 of the 16 subjects who provided a mapping for Saudi Arabia mapped that country to Britain. In contrast, for subjects who mapped the US-91 to Britain, none of the 7 subjects who provided a mapping for Saudi Arabia gave Britain as a response; rather, most suggested France. This shift in mappings for Saudi Arabia was significant,  $\chi^2(1, N = 23) = 5.37, p < .05$ , and provides evidence for ACME's prediction that people prefer one-to-one correspondences: If Britain is captured as the mapping for the US-91, it is not available as a mapping for Saudi Arabia.

Figure 1 depicts the two basic bistable patterns that emerged in the mapping data. When Bush was mapped to FDR, then the US-91 tended to map to US-WW2, allowing Saudi Arabia to map to Britain. When Bush was mapped to Churchill, structural consistency pressured the US-91 to map to Britain, which in turn (because of the one-to-one constraint) forced Saudi Arabia to shift into a mapping to France (the subjects' second choice).

Although subjects tended to generate one-to-one mappings, the presence of occasional one-to-many mapping responses indicates that the preference for one-to-one correspondences is not absolute. We examined the data for the 122 subjects who made some attempt at mapping, looking for cases in which a person or country in the Gulf situation was mapped to more than one object in World War II. Only one case of a one-to-many person mapping was found (a subject who mapped Bush to both Churchill and Chamberlain). However, one-to-many mappings of countries were relatively common. Twelve subjects mapped Kuwait to two or three countries (most often Poland and Austria, as indicated in Figure 1); 9 subjects mapped the US-91 to two or three of the US-WW2, Britain, and France; 3 subjects mapped Saudi Arabia to both Britain and France; and 3 mapped Iraq to both Germany and Japan. Notice that these one-to-many mappings appear far from random. In all these cases it seems that multiple correspondences are drawn from the small set of possibilities that actually share common relational roles. In the ACME model, one-to-many mappings may emerge when positive evidence favoring each correspondence outweighs the negative pressure generated by the one-to-one constraint. This is particularly likely to happen when neither of the multiple-alternative-source elements is captured by some

Table 1  
*Relationship Between Mapping of George Bush and Mapping of US-91: Experiment 1*

Mapping for George Bush	Mapping for US-91	
	US-WW2	Britain
FDR	21	2
Churchill	6	13

Note. US-91 = United States during the Persian Gulf War; US-WW2 = United States during World War II.

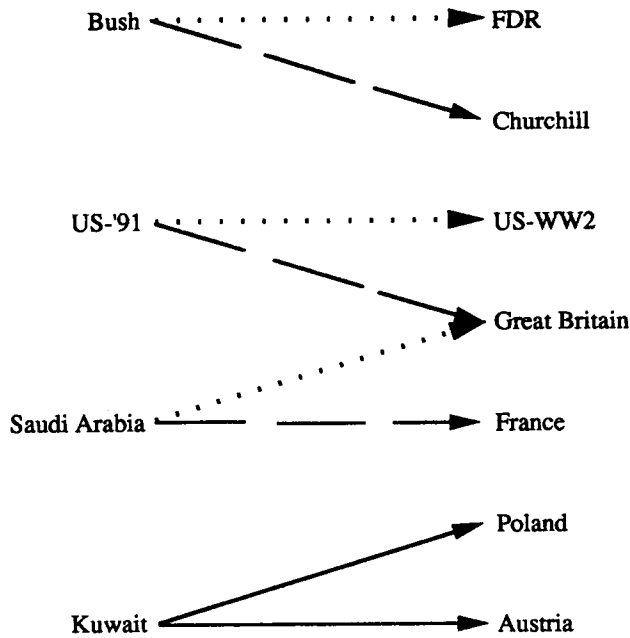


Figure 1. Bistable mapping: If Bush is FDR (Franklin Delano Roosevelt) then the US-91 (United States during the Persian Gulf War) is the US-WW2 (United States during World War II) and Saudi Arabia is Great Britain; if Bush is Churchill then the US-91 is Great Britain and Saudi Arabia is France. (Dotted lines indicate mappings that result when Bush is mapped to FDR; large dashed lines indicate mappings that result when Bush is mapped to Churchill. Solid lines represent mappings that are constant regardless of the mapping for Bush.)

other target element. For example, one reason Kuwait can be mapped to both Poland and Austria is that no other country involved in the Gulf War maps strongly to either of these two source countries.

## Experiment 2

Theories of analogical mapping assume that the constraints on the mapping process operate on active representations of the source and target analogs. It follows that an intervention influencing subjects' representations of the source should have predictable consequences for their choice of preferred mappings.

The results of Experiment 1 provided evidence of analogical coherence in the absence of intervention and also revealed the general lack of knowledge of the subject population about the major participants and events of World War II. In Experiment 2 we attempted to take advantage of that deficit. We designed an analogy experiment, similar to the analogy task in the survey, in which we attempted to induce subjects to make either consistent or crossed mappings by manipulating what we told them about World War II. Subjects read one of four abbreviated histories of World War II. All were historically correct, but each contained slightly different information and emphasized different points. After reading the history, subjects were asked to do the same mappings as in the survey administered in Experiment 1. Each history was designed to elicit a different combina-

tion of mappings for the US-91 (US-WW2 or Britain) and Bush (FDR or Churchill). Thus, there was a "Churchill-Britain" history, a "Churchill-US" history, an "FDR-Britain" history, and an "FDR-US" history. The ACME model predicts that the two histories that supported consistent mappings (Churchill-Britain and FDR-US) would each succeed in producing its intended mapping combination, whereas the two histories that supported crossed mappings (FDR-Britain and Churchill-US) would be less effective.

The experiment was run as an addition to various unrelated experiments from February 13 through March 15, 1991. (President Bush declared a cease-fire in the Gulf War on February 27.)

## Method

**Subjects.** A total of 76 UCLA subjects from an introductory psychology course participated in the experiment.

**Materials.** The four World War II histories were each three paragraphs long; the texts are presented in Appendix A. All were constructed by selectively summarizing the events of World War II as described in two history books (Garraty & Gay, 1972; Palmer & Colton, 1960). Each history began with an identical passage about Hitler's acquisition of Austria, Czechoslovakia, and Poland and the efforts by Britain and France to stop him. In the two Churchill histories, the second paragraph described how Churchill inspired the British and led the Allied forces. In the two FDR histories, the second paragraph described how FDR wanted the US-WW2 to enter the war and how he supplied arms to the Allies.

The third paragraph differed across all four conditions. The Churchill-Britain history emphasized that the US-WW2 did not enter the war until it was bombed by Japan and added information about the military role of the British General Montgomery. Both the Churchill-US and FDR-US histories emphasized how Britain was bombed by Germany, how the US-WW2 provided the most supplies, and how the Allied troops massed in Britain before D day. The Churchill-US history emphasized the personal role of Churchill and the national role of the US-WW2, whereas the FDR-Britain history emphasized the personal roles of FDR and General Eisenhower, while deemphasizing the activities of the US-WW2 as a nation.

Given the constraints of the naturalistic materials (especially the adherence to historical accuracy, albeit selective), it was obviously impossible to emphasize Churchill independently of Britain or FDR independently of the US-WW2. For example, in all versions, Churchill was described as the Prime Minister of Britain and FDR as the President of the United States. Nonetheless, the Churchill-US and FDR-Britain versions introduced information that would seem to lend considerable support to the crossed mappings. However, if people naturally favor consistent mappings, as the ACME model predicts, it should prove much easier to elicit either of the two consistent mappings (Churchill-Britain and FDR-US) than the two possible crossed mappings.

**Procedure.** Subjects were given instructions very similar to those used in Experiment 1, except they were also told that they would first read a brief summary of events in World War II to provide them with information to help them draw the analogy with the Gulf situation. The mapping task included the same items as in Experiment 1 (i.e., Iraq, United States, Kuwait, Saudi Arabia, and Bush). For different subjects the mappings were requested in two alternative orders, exchanging the positions of the United States and Bush. Within each of the four groups, approximately half the subjects answered the questions in each order. Eighteen subjects served in the FDR-Britain condition, 19 served in each of the FDR-US and Churchill-Britain conditions, and 20 served in the Churchill-US condition.

## Results and Discussion

As the results did not vary significantly across the two orders of the questions, all results are reported using the combined data. Of the 76 subjects, 50 mapped the US-WW2 uniquely to either the US-WW2 or Britain and mapped Bush uniquely to either FDR or Churchill. (Of the remaining 26, 13 failed to map one or both of the US-91 and Bush to either appropriate correspondent, and 13 provided a one-to-many mapping for one or both of the US-91 and Bush.) The frequency distribution of mappings for these subjects in the four experimental conditions is shown in Table 2. The combination we tried to elicit with each story labels each row; the actual mapping combination generated by the subject labels each column. The cells in the upper-left-to-lower-right diagonal indicate the number of subjects in each condition who actually gave us the answer we attempted to elicit.

Overall, the variations in the histories of World War II that we provided to subjects did influence their patterns of mapping,  $\chi^2(9, N = 50) = 32.42, p < .01$ . However, it is clear that the four histories were far from equal in producing their intended mappings. As the ACME model predicted, the two histories directed toward the consistent mappings (FDR-US and Churchill-Britain) did in fact produce the intended combination as the dominant answer. From the four corner entries of Table 2, it can be seen that these two histories produced opposite patterns of consistent mappings,  $\chi^2(1, N = 25) = 11.65, p < .01$ . However, neither of the two histories directed toward crossed mappings (i.e., FDR-Britain and Churchill-US) reliably produced the target combination. Instead, subjects continued to produce a consistent mapping as their dominant response: In the FDR-Britain condition, the response FDR-US was most frequent; in the Churchill-US condition, the response Churchill-Britain was most frequent. Thus, subjects exhibited a tendency to map to the "correct" leader rather than the "correct" country. This difference in which consistent mapping was produced for these two stories was significant,  $\chi^2(1, N = 19) = 8.29, p < .01$ .

After collapsing across the two stories directed toward con-

Table 2

*Frequencies of Responses Involving Alternative Combinations of Correspondences to George Bush and US-91 Across the Four History Conditions: Experiment 2*

History condition	Subjects' responses			
	FDR-US	FDR-Britain	Churchill-US	Churchill-Britain
FDR-US	11	0	0	1
FDR-Britain	6	2	0	1
Churchill-US	1	1	0	11
Churchill-Britain	2	2	1	11

*Note.* US-91 = United States during the Persian Gulf War. Boxheads: Mappings of George Bush and the US-91, respectively, to Franklin Delano Roosevelt and the United States (FDR-US), Franklin Delano Roosevelt and Britain (FDR-Britain), Winston Churchill and the United States (Churchill-US), and Winston Churchill and Britain (Churchill-Britain). Stub column headings are for those stories described in Appendix A that promote the mappings in the boxhead.

Table 3

*Relationship Between Mapping of George Bush and Mapping of US-91: Experiment 2*

Mapping for George Bush	Mapping for US-91	
	US-WW2	Britain
FDR	20	5
Churchill	1	24

*Note.* US-91 = United States during the Persian Gulf War; US-WW2 = United States during World War II.

sistent mappings, we found that 89% of subjects produced consistent mappings, whereas after collapsing across the two stories directed toward crossed mappings, we found that 86% of the subjects gave consistent mappings. Indeed, the frequency of consistent rather than crossed responses did not vary across the former and the latter story pairs,  $\chi^2(1, N = 50) = 0.15, ns$ . Table 3 shows the cross-tabulation of mappings after we collapsed across all four conditions. Overall, 88% of subjects produced consistent rather than crossed mappings, a highly significant pattern,  $\chi^2(1, N = 50) = 26.60, p < .01$ , and an overall frequency very similar to the 81% of consistent mappings obtained in Experiment 1.

As in Experiment 1, the interdependency of the mappings extended beyond those provided for Bush and the US-91, also appearing in the mappings given for Saudi Arabia. For subjects who mapped the US-91 to the US-WW2, 6 of the 11 subjects who provided a mapping for Saudi Arabia mapped that country to Britain. In contrast, for subjects who mapped the US-91 to Britain, none of the 15 subjects who provided a mapping for Saudi Arabia gave Britain as a response; rather, most suggested either France or Poland. This shift in mappings for Saudi Arabia is significant,  $\chi^2(1, N = 26) = 7.79, p < .01$ , and provides further evidence that people prefer one-to-one correspondences.

Also as in Experiment 1, the presence of occasional one-to-many mapping responses provided evidence that the preference for one-to-one correspondences is not absolute. Looking at the data from all of the subjects in all of the conditions, 5 subjects mapped Bush to both FDR and Churchill; 5 subjects mapped Kuwait to two or three of Austria, Czechoslovakia, and Poland; 2 subjects mapped Saudi Arabia to both Britain and France; and 5 subjects mapped the US-91 to two or three of the US-WW2, Britain, and France. (In addition, three others mapped the US-91 to the collective Allies.) As in Experiment 1, these one-to-many mappings appear quite systematic, reflecting pressures created by overlap of a target object with the roles of multiple source objects.

## ACME Simulations

So far we have argued that the ACME model is qualitatively consistent with the patterns of mappings between the Gulf War and World War II that we obtained from subjects. However, there are several reasons why it seemed useful to attempt a more

explicit simulation of the mapping process that drives generation of correspondences between the wars. First, the analogs, even though highly simplified in the histories provided to subjects in Experiment 2, are considerably more complex than most of those that have been examined by computational models of analogical mapping. Furthermore, because the analogs are far from isomorphic, they provide strong tests of the robustness of the model when faced with naturalistic analogies in which it is impossible to fully satisfy all the constraints on mapping postulated by the theory. In addition, the results of Experiment 2—in which the histories that were biased toward crossed mappings (i.e., favoring correspondences between Bush-US-91 and either Churchill-US-WW2 or FDR-Britain) failed to yield the favored pattern, instead yielding one of the consistent response patterns (i.e., Churchill-Britain or FDR-US-WW2)—provide a particularly demanding challenge to any computational model. To assess whether the pressures toward analogical coherence for which the present study provide evidence are in fact consistent with the ACME mapping model, we applied the model to the four cases tested in Experiment 2 (i.e., mappings between a representation of the Gulf situation and representations of each of the four histories of World War II used in Experiment 2).

**ACME representations.** ACME takes as inputs representations of a source and target analog, formalized as structural descriptions written in a simple form of predicate calculus. Accordingly, we wrote predicate-calculus representations of (a) the basic information about the Gulf situation that it seemed reasonable to attribute to our subjects and (b) the central information about World War II conveyed by each of the four histories. The full ACME representations are presented in Appendix B. For example, *Iraq attacked Kuwait* was expressed as

(attack(Iraq Kuwait)I\_attack\_K),

where *attack* is a two-place predicate, *Iraq* and *Kuwait* are objects, and *I\_attack\_K* is an arbitrary identifier for the proposition (intended to be mnemonic for human readers). Several caveats must be acknowledged about the representations we provided to ACME. There is no automatic translation system from English to predicate calculus; subjects undoubtedly made inferences that went beyond the actual texts we provided and they also must have differed in the background knowledge about both analogs that they brought to the mapping task. For all of these reasons, our representations should be viewed simply as rough approximations to the knowledge that a typical subject in each condition of Experiment 2 might have used to derive a mapping. Note that the differences among the representations of the four World War II histories are of greatest importance in modeling the varying patterns of mapping responses observed across conditions in Experiment 2.

The representations included a substantial amount of causal information, such as the fact that Churchill's mobilization of Britain's forces was a cause of Britain's victory over Germany. As this example suggests, the structural connections between a leader and his nation were much more extensive than the simple *leader-of* proposition; we attempted to capture some of the rich network of interrelationships linking the activities of

leaders, their countries, their countries' armed forces, and their adversaries. The representation of the Gulf War included 76 propositions (based on 6 one-place, 28 two-place, and 2 three-place predicates). The four variations on World War II all shared 95 propositions; each variation contained an additional 17–29 propositions that reflected the differences of emphasis across the stories.

**Basic operation of the ACME model.** Given predicate-calculus representations of the target and source analogs, ACME proceeds to build a network of *mapping units* representing hypotheses about possible correspondences between elements (e.g., *Saddam = Hitler*). The units formed are restricted such that only elements of the same logical type (objects, predicates of *n* arguments, and propositions) enter into hypotheses about possible correspondences. Once the mapping units are formed, links are set up to enforce the various constraints postulated by the theory. Units take on continuous activation values that reflect the support for the correspondences they represent; links have weights that reflect the degree of positive (excitatory) or negative (inhibitory) support dictated by the various constraints. Weights are fixed at values provided to the program, whereas activations change as the program actually runs.

To capture structural consistency, excitatory links are formed between each unit representing a possible mapping for a pair of propositions and the units that represent mappings between the corresponding predicates and arguments contained in the propositions. Excitatory links are also formed between pairs of the latter types of units. Figure 2 depicts a small fragment of the mapping network that would be formed in mapping the Persian Gulf War to World War II. Most of this network is based on the target propositions

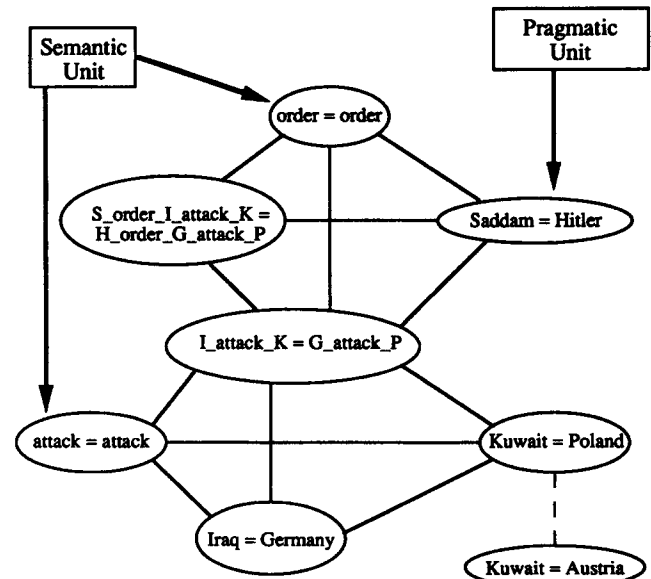


Figure 2. A fragment of the ACME (Analogical Constraint Mapping Engine) network that maps the Persian Gulf War to World War II. (Ovals represent mapping units; solid lines represent excitatory links; dashed lines represent inhibitory links.)



(attack(Iraq Kuwait)L\_attack\_K)  
 (order(Saddam L\_attack\_K)S\_order\_L\_attack\_K)

and the source propositions

(attack(Germany Poland)G\_attack\_P)  
 (order(Hitler G\_attack\_P)H\_order\_G\_attack\_P),

which in fact can generate isomorphic mappings.

Note, for example, that the possible mapping between the propositions *L\_attack\_K* and *G\_attack\_P* generates excitatory links (solid lines) between the unit representing that hypothesis and a unit representing the possible mappings between the respective predicates (*attack = attack*) and two units representing mappings of the arguments (*Iraq = Germany* and *Kuwait = Poland*). To provide pressure favoring one-to-one mapping (the second component of the isomorphic constraint), inhibitory links (broken lines in Figure 2) are set up between competing mapping units. For example, Figure 2 shows the inhibitory connection between the unit *Kuwait = Poland* and the unit for the competing possibility *Kuwait = Austria*. The latter would in turn have various sources of support from other units (not shown in the figure).

Two special units, which are fixed at maximum activation, are used to enforce semantic and pragmatic constraints. The semantic unit has excitatory connections to predicate-mapping units, with weights ranging from a minimum value of 0, representing no similarity, to a maximum value representing identity (e.g., the link to the unit *attack = attack*). ACME can be given intermediate semantic weights for predicates that are similar but not identical (e.g., *annex* and *conquer*).

The special pragmatic unit can give extra excitation to mappings involving any element specified to be especially important or to any mapping unit representing a correspondence that is presumed to hold in advance. In the present simulations, the pragmatic unit was always connected to the unit *Saddam = Hitler*, reflecting the fact that our subjects were told to assume this correspondence as they performed the mapping task.

Once the mapping network has been constructed, an algorithm for parallel constraint satisfaction is used to determine the subset of the mapping units that collectively provide the most coherent set of correspondences. To initialize the network, the activation levels of the semantic and pragmatic units are fixed at 1, and the activations of all other units are set to a minimal positive value. On each cycle of activity, all units (except the semantic and pragmatic units) have their activation levels updated on the basis of their activation levels, the activation levels of neighboring units, and the weights on links connecting each unit to its neighbors. Specifically, the activation level ( $a$ ) of unit  $j$  on cycle  $t + 1$  is given by

$$a_j(t + 1) = a_j(t)(1 - d) + enet_j[\max - a_j(t)] + inet_j[a_j(t) - \min],$$

where  $d$  is decay parameter,  $enet_j$  is the net excitatory input, and  $inet_j$  is the net inhibitory input (a negative number), with *minimum* ( $\min$ ) =  $-.3$  and *maximum* ( $\max$ ) =  $1$  for  $enet_j$  and  $inet_j$ . The value of  $enet_j$  is equal to  $\sum w_{ij}o_i(t)$  for  $w_{ij} > 0$ , and the value of  $inet_j$  is equal to the same quantity when  $w_{ij} < 0$ , where  $o_i(t)$  is the output of unit  $i$  on cycle  $t$  and  $w_{ij}$  is the weight on the link

between unit  $i$  and unit  $j$ . Activation values are constrained to range from *min* to *max*; outputs are equal to activation values when the latter are positive, and they are 0 otherwise. The updating process ceases when all units have settled at asymptotic values, and those units that are highly active at asymptote provide the "winning" set of correspondences. (For a more detailed description of the ACME model, see Holyoak & Thagard, 1989.)

*Simulations of mapping conditions tested in Experiment 2.* The ACME model was used to map the representation of the Gulf situation to each of the four representations of World War II, using a \*LISP version of ACME that runs on a CM2 Connection Machine. (The CM2 is a massively parallel computer with over 16,000 processors that efficiently implements the parallel algorithm for updating activations.) Several numerical parameters for weights on links between mapping units were specified to run the model. An excitation parameter (the weight on links created to enforce the structural consistency constraint) was set at .005. The weight on links from the special semantic unit to predicate-mapping units was set at .005 if the predicates were identical (i.e., maximally similar), .0025 for 13 predicates treated as similar but not identical (e.g., *annex* and *conquer*), and 0 otherwise. The weight on the link between the pragmatic unit and the "presumed" mapping of Saddam to Hitler was set at .3, and the weight for inhibitory links between competing mapping units (enforcing the one-to-one constraint) was set at .16. Finally, the decay parameter,  $d$ , was set at .005. These parameter values are identical to those used previously in other applications of the ACME model to mappings between large, complex analogs (Holyoak et al., in press). (See Holyoak & Thagard, 1989, for a more detailed description of the ACME parameters.)

The mapping networks constructed by ACME contained from 4,121–4,598 units and from 145,040–171,162 links with symmetrical weights. Each of the four runs settled at a stable asymptotic set of activations after 323–397 cycles of updating.

The results of the ACME runs were consistent, at a general qualitative level, with the kinds of mappings given by subjects in Experiment 2. For each of the four histories of World War II, Table 4 shows the winning mapping units for each of the leaders and countries for which subjects provided mappings. For every cell in Table 4, ACME's winning mapping unit(s) corresponds to either the most frequent or next most frequent response of the subjects in the four conditions of Experiment 2. In particular, when the representation of the Gulf situation was mapped to the representation of the Churchill–Britain story, the winning mapping for Bush was Churchill and for the US-'91 was Britain. When the program mapped the Gulf situation to the FDR–US representation, the intended mapping of Bush to FDR and the US-'91 to the US-WW2 was produced. But like human subjects, ACME did not easily produce the intended crossed mappings. For the FDR–Britain story, ACME favored the mapping of Bush to FDR and US-'91 to US-WW2, as did our subjects. Unlike our subjects, however, ACME did produce an approximation to the crossed mapping for the Churchill–US story. In this condition ACME mapped Bush to Churchill (as did our subjects) but produced a one-to-many mapping of US-'91 to US-WW2 (with an activation of .57) and Britain (.41); whereas our subjects tended to select Britain alone as their preferred mapping. Despite this one discrepancy, the ACME



Table 4  
ACME's Winning Mappings Compared With Rank of Subjects' Preferred Mappings for Each of the Biased Histories

If Saddam Hussein is Hitler then who is ...	Biased representation					
	Churchill-Britain		Churchill-US		FDR-Britain	
	Mapping	Frequency	Subjects' rank	Mapping	Frequency	Subjects' rank
Iraq?	Germany	1	.98	Germany	1	.97
George Bush?	Churchill	1	.95	FDR	1	.95
United States?	Britain	1	.78	United States	1	.83
Kuwait?	Poland	1	.43	Poland	2	.37
Saudi Arabia?	Austria	2	.32	Austria	1	.27
	France	1	.85	Britain	2	.80

Note. Mapping strengths are the strengths of the mappings when the network has settled (maximum = 1). All mappings with strengths above .25 are reported. Subjects' ranks reflect the relative frequencies of unique mappings generated by all subjects in Experiment 2. Biased representations correspond to stories in Appendix A that promote mappings of George Bush and the United States during the Persian Gulf War, respectively, to either Winston Churchill and Britain (Churchill-Britain), Winston Churchill and the United States (Churchill-US), Franklin Delano Roosevelt and Britain (FDR-Britain), or Franklin Delano Roosevelt and the United States (FDR-US). ACME = Analogical Constraint Mapping Engine.

\* Indicates the modal mapping. <sup>b</sup> Indicates the mapping with the next highest frequency.

model captures the basic result that people tend to give consistent rather than crossed mappings, even when their representations of the source analog are manipulated in ways that would seem to favor crossed mappings.

As we noted earlier, the links between the key leaders and their countries are much more extensive than the simple *leader-of* propositions, such as "Churchill was the leader of Britain." It follows that ACME should demonstrate a preference for consistent mappings for Bush and the US-'91 even if the source propositions stating that Churchill was the leader of Britain and FDR was the leader of the US-WW2 were deleted from the World War II representations. Although the strengths of the mappings changed somewhat when we performed these additional runs, in all cases the best mappings remained the same. In particular, the FDR-Britain story still yielded a mapping of Bush-US-'91 to FDR-US-WW2, indicating that ACME's assessment of coherence is indeed sensitive to the overall web of relations linking leaders to their countries, rather than to a single crucial match between *leader-of* propositions.

Just as was the case for our human subjects, ACME's pressures toward structurally consistent, one-to-one mappings produced further systematic differences among the mappings generated for each biased history. As the results in Table 4 indicate, Saudi Arabia was mapped to Britain whenever the US-'91 mapped to US-WW2, but in the versions that resulted in a mapping of the US-'91 to Britain, the mapping of Saudi Arabia shifted to France. Overall, ACME produced the same two bi-stable patterns of mappings that subjects gave as their dominant responses in both our experiments (see Figure 1). That is, the selection of a mapping for Bush constrains the mapping of US-'91 to be either US-WW2 or Britain, which in turn influences whether Saudi Arabia will map to Britain or to some other country (usually France). Such cascading linkages between decisions emerge naturally from a system for performing parallel constraint satisfaction.

ACME's isomorphism constraint tends to produce one-to-one mappings (especially when the inhibition parameter is set high, as it was in these runs), and the great majority of the mappings favored by ACME were indeed one-to-one. However, like human subjects, ACME occasionally generated one-to-many mappings for a country included in the Gulf representation. In particular, as the results in Table 4 indicate, Kuwait was consistently mapped to both Poland and Austria, which was the most common one-to-many mapping produced by our subjects. Note that the asymptotic activations of these mappings for Kuwait tended to be relatively low, reflecting the system's disquiet at the continuing competition between the two roughly equal alternatives.

### Experiment 3

The evidence for structural consistency in mapping provided by Experiments 1 and 2 centered on the strong tendency for the most prominent Western leader and his country in the Gulf situation (i.e., Bush and the US-'91) to jointly map to a leader and his country in World War II (either Churchill and Britain or FDR and US-WW2), rather than to a crossed combination that split the leader from his country (i.e., Churchill and US-WW2 or FDR and Britain). It might be argued that this result is simply

due to a strong bias to treat leaders and countries as single conceptual units, rather than to the structural consistency constraint postulated by ACME. We were able to demonstrate that *leader-of* propositions were not necessary for the model to produce a consistent mapping; that is, when we deleted the *leader-of* propositions in the source and target stories, ACME still yielded mappings that kept leaders with their countries. As we pointed out, this consistency resulted from the fact that leaders and their countries are jointly involved in many propositions, not just the single *leader-of* proposition.

If people treat leaders and their countries as indivisible conceptual units, then a single *leader-of* proposition, although not necessary to obtain a consistent mapping, would nonetheless be sufficient to do so. In contrast, the ACME model predicts simply that in the absence of any other competing information, a *leader-of* relation (just like any other mappable relation) would be sufficient to produce a consistent mapping. If, however, other information is provided about the leader and country (beyond the simple fact that the leader leads the country), then competing pressures could in principle result in the optimal mapping being one that splits leaders and their countries. That is, ACME predicts that in the presence of strong opposing constraints, crossed mappings that separate leaders from their countries may sometimes be obtained.

ACME's prediction that crossed mappings are possible could not be tested using the analogy between the Gulf situation and World War II, because the facts (even in the biased histories used in Experiment 2) do not provide strong enough competing pressures. Accordingly, in Experiment 3 we designed materials to demonstrate that a crossed mapping may be preferred by subjects and by ACME. We wrote stories in which the individual characteristics and roles of leaders and their countries were somewhat separable. Using a science-fiction context, all subjects read a target story about a planet on which there was one big prosperous country, Anthar, ruled by a good President. Then subjects read two source stories about two different countries on another planet: a large industrialized country called Grandus and a small poor country called Minutus. Two versions of these source stories were created. In the consistent condition, Grandus was ruled by the benevolent King and Minutus was ruled by the evil Dictator; in the crossed condition, the leaders were switched. (For consistency, all the leaders in the stories were described as male.) After reading the stories, subjects were asked to match several of the objects in the target story, including the country (Anthar) and its leader (the President), to objects from either of the source stories.

For the consistent condition, ACME predicts that subjects will strongly prefer the consistent mapping of the good President to the benevolent King and prosperous Anthar to industrialized Grandus. In the crossed condition, the structural pressure to keep leaders with their countries will (Dictator with Grandus; King with Minutus) be opposed by strong pressures supporting mapping the good leaders and rich countries to each other. Accordingly, ACME predicts that at least some subjects will produce a crossed mapping in this condition (i.e., map the President to the King and Anthar to Grandus despite the fact that the King rules Minutus). In contrast, if leaders and countries form inviolate conceptual units, crossed mappings should not be obtained in either condition.

To test ACME's prediction that a single relational proposition can be sufficient to produce a consistent mapping, each of the three stories included the role of a diplomat: the Ambassador, nominated by the President; the Minister, designated by the leader of Grandus; and the Consul, appointed by the leader of Minutus. These characters were described in similar minimalist terms: Each story mentioned only that the diplomat was assigned by the particular leader to engage in negotiations. ACME predicts that given this minimal information, subjects' mapping for the Ambassador will depend solely on the mapping provided for the President; that is, given that the President is mapped to a particular ruler, the Ambassador will be mapped to the diplomat assigned by that ruler. Thus, although semantic pressures to map Ambassador to Consul or Ambassador to Minister are equal, the structural pressure from the one relation in which the diplomat is involved—being appointed by a particular leader—will be sufficient to cause the diplomat to be mapped consistently with whichever ruler made the appointment. Note that this situation is analogous to one in which the only proposition known about a person is that he or she is the *leader of* a country. In such situations, ACME predicts that the single proposition, coupled with the structural consistency constraint, will be sufficient to produce the preferred mapping.

Experiment 3 also introduced a minor but theoretically important change in the wording of the question with which mappings were elicited from subjects. Rather than being asked for "the most natural match" for each target item, as in Experiments 1 and 2, subjects were asked for "the most natural match or matches." It could be argued that the singular wording used in the earlier experiments may have discouraged production of one-to-many mappings; the plural wording was intended to be more neutral.

### Method

**Subjects.** A total of 67 UCLA students participated in the experiment. Of these, 45 were students in an upper division elective course in psychology who participated as part of a class demonstration, and 22 were students in an introductory psychology course who participated in partial fulfillment of a course requirement.

**Materials and procedure.** Subjects were given booklets containing instructions, story materials, and places to write their answers to various questions. On the first page subjects were told about Captain Krick of the Federation, who had just returned from exploring two new planets and who knew that he was going to have to make recommendations about whether to begin trading with the countries on those planets and about whether to invite the countries on those planets to become trial members of the Federation. The important qualities for a trading partner were that it had things the Federation would like to obtain and that it wanted things the Federation already had. (Trading partners were not judged on humanitarian values, as it was assumed that increased contact with the Federation would have a positive effect on other societies.) The most important qualities for a member of the Federation were that it was open and receptive to new foreign ideas and that it respected all forms of life.

Subjects then read descriptions of three countries located on the two planets. These descriptions are presented in Appendix C. First, all subjects read Captain Krick's report of his exploration of the planet Antares II. The country he found there, Anthar, was big and prosperous and had made many medical advances, but was somewhat techno-

logically underdeveloped. The country had just elected a President who seemed compassionate in his dealings with another, less prosperous country (the "winter country"). The President nominated an Ambassador to interact with the representatives of the Federation.

Subjects then read about two countries that Krick explored on the planet Zenoba III. Different subjects read one of two different descriptions of the countries of Zenoba III. In all versions, Grandus was described as a large, technologically advanced country, rich in natural resources, but that occasionally experienced food shortages. Minutus was described as a small, poor country, lacking in resources. In the consistent condition, the ruler of Grandus was a benevolent King. The King promised to improve farming techniques and develop culture. He seemed humane in his dealings with a hurricane-torn tropical island country on Zenoba III, and he appointed a Minister to confer with the Federation. The ruler of Minutus was an evil Dictator, who had seized power during a coup many years back. The Dictator restricted communications within his country and was hostile to the island country. He appointed a Consul to negotiate with the Federation. In the crossed condition, the leaders of the two countries were switched. Thus, Grandus was ruled by the evil Dictator and Minutus was ruled by the benevolent King. The paragraphs describing the actions of the leaders were kept intact when they were moved except for (a) the description of what the King sent to the suffering island country (when the King was the ruler of Grandus he sent technological assistance; when the King was the ruler of Minutus he sent vegetables) and (b) what the King tried to improve in his own country (food for Grandus and farmland for Minutus). Also, in this crossed condition the King appointed the Consul, and the Dictator appointed the Minister.

In all other respects the two versions of the Zenoba III descriptions were identical. Within each condition the order of the descriptions of the countries on Zenoba III was counterbalanced: Half of the subjects read about Grandus first, and the other half read about Minutus first.

After reading the description of each country, subjects were asked to evaluate two questions about it, using a 7-point rating scale ranging from *strongly negative* to *strongly positive*. The questions were whether the country should be selected as a trading partner and whether it should be admitted to trial membership in the Federation. This evaluation task was intended to encourage subjects to think carefully about each of the descriptions of countries and their leaders.

For all subjects, the final page of the booklet contained a matching and rating task. Subjects were told that Captain Krick was asked to describe the similarities between the situations on Antares II and Zenoba III and were asked what they thought Krick would respond. They were instructed as follows:

For each of the people or countries listed below from Antares II, please write down the most natural match or matches from the planet Zenoba III. If you think there is no good match, write "none." After you have written down the match or matches, please rate how happy you are with your answer by writing a number from 1 to 7 on the line to the right of your answer.

A scale was pictured showing 1 as *extremely unhappy* and 7 as *extremely happy*. Each interval marker was labeled, with 4 labeled as *neutral*. Subjects were told to write *N/A* on the rating line if they had written *none* for the match. They were also told that they were allowed to look back at the descriptions on the previous pages. The matching task involved five people and countries on Antares II (the target analog): the winter country, the country Anthar, the President's wife, the President, and the Ambassador. For half of the subjects the items in the mapping and rating task were presented in the above order, and for the other half of the subjects the serial positions of Anthar and the President were switched.

### Results and Discussion

Of the 67 subjects, data from 8 subjects who gave highly confused answers (repeatedly mixing up names from the target and

source analogs and/or mapping names of people to names of countries) were discarded. The remaining 59 subjects included 30 in the consistent condition and 29 in the crossed condition. The most crucial result concerns the frequencies with which subjects generated crossed mappings in the two conditions. Table 5 presents these data for all subjects (46 of 59) who mapped the President to either the King or the Dictator and Anthar to either Grandus or Minutus. In the consistent condition, all 24 of the subjects mapped the President and Anthar to the King and Grandus, respectively. This is to be expected, of course, because all pressures encouraged this consistent mapping. In the crossed condition, however, 9 of 22 subjects mapped the President to the benevolent King and Anthar to industrialized Grandus, even though the King ruled Minutus and the Dictator ruled Grandus. Another 9 subjects mapped these two target elements to the King and Minutus, and 4 others mapped them to the Dictator and Grandus. Both of the latter mappings keep leaders with their countries. The proportion of crossed mappings was significantly higher in the crossed (41%) than the consistent condition (0%),  $\chi^2(1, N = 46) = 9.75, p < .01$ .

These results contrast with those of Experiment 2, in which the proportion of crossed mappings did not increase even when subjects were given biased histories of World War II intended to support such mappings. The findings in Experiment 3 indicate that the earlier results are not attributable to leaders and countries forming indivisible conceptual units. Rather, it is simply the case that the facts of World War II—even as described in the histories that were biased toward crossed mappings—do not provide strong enough support for crossed mappings to offset the wealth of information that ties Churchill to Britain and FDR to the United States. In Experiment 3, however, we succeeded in creating a crossed condition in which the opposing pressures were sufficiently strong that leaders and countries were sometimes separated during analogical mapping.

The mapping provided for the Ambassador (who was appointed by the President of Anthar) was almost perfectly predicted by the mapping given for the President. In the consistent condition, a total of 25 subjects mapped the President to the King; of these, 24 mapped the Ambassador to the Minister (whom the King appointed in the consistent version). In the crossed condition, a total of 22 subjects mapped the President

Table 5  
Frequencies of Mappings for Anthar (Country) and President (Leader): Experiment 3

Mapping for President	Mapping for Anthar	
	Grandus	Minutus
Consistent condition		
King	24	0
Dictator	0	0
Crossed condition		
King	9	9
Dictator	4	0

Note. Number in boldface is frequency for cell in which mapping separates country and leader, as suggested by the stories in the crossed condition.

to the King, and all of these subjects mapped the Ambassador to the Consul (whom the King appointed in the crossed version). Four other subjects in the crossed condition mapped the President to the Dictator, of these, three mapped the Ambassador to the Minister (the Dictator's appointee in the crossed condition), and one did not provide any mapping. These results support ACME's prediction that in the absence of any competing information, a single mappable relation involving one mapped object (in this case, being appointed by the President) is sufficient to generate a consistent mapping for a second object (the Ambassador) on the basis of the structural consistency constraint.

Of the 59 subjects, all but 3 generated only one-to-one mappings, even though the instructions explicitly allowed the possibility of providing multiple matches. Subjects' strong preferences for one-to-one mappings (also observed in Experiments 1 and 2) thus appear to reflect a basic constraint on analogical mapping, rather than a demand characteristic of the mapping instructions used in the earlier experiments.

Analyses of variance were performed on the happiness ratings that subjects provided for each mapping (ignoring subjects who failed to rate the relevant mapping). Only one item yielded a significant difference across the two conditions: the mapping for Anthar, the question for which subjects were much more divided in their answers within the crossed than the consistent condition. Subjects in the former condition gave lower happiness ratings for their Anthar mapping than did subjects in the latter condition (means of 5.13 and 5.82, respectively),  $F(1, 49) = 3.95$ ,  $p = .05$ . Within the crossed condition, happiness ratings for Anthar did not differ significantly as a function of the country to which it was mapped.

### *ACME Simulations*

As in Experiment 2, we ran ACME simulations to assess the degree to which the model in fact accounts for the major qualitative results obtained in the mapping task. To perform the simulations, we wrote predicate-calculus representations of all the descriptions provided to subjects. The Anthar representation (66 propositions) was treated as the target, and the combined representations of Grandus and Minutus (111 propositions) was treated as the source. Two versions of the source representation were generated (differing in just 17 propositions) to reflect the differences in the descriptions provided in the consistent versus the crossed conditions. In two separate runs, the target representation was mapped to each of the two alternative source representations, with all parameters set at the same values as were used for the simulation in Experiment 2. The correspondence between the planets Antares II and Zenoba III (that subjects were told to assume) was treated as a "presumed" mapping. Each run involved creation of a mapping network based on almost 3,900 units interconnected by almost 130,000 links, which settled at a stable asymptote after about 450 cycles of updating.

The asymptotic activations of the mapping units involving the key target elements—the country Anthar, the President of Anthar, and his Ambassador—were qualitatively consistent with the mapping responses generated for these items by human subjects. For the simulation of the consistent condition,

the preferred mapping of Anthar was Grandus (activation = .77, where the maximum value is 1), with Minutus a weak second choice (.36). The President clearly mapped to the King of Grandus (.95), and the President's Ambassador mapped to the King's Minister (.82), with all alternative mappings attaining activations less than .20. For each of these three target elements, the clear majority of our subjects selected the mapping that ACME preferred most strongly.

The simulation of the crossed condition yielded one major difference from the simulation of the consistent condition: In the crossed condition, Anthar mapped to Grandus and Minutus with almost equal activations (.59 and .57, respectively). Similarly, for subjects in the crossed condition Grandus was the most frequent choice, with the match for Anthar and Minutus a close second. However, whereas ACME produced a one-to-two mapping for Anthar, subjects almost invariably generated only one of the two plausible matches. This discrepancy between the simulation results and subjects' mappings suggests that different subjects may have selectively focused on different aspects of the analogs, rather than giving equal weight to all information, as was assumed for the simulations.

In the simulation of the crossed condition, as in the simulation of the consistent condition, ACME preferred to map the President of Anthar to the benevolent King (now of Minutus), with an activation of .92. Similarly, the great majority of our subjects also mapped the President to the King in the crossed condition. Finally, ACME, again like most of our subjects, mapped the President's Ambassador to the diplomat appointed by the leader to whom the President mapped—that is, to the King's Consul (.82).

To summarize the major results of the simulations, ACME, like our subjects, had a tendency to support the crossed mapping (President to King and Anthar to Grandus) in the crossed condition. In both conditions, the preferred mapping for the President's Ambassador was controlled by the mapping selected for the President.

## General Discussion

### *Summary and Implications*

The data obtained in the present study provide clear evidence that people have a strong tendency to generate mappings that honor certain basic coherence constraints. For our (fairly naive) subject population in Experiments 1 and 2, the analogy between the Persian Gulf War and World War II tends to be bi-stable, a sort of "analogical Necker cube" (Rumelhart et al., 1986). If Saddam is Hitler, then George Bush may be Churchill, in which case the US-'91 is Britain; but Bush may instead be Roosevelt, in which case the US-'91 is the US-WW2. Mixed mappings (i.e., Bush to Churchill, but the US-'91 to US-WW2; or Bush to FDR, but the US-'91 to Britain) proved very difficult to elicit from subjects, even when in Experiment 2 they were given biased histories of World War II that created pressures toward such mappings. However, using science-fiction materials, we were able to show in Experiment 3 that given sufficient opposing pressures, a significant number of subjects can be induced to map a leader and his country separately.

Subjects in all the experiments tended to give one-to-one

mappings, so that, for example, Saudi Arabia was only mapped to Britain if the US-91 was not. In particular, almost all subjects in Experiment 3 generated only one-to-one mappings, even though the instructions explicitly mentioned the possibility of providing more than one match for a person or country. These findings support the conclusion that people's preferences for one-to-one mappings are the product of a central constraint on analogical mapping, rather than of experimental demand characteristics. Nonetheless, one-to-many mappings occasionally were given in Experiments 1 and 2 when a person or country in the target was ambiguous, and no rival target element captured either of the possible source elements (e.g., Kuwait was sometimes mapped to two or three of Austria, Czechoslovakia, and Poland). Such systematic one-to-many mappings provide support for ACME's assumption that the human preference for one-to-one mappings is a pressure rather than a strict requirement.

Naturalistic analogical mapping, with analogs that are complex and far from isomorphic, thus generates systematic patterns of correspondences. These patterns appear to reflect the interactions of multiple constraints that determine analogical coherence. The simulation results obtained in Experiments 2 and 3, using Holyoak and Thagard's (1989) ACME model of analogical mapping, demonstrated that the kinds of mappings produced by subjects could be generated by a mechanism of parallel constraint satisfaction, in which the constraints consist of pressures favoring isomorphic mappings, semantic similarity of corresponding predicates, and pragmatic centrality of presumed correspondences.

Analogical mapping by constraint satisfaction may provide a paradigmatic example of cognitive processes that are central to social cognition. In particular, a model such as ACME instantiates two key elements that have figured prominently in classical theoretical work in social psychology. First, analogical mapping fundamentally involves the extraction of relational roles from sets of specific individuals that fill those roles, a process fundamental to role theory (e.g., Sarbin & Allen, 1968). Second, parallel constraint satisfaction provides a mechanism for establishing cognitive coherence in the face of partially contradictory pressures, a process fundamental to all versions of consistency theory derived from the seminal work of Heider (1946). We briefly examine these theoretical links.

### *Analogical Mapping Between Systems of Social Roles*

An important function of analogy in social cognition may be to provide a mechanism by which people can come to understand a system of social roles when they initially lack appropriate background knowledge. When Iraq's invasion of Kuwait in August 1990 initiated the Persian Gulf crisis, the entire situation was essentially novel, with many discrepant elements that generated considerable uncertainty in most Americans (including policymakers). The average American had previously been only dimly aware that Kuwait existed, was now told that Kuwait was not a democracy but had oil that America needed, knew little about Saddam Hussein, might have heard that Saddam Hussein had been supported by the United States in his previous war with Iran, was now told that Saddam Hussein threatened Saudi Arabia, and so on. Such unsystematic beliefs either

did not support any clear policy decision or provided support for conflicting policies.

A central function of the World War II analogy was to impose coherence on people's understanding of the Gulf situation. A commonsensical mental representation of World War II (at least by a Briton or an American) can be construed as a story figuring an evil villain, Hitler, misguided appeasers such as Neville Chamberlain, and clear-sighted heroes such as Churchill and FDR. By metonymy, we also view nations as people endowed with traits in part derived from their leaders; hence Germany was villainous, and Great Britain and the United States were heroic. The story of World War II includes the victims, such as Austria and Poland; the aggressors, notably Germany and Japan; and the defenders, Britain, the United States, and the other Allies. Each role is defined by a complex web of relationships to other roles. For example, the role of a victim nation, such as Poland, is based on its relative weakness in relation to the aggressor, its pleas for help directed to the defenders, and the defenders' retaliatory actions against the aggressor, motivated in part by desire to aid the victim. We understand many of these relations to be causal in nature; thus, the early appeasement of Hitler by Chamberlain is viewed as having unintentionally encouraged Hitler's subsequent attacks on other countries. The temporal and causal links make the story dynamic. For example, the defender, Britain, suffers early defeats in part because of its lack of adequate preparation for war (due to the misjudgments of appeasers such as Chamberlain), but it hangs on bravely, and with the aid of a strong ally, the United States, is eventually able to turn the tide and defeat the aggressors.

By drawing the analogy between Saddam Hussein and Hitler, President Bush encouraged a reasoning process that led to the construction of a coherent system of roles for the players in the Gulf situation. World War II (or more precisely, the popular story of World War II) provided the source, and the mapping process in effect imposed a set of roles on the target Gulf situation by selectively emphasizing the most salient relational parallels between the two situations. Once the analogous role system was established (in particular, with Iraq identified as an expansionist dictatorship like Germany, Kuwait as its first victim, Saudi Arabia as the next potential victim, and the United States as the main defender), analogical transfer readily yielded the inference that it was right for the United States to intervene militarily.

More generally, analogy may offer a solution to a central problem facing theories of social roles (e.g., Merton, 1957; Sarbin & Allen, 1968): the need to specify a mechanism by which relational roles could be abstracted from the fluid variations in social interactions. Analogical mapping provides a basic cognitive mechanism that may drive the construction and transfer of social understanding based on roles. The mapping process is sufficiently robust that it is possible to identify parallel roles even when the target situation involves unfamiliar actors and when both the source and target involve actors that lack any obvious corresponding element in the other analog. (It seems hard, for example, to map imperial Japan onto any participant in the Gulf War or to map the Palestinians onto some group involved in World War II.) Analogical mapping is able to identify systematic partial correspondences between systems of so-

cial roles even when these are embedded within wider networks of actors and relations that lack such systematic correspondences. Such a mechanism could play a key role in the induction of role systems.

### *Parallel Constraint Satisfaction and Cognitive Coherence*

As Holyoak and Thagard (1989) pointed out, there is a clear affinity between parallel constraint satisfaction, which is the basic processing mechanism embodied in ACME and other similar connectionist-style models, and certain basic intuitions associated with Gestalt psychology. In particular, constraint satisfaction resolves the tension among competing local pressures favoring alternative hypotheses about element correspondences and in the process settles on a global interpretation of the analogical mapping that maximizes coherence. As we noted earlier, similar mechanisms can resolve high-level perceptual ambiguities, such as the alternative interpretations of the bistable Necker cube.

The Gestaltist emphasis on the emergence of cognitive coherence, particularly as articulated by Heider (1946, 1958), has had an enormous influence on theories in social psychology. Numerous consistency theories have been proposed, including Heider's (1946) balance theory, Festinger's (1957) dissonance theory, and Abelson and Rosenberg's (1958) "psycho-logic." Despite their many significant differences, these consistency theories share the basic assumption that social cognition is molded by the dynamic interplay of multiple forces and that the relationships among beliefs, attitudes, and actions create pressures that move the cognitive system toward states of greater internal coherence. As Heider (1946) stated "If no balanced state exists, then forces toward this state will arise. Either the dynamic characters will change, or the unit relations will be changed through action or through cognitive reorganization" (pp. 107–108). Much like the soft constraints embodied in the ACME model, Heider (1958) characterized these forces as preferences or tendencies, rather than as strict requirements.

There are good reasons why consistency theories have been influential in social psychology. Many aspects of social cognition indeed seem to reflect the balance between competing and complementary constraints. For example, as Sarbin and Allen (1968) pointed out, people often play multiple simultaneous roles (e.g., both friend and teacher), and their actions and role expectations commonly involve compromises between the different role requirements. Causal attributions depend on the adjudication between alternative possible causes, as captured by Kelley's (1972) "discounting principle." At the same time, consistency theories have had great difficulty providing well-specified mechanisms that describe when inconsistencies create pressure for change, how such changes are effected, and what kinds of changes serve to restore coherence. Attempts to develop formal models in this area (see Zajonc, 1968, for a review) yielded at most only modest success.

There is reason to hope that recent theoretical developments in cognitive science may stimulate renewed efforts to formulate well-specified models of cognitive coherence in the context of social cognition. Models of parallel constraint satisfaction, such as ACME and other related models (see Holyoak, 1991), provide computational realizations of core Gestaltist ideas concerning

the emergence of coherence. Within this general framework, a consistency theory can be expressed as a set of general constraints embodied as links between hypotheses; the resulting network can then be allowed to settle into a state that optimizes a mathematical measure of "harmony" (Rumelhart et al., 1986; Smolensky, 1986). Thagard's (1989) Explanatory Coherence by Harmony Optimization (ECHO) model uses such principles to describe the process by which people may assess "explanatory coherence": the degree to which interrelated explanatory hypotheses are mutually consistent.

This is not to say, of course, that all the theoretical issues facing consistency theories can be resolved simply by applying constraint-satisfaction models as currently formulated. Rather, additional theoretical work will be required. For example, consider the question of how detection of partial inconsistency may be resolved by conceptual change. In the case of analogical mapping, this issue arises in situations in which ACME settles on a one-to-many mapping, due to pressures that manage to override the constraint of one-to-one mapping. As we saw in the example of Kuwait's mapping to both Poland and Austria, the lingering competition between the two possible correspondences causes the activation of each to be relatively low (see Table 4), which might be taken as a sign of cognitive tension.

A troublesome one-to-many mapping can potentially be eliminated by a conceptual change in the representations of the source or target. In principle, two distinct types of change are possible: One could recode the "many as one" (by categorizing the multiple correspondences as members of a common category) or recode the "one as many" (by differentiating distinct aspects of what was previously a unitized object). The former type of change is appropriate when the dual mapping arises because one object in the target is similar to each of multiple objects in the source in basically the same way. This is the case for the Kuwait example: Kuwait is similar to Poland and Austria in roughly the same way, in that all are countries that fit the role of "victim." In this situation, coherence could be improved by forming a new role category, *victim of Germany in World War II*, of which Poland and Austria (as well as other nations) would be instances. Kuwait could then be mapped uniquely to this unified role category, reducing the tension caused by the competing mappings to individual countries. In fact, several of our subjects spontaneously stated that Kuwait mapped to *countries taken over by Germany* (rather than to one or more specific countries).

In other cases of one-to-many mappings, however, a different type of conceptual change may be triggered. For example, if the direction of mapping were reversed, someone might choose to map Great Britain of World War II to both the US-91 and to Saudi Arabia. Such a dual mapping could arise because Britain-WW2 is similar in different ways to two possible correspondences in the Gulf situation: It was a defender against Germany (just as the US-91 was a defender against Iraq), and it was attacked by Germany with bombs and missiles (just as Saudi Arabia came under missile attack from Iraq). In such a case, it would seem that coherence could be improved by differentiating Britain-WW2 into two conceptual roles: a "defender" role and an "attacked" role, each of which would then yield a one-to-one mapping (to the US-91 and to Saudi Arabia, respectively). Abelson (1959) proposed a similar differentiation mechanism

as one way to restore attitudinal balance (e.g., by reconceptualizing an object that is both liked and disliked as two conceptual entities, one good and one bad).

As these examples illustrate, establishing cognitive coherence may sometimes require not simply a single settling process to find a maximally coherent state, but rather an iterative process involving settling the initial network, revising the network by generation of new conceptual elements and relations, and further settling the revised network. The ACME model, although offering far less than a complete theory of cognitive coherence, may at least suggest some fruitful directions for future theoretical developments in an area that is central to social cognition.

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(Appendix follows on next page)



## Appendix A

## Biased Histories of World War II (Experiment 2)

## Churchill–Britain History

Hitler became Chancellor of Germany in 1933 and immediately began to greatly increase the military power of Germany. In 1938, Hitler annexed Austria without a shot, claiming that Austria was really part of Germany and that the two countries should be united. Later in 1938, Hitler decided to take Czechoslovakia. Chamberlain, the Prime Minister of Great Britain since 1937, persuaded the Czechs to give up some of their country to Hitler in order to avoid war. In 1939, Hitler took over the rest of Czechoslovakia. This angered Britain and France. Fearing what Hitler would do next, they promised to defend Poland if it were attacked by Germany. Hitler attacked Poland on September 1. On September 3, Britain and France declared war on Germany. These countries were not well-prepared for war, and Germany captured Poland and then several other European countries, including France.

In 1940, Churchill became Prime Minister of Britain. He had long opposed giving in to the Germans and had called much earlier for the build-up of Britain's military strength. Churchill inspired the British, telling them that they were fighting for freedom. He pleaded with the United States to send supplies so that Britain could carry on that fight. For the next few years, Churchill was the leader of the Allied forces. During this time his top general, General Montgomery, led the Allies in tank warfare against the Germans in the deserts of North Africa.

During this time, the United States was not involved in the war. When Roosevelt was reelected president in 1940, he had promised not to get involved in a foreign war. Then, in December 1941, the Japanese bombed Pearl Harbor. The United States declared war on Japan and Germany declared war on the United States. The United States then fully mobilized for war. Great Britain, with the help of the United States and other Allies, won the war.

## Churchill–US History

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The German air force began to bomb Britain. (Later in the war, Germany attacked Britain with rockets and missiles.) When Roosevelt was reelected president in 1940, he had promised not to get involved in a foreign war. However, the United States started supplying arms to the Allies. The United States was to be "the great arsenal of democracy,"

and it began to build up its army, navy, and air force. Then, in December 1941, the Japanese bombed Pearl Harbor. The United States then fully mobilized for war. Its mainland was never threatened and it offered great resources to the Allies—ships, planes, and soldiers. At first its ships carried materials and supplies across the ocean. American planes bombarded Germany. Later the ships carried troops. With Churchill's continuing leadership, these resources eventually turned the tide of the war. In June 1944 the Allied troops massed in Britain, then landed on the beach in France on D-day. This attack led to the liberation of many European countries and the eventual defeat of Germany. The United States, with the help of Britain and other Allies, won the war.

## FDR–Britain History

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In the United States, opinions about entering World War II were divided. The "isolationists" wanted to stay out; "interventionists," like President Roosevelt, were convinced that Germany was dangerous and America should enter the war. Roosevelt got the United States involved by supplying arms to the Allies. He called the United States "the great arsenal of democracy" and ordered the build up of its army, navy, and air force. He inspired everyone by saying that both Britain and the United States were fighting for freedom.

During this time, the United States was not actually at war. Then, in December 1941, the Japanese bombed Pearl Harbor. The United States declared war on Japan, and Germany declared war on the United States. The United States then fully mobilized for war. In June 1944 the English and other Allied troops massed for an attack. Unified under the command of General Eisenhower, the top general serving Roosevelt, they landed on the beach in France on D-day. This attack, directed from Britain, led to the liberation of many European countries and the eventual defeat of Germany. Great Britain, with the help of the United States and other Allies, won the war.

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## Appendix B

### ACME Representations (Simulation of Experiment 2)

#### Persian Gulf War Representations

##### *Identification of Countries and Leaders*

(country (Iraq) G1)  
 (country (US) G2)  
 (country (Kuwait) G3)  
 (country (Saudi-Arabia) G4)  
 (country (Britain) G5)  
 (p\_Iraq (Iraq) G6)  
 (p\_US (US) G7)  
 (p\_Kuwait (Kuwait) G8)  
 (p\_Saudi-Arabia (Saudi-Arabia) G9)  
 (p\_Britain (Britain) G10)  
 (person (Saddam) G11)  
 (person (Bush) G12)  
 (person (emir-of-Kuwait) G13)  
 (person (sheik-of-SA) G14)  
 (person (pm-of-Britain) G15)  
 (leader-of (Saddam Iraq) G16)  
 (leader-of (Bush US) G17)  
 (leader-of (emir-of-Kuwait Kuwait) G18)  
 (leader-of (sheik-of-SA Saudi-Arabia) G19)  
 (leader-of (pm-of-Britain Britain) G20)

##### *Relationships Between Countries*

(neighbor-of (Kuwait Iraq) GK\_neighbor-of\_I)  
 (neighbor-of (Saudi-Arabia Iraq) GSA\_neighbor-of\_I)  
 (weaker-than (Kuwait Iraq) GK<I)  
 (weaker-than (Saudi-Arabia Iraq) GSA<I)  
 (weaker-than (Iraq US) GI<US)

##### *Defining the UN Allies*

(allies (UN\_allies) Gallies)  
 (included-in (Britain UN\_allies) GE\_is\_ally)  
 (included-in (US UN\_allies) GUS\_is\_ally)  
 (included-in (Saudi-Arabia UN\_allies) GSA\_is\_ally)  
 (included-in (Kuwait UN\_allies) GK\_is\_ally)

##### *Iraq's Actions Against Kuwait*

(attack (Iraq Kuwait) GI\_attack\_K)  
 (capture (Iraq Kuwait) GI\_capture\_K)  
 (annex (Iraq Kuwait) GI\_annex\_K)  
 (take-first (Iraq Kuwait) GI\_take-first\_K)

##### *Saddam Militarizes Iraq and Orders the Actions Against Kuwait*

(militarize (Saddam Iraq) GS\_militarize\_I)  
 (order (Saddam GI\_attack\_K) GS\_order\_I\_attack\_K)  
 (order (Saddam GI\_annex\_K) GS\_order\_I\_annex\_K)

##### *Militarization and Weakness Enables the Attack and the Capture*

(enable (GI\_attack\_K GI\_capture\_K) Genable1)  
 (enable (GK<I GI\_capture\_K) Genable2)  
 (enable (GS\_militarize\_I GI\_capture\_K) Genable3)  
 (enable (GI\_capture\_K GI\_annex\_K) Genable4)

##### *Consequences of the Capture of Kuwait*

(feared-what-would-do-next (Saudi-Arabia Saddam) GSA\_feared\_S)  
 (feared-what-would-do-next (US Saddam) GUS\_feared\_S)  
 (feared-what-would-do-next (Bush Saddam) GB\_feared\_S)  
 (cause (GI\_capture\_K GSA\_feared\_S) Gcause1)  
 (cause (GI\_capture\_K GUS\_feared\_S) Gcause2)  
 (ask-help (emir-of-Kuwait US) Ge\_ask\_US)  
 (ask-help (sheik-of-SA US) Gs\_ask\_US)  
 (cause (GI\_annex\_K Ge\_ask\_US) Gcause3)  
 (cause (GI\_capture\_K Gs\_ask\_US) Gcause4)

##### *US Attacks Iraq Because of Fear and Pleas for Help*

(attack (US Iraq) GUS\_attack\_I)  
 (cause (GUS\_feared\_S GUS\_attack\_I) Gcause5)  
 (cause (GB\_feared\_S GUS\_attack\_I) Gcause6)  
 (cause (GI\_attack\_K GUS\_attack\_I) Gcause7)  
 (cause (Ge\_ask\_US GUS\_attack\_I) Gcause8)  
 (cause (Gs\_ask\_US GUS\_attack\_I) Gcause9)

*Actions Taken by Bush and the US*

(mobilize (Bush US) GB\_mobilize\_US)  
 (inspire (Bush US) GB\_inspire\_US)  
 (inspire (Bush UN\_allies) GB\_inspire\_UN)  
 (order (Bush GUS\_attack\_I) GB\_order\_US\_attack\_I)  
 (supplies (obj\_supplies) Gsupplies)  
 (provide (US Saudi-Arabia obj\_supplies) GUS\_provide\_supplies)  
 (order (Bush GUS\_provide\_supplies) GB\_order\_US\_provide\_supplies)  
 (cause (GB\_feared\_S GB\_order\_US\_provide\_supplies) Gcause 10)  
 (cause (Gs\_ask\_US GB\_order\_US\_provide\_supplies) Gcause 11)  
 (bomb (US Iraq) GUS\_bomb\_I)  
 (missile (Iraq Saudi-Arabia) GI\_missile\_SA)

*Defining the US and UN Forces*

(forces (US\_forces) GUS\_forces)  
 (forces (UN\_forces) GUN\_forces)  
 (has (US US\_forces) GUS\_has\_forces)  
 (has (UN\_allies UN\_forces) GUN\_has\_forces)  
 (command (Bush US\_forces) GB\_command\_US\_forces)  
 (person (Schwarzkopf) GGNS)  
 (general-of (Schwarzkopf Bush) GGNS\_general-of\_B)  
 (lead (Schwarzkopf US\_forces) GGNS\_lead\_US\_forces)  
 (lead (Schwarzkopf UN\_forces) GGNS\_lead\_UN\_forces)  
 (directs-from (Schwarzkopf Saudi-Arabia UN\_forces) GGNS\_direct\_UN\_forces)  
 (directs-from (Schwarzkopf Saudi-Arabia US\_forces) GGNS\_direct\_US\_forces)  
 (mass-in (UN\_forces Saudi-Arabia) GUN\_forces\_mass-in\_SA)

*Why the US Is Beating Iraq*

(beating (US Iraq) GUS\_beating\_I)  
 (cause (GI<US GUS\_beating\_I) Gbeating1)  
 (cause (GB\_mobilize\_US GUS\_beating\_I) Gbeating2)  
 (cause (GUS\_bomb\_I GUS\_beating\_I) Gbeating3)  
 (cause (GGNS\_lead\_US\_forces GUS\_beating\_I) Gbeating4)  
 (cause (GGNS\_lead\_UN\_forces GUS\_beating\_I) Gbeating5)  
 (cause (GB\_command\_US\_forces GUS\_beating\_I) Gbeating6)  
 (cause (GUN\_forces\_mass-in\_SA GUS\_beating\_I) Gbeating7)

**World War II Representations***Identification of Countries and Leaders*

(country (Germany) W1)  
 (country (US) W2)  
 (country (Britain) W3)  
 (country (France) W4)  
 (country (Austria) W5)  
 (country (Czechoslovakia) W6)  
 (country (Poland) W7)  
 (country (Japan) W8)  
 (p\_Germany (Germany) W9)  
 (p\_US (US) W10)  
 (p\_Britain (Britain) W11)  
 (p\_Czechoslovakia (Czechoslovakia) W12)  
 (p\_Poland (Poland) W13)  
 (p\_France (France) W14)  
 (p\_Austria (Austria) W15)  
 (p\_Japan (Japan) W16)  
 (person (Hitler) W17)  
 (person (FDR) W18)

(person (Chamberlain) W19)  
 (person (Churchill) W20)  
 (person (leader-of-France) W21)  
 (person (leader-of-Czechs) W22)  
 (person (leader-of-Poles) W23)  
 (person (leader-of-Austria) W24)  
 (person (Hirohito) W24a)  
 (leader-of (Hitler Germany) W25)  
 (leader-of (FDR US) W26)  
 (leader-of (Chamberlain Britain) W27)  
 (leader-of (Churchill Britain) W28)  
 (leader-of (leader-of-France France) W29)  
 (leader-of (leader-of-Czechs Czechoslovakia) W30)  
 (leader-of (leader-of-Poles Poland) W31)  
 (leader-of (leader-of-Austria Austria) W32)  
 (leader-of (Hirohito Japan) W33)

*Relationships Between Countries*

(neighbor-of (Austria Germany) WA\_neighbor-of\_G)  
 (neighbor-of (Czechoslovakia Germany) WC\_neighbor-of\_G)  
 (neighbor-of (Poland Germany) WP\_neighbor-of\_G)  
 (neighbor-of (France Germany) WE\_neighbor-of\_G)  
 (weaker-than (Austria Germany) WA<G)  
 (weaker-than (Czechoslovakia Germany) WC<G)  
 (weaker-than (Poland Germany) WP<G)  
 (weaker-than (France Germany) WF<G)

*Defining the Allies and the Axis*

(allies (allies) Wallies)  
 (allies (axis) Waxis)  
 (included-in (France allies) WE\_is\_ally)  
 (included-in (Britain allies) WE\_is\_ally)  
 (included-in (US allies) WUS\_is\_ally)  
 (included-in (Germany axis) WG\_is\_axis)  
 (included-in (Japan axis) WJ\_is\_axis)

*Germany's Actions Against Austria*

(militarize (Hitler Germany) WH\_militarize\_G)  
 (annex (Germany Austria) WG\_annex\_A)  
 (take-first (Germany Austria) WG\_take-first\_A)  
 (enable (WA<G WG\_annex\_A) WenableG/A1)  
 (enable (WH\_militarize\_G WG\_annex\_A) WenableG/A2)  
 (order (Hitler WG\_annex\_A) WH\_order\_G/A)

*Germany's Actions Against Czechoslovakia*

(take-over (Germany Czechoslovakia) WG\_take-over\_C)  
 (enable (WC<G WG\_take-over\_C) WenableG/C1)  
 (enable (WH\_militarize\_G WG\_take-over\_C) WenableG/C2)  
 (order (Hitler WG\_take-over\_C) WH\_order\_G/C)

*Responses to the Actions Against Czechoslovakia*

(feared-what-would-do-next (Britain Hitler) WE\_feared\_H)  
 (feared-what-would-do-next (France Hitler) WF\_feared\_H)  
 (feared-what-would-do-next (leader-of-France Hitler) Wlof\_feared\_H)  
 (cause (WG\_take-over\_C WE\_feared\_H) WcauseEfear)  
 (cause (WG\_take-over\_C WF\_feared\_H) WcauseFfear)  
 (permit (Chamberlain WG\_take-over\_C) WNC\_permit\_G\_take-over\_C)

*Germany's Actions Against Poland*

(attack (Germany Poland) WG\_attack\_P)  
 (order (Hitler WG\_attack\_P) WH\_order\_G/P)  
 (capture (Germany Poland) WG\_capture\_P)  
 (enable (WG\_attack\_P WG\_capture\_P) WenableG/P1)  
 (enable (WP<G WG\_capture\_P) WenableG/P2)  
 (enable (WH\_militarize\_G WG\_capture\_P) WenableG/P3)

*Responses to the Actions Against Poland*

(attack (Britain Germany) WE\_attack\_G)  
 (cause (WG\_attack\_P WE\_attack\_G) WG/PcauseE/G)  
 (cause (WE\_feared\_H WE\_attack\_G) WEfearcauseE/G)  
 (attack (France Germany) WE\_attack\_G)  
 (cause (WG\_attack\_P WE\_attack\_G) WG/PcauseF/G)  
 (cause (WE\_feared\_H WE\_attack\_G) WFfearcauseF/G)

*Germany's Actions Against France*

(attack (Germany France) WG\_attack\_F)  
 (capture (Germany France) WG\_capture\_F)  
 (enable (WH\_militarize\_G WG\_capture\_F) WenableG/F1)  
 (enable (WF<G WG\_capture\_F) WenableG/F2)

*Defining the US, British, and Allied Forces*

(forces (allied\_forces) WA\_forces)  
 (forces (British\_forces) WE\_forces)  
 (forces (US\_forces) WUS\_forces)  
 (has (allies allied\_forces) WA\_has-forces)  
 (has (Britain British\_forces) WE\_has-forces)  
 (has (US US\_forces) WUS\_has-forces)

*Later Facts About the War*

(ask-help (Churchill US) WWC\_ask\_US)  
 (attack (Japan US) WJ\_attack\_US)  
 (attack (US Japan) WUS\_attack\_J)  
 (cause (WJ\_attack\_US WUS\_attack\_J) WJ/UScauseUS/J)  
 (declare-war-on (Germany US) WG\_declare-war-on\_US)  
 (attack (US Germany) WUS\_attack\_G)  
 (cause (WG\_declare-war-on\_US WUS\_attack\_G) WG/UScauseUS/G)  
 (mobilize (FDR US) WFDR\_mobilize\_US)

*Churchill—the Following Are Used in Both Histories That Attempt to Map Bush to Churchill*

(feared-what-would-do-next (Churchill Hitler) WWC\_feared\_H)  
 (inspire (Churchill Britain) WWC\_inspire\_E)  
 (militarize (Churchill Britain) WWC\_militarize\_E)  
 (mobilize (Churchill Britain) WWC\_mobilize\_E)  
 (command (Churchill British\_forces) WWC\_command\_E\_forces)  
 (command (Churchill allied\_forces) WWC\_command\_A\_forces)  
 (person (Montgomery) WMonty)  
 (general-of (Montgomery Churchill) WMonty\_general-of\_WC)  
 (lead (Montgomery British\_forces) WMonty\_lead\_E\_forces)  
 (lead (Montgomery allied\_forces) WMonty\_lead\_A\_forces)

*CHURCHILL/BRITAIN—the Following Are Used Only in the History That Attempts to Map Bush to Churchill and the US-91 to Britain. Reasons Why Britain Conquered Germany*

(conquer (Britain Germany) WE/G)  
 (cause (WWC\_inspire\_E WE/G) WWCEcause1)

(cause (WWC\_militarize\_E WE/G) WWCEcause2)  
 (cause (WWC\_mobilize\_E WE/G) WWCEcause3)  
 (cause (WMonty\_lead\_E\_forces WE/G) WWCEcause4)  
 (cause (WMonty\_lead\_A\_forces WE/G) WWCEcause5)  
 (cause (WWC\_command\_E\_forces WE/G) WWCEcause6)  
 (cause (WWC\_command\_A\_forces WE/G) WWCEcause7)

*CHURCHILL/US—the Following Are Used Only in the History That Attempts to Map Bush to Churchill and the US-91 to US-WW2. Additional Facts*

(bomb (Germany Britain) WG\_bomb\_E)  
 (missile (Germany Britain) WG\_missile\_E)  
 (militarize (FDR US) WFDR\_militarize\_US)  
 (bomb (US Germany) WUS\_bomb\_G)  
 (supplies (obj\_supplies) Wsupplies)  
 (provide (US Britain obj\_supplies) WUS\_provide\_supplies)  
 (cause (WWC\_ask\_US WUS\_provide\_supplies) WWCcausesupplies)  
 (mass-in (allied\_forces Britain) WA\_forces\_mass-in\_E)

*CHURCHILL/US—the Following Are Used Only in the History That Attempts to Map Bush to Churchill and the US-91 to US-WW2. Reasons Why the US Conquered Germany*

(conquer (US Germany) WUS/G)  
 (cause (WWC\_inspire\_E WUS/G) WWCUScause1)  
 (cause (WWC\_militarize\_E WUS/G) WWCUScause2)  
 (cause (WWC\_mobilize\_E WUS/G) WWCUScause3)  
 (cause (WWC\_ask\_US WUS/G) WWCUScause4)  
 (cause (WWC\_command\_E\_forces WUS/G) WWCUScause5)  
 (cause (WWC\_command\_A\_forces WUS/G) WWCUScause6)  
 (cause (WMonty\_lead\_E\_forces WUS/G) WWCUScause7)  
 (cause (WMonty\_lead\_A\_forces WUS/G) WWCUScause8)  
 (cause (WFDR\_militarize\_US WUS/G) WWCUScause9)  
 (cause (WFDR\_mobilize\_US WUS/G) WWCUScause10)  
 (cause (WUS\_bomb\_G WUS/G) WWCUScause11)  
 (cause (WUS\_provide\_supplies WUS/G) WWCUScause12)  
 (cause (WA\_forces\_mass-in\_E WUS/G) WWCUScause13)

*FDR—the Following Are Used in Both Histories That Attempt to Map Bush to FDR*

(feared-what-would-do-next (Roosevelt Hitler) WFDR\_feared\_H)  
 (supplies (obj\_supplies) Wsupplies)  
 (provide (US Britain obj\_supplies) WUS\_provide\_supplies)  
 (order (FDR WUS\_provide\_supplies) WFDR\_order\_supplies)  
 (cause (WFDR\_feared\_H WFDR\_order\_supplies) WFDRfearcause\_order\_supplies)  
 (militarize (FDR US) WFDR\_militarize\_US)  
 (cause (WFDR\_feared\_H WFDR\_militarize\_US) WFDRfearcause\_militarize)  
 (inspire (FDR US) WFDR\_inspire\_US)  
 (inspire (FDR allies) WFDR\_inspire\_A)  
 (person (Eisenhower) WDDE)  
 (general-of (Eisenhower FDR) WDDE\_general-of\_FDR)  
 (lead (Eisenhower US\_forces) WDDE\_lead\_US\_forces)  
 (lead (Eisenhower allied\_forces) WDDE\_lead\_A\_forces)

*FDR-Britain—the Following Are Used Only in the History That Attempts to Map Bush to FDR and the US-91 to Britain. Additional Facts*

(directs-from (Eisenhower Britain US\_forces) WDDE\_directs\_US\_forces)

(directs-from (Eisenhower Britain allied\_forces) WDDE\_directs\_A\_forces)  
 (mobilize (Churchill Britain) WWC\_mobilize\_E)  
 (militarize (Churchill Britain) WWC\_militarize\_E)

*FDR-Britain—the Following Are Used Only in the History That Attempts to Map Bush to FDR and the US-91 to Britain. Reasons Why Britain Conquered Germany*

(conquer (Britain Germany) WE/G)  
 (cause (WFDR\_inspire\_A WE/G) WFDRUScause1)  
 (cause (WFDR\_militarize\_US WE/G) WFDRUScause2)  
 (cause (WFDR\_mobilize\_US WE/G) WFDRUScause3)  
 (cause (WFDR\_order\_supplies WE/G) WFDRUScause4)  
 (cause (WDDE\_lead\_A\_forces WE/G) WFDRUScause5)  
 (cause (WWC\_militarize\_E WE/G) WFDRUScause6)  
 (cause (WWC\_mobilize\_E WE/G) WFDRUScause7)

*FDR-US—the Following Are Used Only in the History That Attempts to Map Bush to FDR and the US-91 to the US-WW2. Additional Facts*

(bomb (Germany Britain) WG\_bomb\_E)  
 (missile (Germany Britain) WG\_missile\_E)  
 (bomb (US Germany) WUS\_bomb\_G)  
 (mass-in (US\_forces Britain) WUS\_forces\_mass-in\_E)  
 (mass-in (allied\_forces Britain) WA\_forces\_mass-in\_E)

*FDR/US—the Following Are Used Only in the History That Attempts to Map Bush to FDR and the US-91 to the US-WW2. Reasons Why the US Conquered Germany*

(conquer (US Germany) WUS/G)  
 (cause (WFDR\_inspire\_US WUS/G) WFDRUScause1)

(cause (WFDR\_inspire\_A WUS/G) WFDRUScause2)  
 (cause (WFDR\_militarize\_US WUS/G) WFDRUScause3)  
 (cause (WFDR\_mobilize\_US WUS/G) WFDRUScause4)  
 (cause (WFDR\_order\_supplies WUS/G) WFDRUScause5)  
 (cause (WDDE\_lead\_A\_forces WUS/G) WFDRUScause6)  
 (cause (WDDE\_lead\_US\_forces WUS/G) WFDRUScause7)  
 (cause (WUS\_bomb\_G WUS/G) WFDRUScause8)  
 (cause (WUS\_provide\_supplies WUS/G) WFDRUScause9)  
 (cause (WA\_forces\_mass-in\_E WUS/G) WFDRUScause10)

*The Following Pairs of Nonidentical Predicates Were Marked as Similar in Meaning*

(annex beating)  
 (annex capture)  
 (annex conquer)  
 (annex take-over)  
 (beating capture)  
 (beating conquer)  
 (beating take-over)  
 (capture conquer)  
 (capture take-over)  
 (conquer take-over)  
 (bomb missile)  
 (command lead)  
 (mobilize militarize)  
 (order cause)

*The Following Correspondence Was Marked as Presumed*

(Saddam Hitler)

## Appendix C

### Stories Used in Experiment 3

#### Antares II: Anthar (All Conditions)

On Antares II we sent a landing party to the country Anthar, and we met with its recently elected President.

Anthar is the biggest and most prosperous country on Antares II. It is located in the hemisphere of the planet that is always tilted toward the sun, so it has an endless growing season. The land is fertile and underutilized. Although not technologically sophisticated, Anthar has flourishing artistic and literary culture. Their doctors have made many medical breakthroughs and are more knowledgeable than us about the treatment of some diseases.

The President wants to develop more advanced communication systems across the entire country and planet. There is at least one other country on Antares II, located on the winter hemisphere of the planet. The President has arranged for exports of food to this “winter country” when the weather conditions are particularly severe. Sometimes the people of the winter country send back various flowers that grow only in glaciers and are used in certain medicines. Both the President and his wife were quite gracious to us during our visit. He expressed a desire to have increased contact with emissaries from other planets and nominated a special Ambassador to ensure that this contact continues.

#### Zenoba III: Grandus (Consistent Condition)

Grandus is a large country on the major continent of Zenoba III. It is ruled by a new King.

Grandus is the most industrialized country on Zenoba III. It is rich in natural resources, especially fossil fuels. Grandus has an excellent communication system. Practically everyone has all of the latest technological devices—some of which are more advanced than our own. There are, however, occasional food shortages.

The new King is trying to raise the standard of living in his country. In particular he would like to improve farming techniques. He would also like to develop the culture of Grandus—to bring music and theater to all of the people. There is a tropical island country on Zenoba III on which grows an abundance of mango-like fruits. The King is trying to open trade with the tropical island country. After the last tropical hurricane he sent down some communications experts; he hopes eventually to get some of their mango-like fruit in return. The King was hospitable to our visit; he would like to maintain future relations and has appointed a Minister of Extra-Planetary Affairs to talk with us and explore the possibilities.

### Zenoba III: Minutus (Consistent Condition)

We met some of the people of Minutus, a small country on Zenoba III's major continent, and the Dictator, who took over during a coup many years ago.

Minutus is a small poor country located across a wide desert from Grandus. Minutus does not have very good farmland; the people subsist mostly on a few kinds of hardy starchy vegetables, similar to potatoes and turnips, that can grow in the poor soil. Minutus has practically no natural resources. The people are mostly illiterate and have a short lifespan relative to their Grandus neighbors.

The Dictator blames the problems of his country on a subversive group of radicals. He seized control of the media, and all reports released to the public must be cleared through him. He is generally hostile to other countries. For example, during food shortages in Minutus, the Dictator has sent raiders to the tropical island country and stolen much of their stores. We were told that the majority of these supplies went to feed the Dictator, his political allies, and his elite military guard. The Dictator was clearly disturbed and threatened by our visit. He designated a Consul for Open Exchange to carry on further discussions with us.

### Zenoba III: Grandus (Crossed Condition)

Grandus is a large country on the major continent of Zenoba III. It is ruled by a Dictator, who took over during a coup many years ago.

Grandus is the most industrialized country on Zenoba III. It is rich in natural resources, especially fossil fuels. Grandus has an excellent communication system. Practically everyone has all of the latest technological devices—some of which are more advanced than our own. There are, however, occasional food shortages.

The Dictator blames the problems of his country on a subversive group of radicals. He seized control of the media, and all reports re-

leased to the public must be cleared through him. He is generally hostile to other countries. For example, there is a tropical island country on Zenoba III on which grows an abundance of mango-like fruits. During food shortages in Grandus, the Dictator has sent raiders to the tropical island country and stolen much of their stores. We were told that the majority of these supplies went to feed the Dictator, his political allies, and his elite military guard. The Dictator was clearly disturbed and threatened by our visit. He designated a Minister of Extra-Planetary Affairs to carry on further discussions with us.

### Zenoba III: Minutus (Crossed Condition)

We met some of the people of Minutus, a small country on Zenoba III's major continent, and we were introduced to their new King.

Minutus is a small poor country located across a wide desert from Grandus. Minutus does not have very good farmland; the people subsist mostly on a few kinds of hardy starchy vegetables, similar to potatoes and turnips, that can grow in the poor soil. Minutus has practically no natural resources. The people are mostly illiterate and have a short lifespan relative to their Grandus neighbors.

The new King is trying to raise the standard of living in his country. In particular he would like to improve farming techniques. He would also like to develop the culture of Minutus—to bring music and theater to all of the people. The King is trying to open trade with the tropical island country on Zenoba III. After the last tropical hurricane he sent down some vegetables; he hopes eventually to get some of their mango-like fruit in return. The King was hospitable to our visit; he would like to maintain future relations and has appointed a Consul for Open Exchange to talk with us and explore the possibilities.

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