Semantic Networks and Shared Understanding: A Network-Based Approach to Representing and Visualizing Shared Understanding

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***Abstract*—Semantic networks were developed in the organizational communication literature to provide a means of representing the shared interpretations that people have of organizational message content. Semantic networks can also be used, we suggest, to support the representation and visualization of shared understanding in military coalition contexts. The basic approach is to create a network representing the degree of similarity between individuals with respect to their understanding of some item of interest. In principle, the data for such networks could be obtained in a variety of ways, although, in the current paper, we focus on the use of 'cultural models' (developed at either the individual or group level) to provide a measure of shared understanding. The use of a semantic network based approach to representing and visualizing shared understanding has a number of advantages, each of which are discussed at length in the current paper. These include the use of network techniques to analyse changes in shared understanding across time (particularly in response to organizational and technological changes) and the easy identification of individuals that may play special roles in supporting cross-community understanding. Furthermore, by combining semantic networks with techniques such as cultural network analysis (which can be used to develop individual- or group-level mental models) we can create semantic network models of shared understanding at either the individual or collective level. In the latter case, the technique affords a means of representing and visualizing the degree of shared understanding between specific cultural groups, and it is therefore ideally suited to military coalition environments, which feature the requisite inter-operation of culturally- and linguistically-disparate communities.**

I. Introduction

Military operations increasingly rely on multi-national coalitions, which bring together individuals from linguistically- and culturally-diverse communities. One recent operation in Afghanistan, for example, involved forces from multiple nations, including Canada, Denmark, Estonia, France, the United Kingdom, the United States and Afghanistan[1]. The ability to operate effectively in such multi-national coalitions requires the resolution of a number of challenges. One challenge relates to the inter-operability of military networks and systems [16], with different nation states relying on different technical infrastructures, information exchange solutions and communication protocols. Another challenge relates to the linguistic and cultural diversity of military coalitions. Here, linguistic differences can contribute to miscommunication and misunderstanding between coalition members [10, 11], and cultural differences in beliefs, attitudes and values may result in disagreements about the most appropriate or acceptable course of action. As highlighted by a recent UK Ministry of Defence report:

> "...[the] technical and cultural disparities within coalition [forces] may well prevent the entire force acting as an integrated, networked whole and limit the extent to which certain elements can inter-operate with others. Insufficient knowledge of the socio-cultural, political or economic environments could make the task of identifying the required effects equally difficult." [9, pg. 3-5]

Overcoming the challenges faced by military coalitions is of major importance. Both the UK and US recognize the importance of trans-national coalitions as the basis for future military operations, and, in light of this, getting to grips with the challenges faced by military coalitions is an important topic for both current and future research.

One of the challenges faced by military coalitions concerns the issue of 'shared understanding'. Establishing precisely what this term means has proved somewhat problematic [17, 18]; however, the term seems to be most commonly used to refer to the ability of coalition forces to work together and coordinate their actions in the service of some common or shared goal. As Smart et al [17] comment:

> "...the notion of shared understanding is typically seen as an enabling factor for what is called 'unity of effort'. This is the notion that coalition force elements, perhaps from different command structures, are able to coordinate their efforts in order to realize common mission objectives."

[1]See http://en.wikipedia.org/wiki/Operation_Moshtarak.

In fact, shared understanding may provide a number of benefits to military coalitions [see 17, 18], and this surely justifies its status as the target of ongoing research efforts[2]. In undertaking scientific research on shared understanding, researchers need analytic and presentational techniques that support their understanding of the various factors that influence shared understanding. In the current paper, we attempt to identify such techniques. We present an approach to representing and visualizing shared understanding (either at the individual or collective level) that is grounded in the use of network-based representational solutions. The approach is based on the use of a particular kind of network that has proved useful in the organizational communication literature for representing the shared interpretations that individuals have of organizational message content (see Section II). By adapting this technique to support the representation of inter-individual differences in understanding, we are (we suggest) able to deliver a number of analytic and presentational benefits, including the ability to monitor the development of shared understanding across time, particularly in response to specific technological and organizational changes (see Section III). The current paper also discusses a number of approaches to the measurement of shared understanding (see Section IV). One approach that we examine concerns the use of cultural network analysis techniques to develop mental models at either the individual or group level [14, 15]. We suggest that the structural isomorphism of such models could serve as the basis for creating network-based representations of shared understanding, although we also identify a number of potential difficulties concerning the use of this approach (see Section IV-C). Together, the proposals presented here provide a candidate set of techniques that can be used to support the measurement, monitoring and (ultimately) manipulation of shared understanding in military coalitions. We suggest that the use of such techniques will provide a number of benefits to our understanding of how shared understanding contributes to performance outcomes during the course of coalition operations (see Section V).

II. Semantic Networks

In order to explore the shared interpretations that people have of organizational message content (particularly those messages that highlight important elements of an organization's cultures, such as corporate goals, slogans, myths and stories), Monge and Eisenberg [8] developed a technique that relies on the network-based articulation of individual differences (and similarities) in the interpretation of message content. The basic approach adopted by Monge and Eisenberg [8] was to measure peoples' interpretations of message content, and then create a network of weighted links, with each node in the network representing a specific individual and each link representing the extent of agreement between individuals. The resulting network is referred to as a 'semantic network', a term that unfortunately conflicts with the notion of a semantic network in the artificial intelligence and cognitive science communities. In the organizational communication literature, the notion of a semantic network refers to the similarity of individuals' interpretations of particular things, e.g. messages, events or artefacts, whereas in the artificial intelligence and cognitive science literature the notion of a semantic network most commonly refers to a network representing the semantic relations between a number of concepts. The use of the term 'semantic network' in the current paper is intended to reflect the former usage of the term; i.e. a semantic network refers to a network representation of inter-individual similarities (or differences).

It should be clear from the foregoing discussion that the notion of a semantic network is quite straightforward. Given a set of scores reflecting peoples' response to something, we can construct a network of linkages that reflects the extent of inter-individual similarity between those scores. Although this idea is very simple, it helps to have a concrete example demonstrating the process of semantic network construction. The example presented here preserves the original use of semantic networks to represent shared interpretations, but it assumes that the interpretations in question apply to the content of coalition plans rather than specific organizational messages. Thus, whereas semantic networks were originally used to represent shared interpretations of organizational message content, we wish to show how they can also be used to support the interpretations of a specific military artefact, namely a coalition plan.

Imagine that a coalition plan has been developed and we want to develop a semantic network to support the analysis of people's interpretations of the plan. We can start by asking military personnel to rate the plan with regard to particular criteria. For example, we could ask them to rate the plan with regard to its perceived quality, its ability to support flexible action, the extent to which it restricts the autonomy of subordinate commanders, and so on. Once we have obtained the scores for each individual with respect to these criteria, we can then calculate the dissimilarity of ratings for any two individuals (Sij) by using the following equation:

$$S_{ij} = |(C1_i - C1_j)| + |(C2_i - C2_j)| + ... \tag{1}$$

where C_i represents the rating of individual *i* with respect to a particular criteria.

This measure of dissimilarity in shared interpretations can, of course, be converted to a measure of similarity (S'_{ij}) using the following equation:

$$S'_{ij} = S_{ij}max - S_{ij} \tag{2}$$

where $S_{ij}max$ is the maximum possible difference between individuals *i* and *j* (as determined by the range of values used for the various criteria).

[2]For example, major coalition-oriented research programmes, such as the International Technology Alliance (ITA), have identified shared understanding as a hard problem for future coalition operations, and considerable research effort is now being invested into developing techniques and technologies to support improvements in shared understanding.

TABLE I
MATRIX OF SIMILARITY SCORES REFLECTING SIMILARITY OF INTERPRETATIONS BETWEEN INDIVIDUALS P1-P10.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
P1	-	0.4	0.3	1.5	0.2	0.2	0.1	0.2	0.2	0.1
P2		-	1	1.3	0.9	0.3	0.1	0.4	0.1	0.3
P3			-	0.8	0.6	0.4	0.4	0.3	0.4	0.2
P4				-	1.5	0.3	0.5	0.1	0.3	0.3
P5					-	0.4	0.4	0.4	0.2	0.4
P6						-	0.3	0.4	0.1	0.4
P7							-	0.7	0.7	0.7
P8								-	1.3	0.6
P9									-	1.4
P10										-

The application of the above equations will give us a matrix of pairwise similarity scores (S'_{ij}) between all individuals in the target population. An example of such a matrix using contrived data from 10 individuals (P1-P10) is presented in Table I. It should now be clear that we can use these similarity scores to create a network of weighted links between all the individuals in the population. In most cases, the structural topology of this network will be fully connected; i.e. all individuals will be connected to all other individuals in the network. However, we can refine the structure of the network by applying a threshold to the similarity scores. Thus suppose we apply a threshold of 0.5 to the scores in Table I (any value below 0.5 is automatically set to zero and the corresponding linkage therefore drops out of the network). Now we can construct a network consisting only of those similarity scores that exceed the threshold value. The result of this manipulation is depicted in Fig. 1.

The network representation of the similarity scores (see Fig. 1) reveals a number of important facts about the distribution of interpretations in the target population. For a start, we can see from Fig. 1 that there are two distinct clusters of individuals. These clusters (or cliques) represent two sub-groups that are differentiated with respect to their interpretation of the coalition plan. Within each sub-group, individuals share similar interpretations of the plan, but these interpretations are different from those of individuals belonging to the other sub-group. We can also see that one individual (node C) is an isolate. This individual has an interpretation that differs from all other members of the focal population. Another feature of the network representation is its ability to highlight nodes of particular interest. Thus, we can see that nodes A and B are *bridging* or *liaison* nodes. They provide weak links between one sub-group and the other sub-group. Such nodes may have particular significance when it comes to understanding the contribution of particular individuals to coordinating interpretations between different sub-groups. Other features of the network representation include the following:

- the overall connectivity of the network highlights the degree or extent of commonality in the interpretations of the entire population
- the number of links associated with a specific individual indicates that that individual has interpretations in common with lots of other individuals
- a disconnected component (disconnected subset of nodes) indicates a group of members who lack any commonality with the wider population
- an individual who has high degree centrality in the semantic network is one who shares interpretations in common with many other individuals

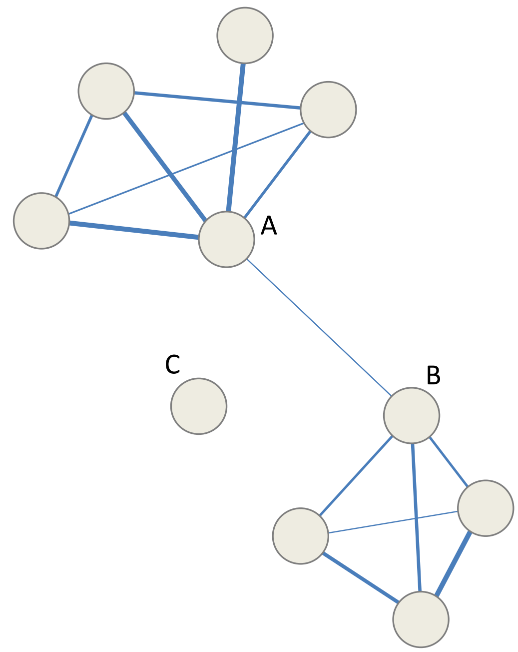

Fig. 1. Semantic network of the similarity scores in Table I following the application of a threshold criterion (any link with a weighting value below 0.5 is eliminated from the network).

These, then, are just some of the features that emerge from an analysis of individuals' responses to a specific artefact (i.e. a coalition plan). Differences in the way individuals interpret the plan might be expected to impact a coalition's ability to work together in order to achieve common mission objectives. In particular, we might expect differences in the interpretation of coalition plan content to result in the kind of problems that are typically attributed to breakdowns in shared understanding (e.g. breakdowns in 'unit of effort'). This should not come as a surprise, for the distinction between the notions of shared interpretation and shared understanding is not necessarily clear-cut[3]. In the next section, we move away from a discussion of shared interpretations and talk explicitly about the use of semantic networks to support the visualization and representation of shared understanding.

[3]Monge and Contractor [7], for example, suggest that a semantic network "provides a picture of the groups of people who share common *understandings*" (pg. 187) [emphasis added].

III. Using Semantic Networks to Represent Shared Understanding

As mentioned in the introduction, it has proved somewhat difficult to define what is meant by the term 'shared understanding' [see 17]. Many attempts to provide universally-accepted definitions of shared understanding (and understanding) have run into problems, with at least one commentator resigned to the rather dismal conclusion "that to understand understanding is a task to be attempted and not to be achieved today, or even tomorrow" [23, pg. 20]. Clearly, such definitional difficulties do not augur well for our ability to measure shared understanding in the context of empirical studies. For the time being, however, let us leave measurement issues to a later section (see Section IV-B) and focus instead on the potential use of semantic networks to represent and visualize shared understanding.

One thing that should be clear from the discussion in Section II is that providing we can obtain a reliable measure of individual understanding, we can easily create a network-based representation of shared understanding. Nothing restricts the application of semantic networks to interpretations of message content, and, providing we can measure understanding, the process of developing a semantic network representation of shared understanding is relatively straightforward – it is, in fact, identical to the process outlined in the previous section. When used to represent shared understanding, semantic networks yield a number of important benefits and opportunities. For example, the network-based representation supports the easy visual identification of particular features, such as those listed in Section II. Thus, semantic networks can reveal individuals whose understanding is similar to those of many others (stars), individuals that serve to link two or more otherwise disconnected groups (liaisons), and individuals whose interpretations are at odds with everyone else's (isolates). The structural profile of a semantic network across time can also reveal important insights as to how shared understanding emerges within a particular community. A sudden transition in network density, for example, indicates discontinuous jumps in the level of shared understanding, while a slow, progressive increase in network connectivity indicates a more gradual form of emergence. Importantly, this ability to monitor dynamic changes in network structure across time has profound implications for the scientific study of shared understanding. Any manipulation that enhances shared understanding within the target population will be reflected in an increase in the overall connectivity of the network, as well as an increase in the strength of connections between particular nodes; a decrease in shared understanding will be reflected in a progressive weakening of the connection strengths and, eventually, a fragmentation of the network into distinct components. As such, the structural analysis (across time) of semantic networks can serve a number of useful purposes. It can highlight important changes or fluctuations in shared understanding (as when a previously highly connected network component, reflecting high levels of shared understanding, begins to fragment into smaller constituents). It can also (potentially) shed light on the ways in which shared understanding develops within a community across time. For example, if we note that a semantic network (representing inter-individual commonalities in understanding) begins to grow according to a particular law (say the law of preferential attachment), then we can hypothesize that the understanding achieved by certain individuals (those to which others preferentially attach) may represent a form of understanding through which all individuals must go *en route* to the realization of shared understanding. Semantic networks may also help us understand some of the factors that contribute to changes in shared understanding. For example, we can monitor dynamic changes in the values of particular network-level variables (average path length, inclusivity, density, centralization, etc.), or the variables associated with particular nodes (e.g. degree, centrality, closeness, etc.), in response to certain manipulations or events. Of particular interest, is the fact that we can use semantic networks to assess the effect of other types of networks on dynamic changes in a community's shared understanding. Thus suppose we are interested in how the topology of a communication network impacts the shared understanding of a community. We can begin to assess this by investigating how the features of one network (the communication network) affects the features of another network (the semantic network). This was, in fact, one of the early motivations for the introduction of semantic networks into the organizational communication literature:

> "An early motivation for the study of semantic networks was to disambiguate the relationship between communication and shared understanding. A semantic network perspective challenges the received view that communication does, or even should, lead to shared interpretations and understanding. The focus therefore is on understanding how other relations among individuals may influence a semantic relation, which is a relation of shared interpretations among people" [7, pg. 187]

Thus one might assume that increments in the density of communication networks would lead to greater convergence in understanding and increases in the density in semantic networks, but this may not necessarily be the case, especially once one begins to factor in the psychological processes that regulate understanding at the individual level. To date, very few studies have examined how changes in one type of network influence the dynamic structural profile of semantic networks. In one study, however, Contractor and Grant [4] examined the effect of social contagion in communication and semantic networks using a computer simulation approach. They found that the latency for semantic convergence (i.e. the time required to develop a common interpretation or shared understanding) was positively related to the initial density of the communication and semantic networks, inversely related to the heterogeneity of the communication network, and inversely related to the individual's resistance to social influence. Studies such as this provide an interesting starting point for further simulations that aim to examine the effect of multiple networks (e.g. social networks) on the dynamic profile of shared understanding within a particular population (e.g. military coalitions). Ideally, such simulations should aim to include at least some of the factors that affect an individual's resistance to particular kinds of knowledge and information, for example, the pre-existing level of consistency in an individual's belief network [see 19]. Above all, what should now be clear is that semantic networks do not merely provide a representational format that supports the easy visual identification of particular features associated with a community's understanding, they also pave the way for applications and analyses that benefit from the tools, techniques and concepts made available by the emerging science of networks [see 20]. By developing a network-based articulation of shared understanding, we make it amenable to various forms of network scientific analysis.

IV. Shared Understanding: Meaning, Measurement and Mental Models

A. What is Understanding?

In order to undertake empirical studies of shared understanding it is important to know what is meant by the term. Unfortunately, as pointed out earlier in the paper, there has been little consensus regarding an appropriate definition of understanding, either at the individual or shared level. Føllesdal [5] argues that understanding is a particular form of knowledge, and this is similar to the approach taken by Smart et al [18]. They define understanding as "an ability to exploit bodies of causal knowledge (i.e. knowledge about the antecedents and consequents of particular phenomena) for the purpose of accomplishing cognitive and behavioural goals." In a subsequent paper, Smart et al [17] provide a somewhat different characterization of understanding. They argue, following Wittgenstein [22], that understanding is akin to an ability, and the knowledge of causal (and perhaps other) relationships is the thing that makes the expression of these abilities possible. Understanding is not, therefore, the knowledge of causal contingencies *per se*; it is rather the ability to express the kind of behaviours that warrant the ascription of understanding to an agent[4].

Following on from their characterization of understanding as a kind of ability, Smart et al [17] suggest that shared understanding is apparent whenever two or more individuals have certain abilities in common. The process of assessing shared understanding is thus one of measuring certain kinds of abilities (the kinds of abilities that warrant the ascription of understanding). Thus, two individuals who possess shared understanding will, at least in some cases, establish the same set of (e.g.) explanations and expectations given identical information about the object of understanding (e.g. a specific situation). In a coalition context, for example, we might say that two commanders have the same (i.e. shared) understanding of a situation if they are able to anticipate the same effects of military actions, and they are also able to cite the same reasons as to why particular military actions should be undertaken (e.g. to ensure the efficient realization of particular mission objectives).

[4]Clearly, the possession of certain types of knowledge (e.g. causal knowledge) might be highly relevant to an individual's ability to manifest these behaviours.

B. Measuring Understanding

Smart et al's [17] characterization of shared understanding does not necessarily help pinpoint a specific set of techniques that might be used to measure shared understanding. However, the characterization does at least suggest that shared understanding is the kind of thing that *can* be measured. By casting shared understanding as a kind of shared ability, the process of measuring shared understanding emerges as the measurement of shared abilities. And abilities (shared or otherwise) are clearly the kinds of things that can (in principle) be measured. What seems to be important when it comes to the measurement of shared understanding is to determine the kinds of responses that warrant the ascription of understanding to an individual and then to develop a way of measuring those responses. So, if we want to determine whether two individuals have the same understanding of a specific situation, we may decide that the kind of understanding we are interested in is evidenced by an ability to 1) identify what events led to the current situation, 2) predict how the situation will evolve in the future, and 3) determine the kinds of constraints and opportunities the situation presents for ongoing military actions. Following this characterization, we can devise tests that tap into these abilities. Admittedly, the process of designing and validating these tests is likely to be a difficult undertaking. In all likelihood, the nature of the tests to measure shared understanding will vary according to the measurement context – the kind of thing that is to be understood, the people who do the understanding, and so on. As such, the development of a single all-purpose test for shared understanding is something that is unlikely to be achieved. There may, however, be some value in looking at general approaches to the assessment of understanding. White and Gunstone [21], for example, describe a range of techniques, primarily for use in educational contexts, that could be used to probe understanding. These include the use of concept maps, relational diagrams and word association tests. By adapting these techniques for specific application contexts (e.g. the understanding of coalition plan content), we might obtain indices of understanding that can be used as the starting point for semantic network construction.

C. Cultural Models

There is, we suggest, an alternative approach to the measurement of shared understanding that is worth presenting here. This approach is based on the comparative analysis of models that target an individual's (usually) causal knowledge of some domain. The models in question are called cultural models, and they are intended to support the analysis of cultural differences in target communities. Importantly, the models can be pitched at the level of specific individuals or groups, so their value in terms of measuring shared understanding is

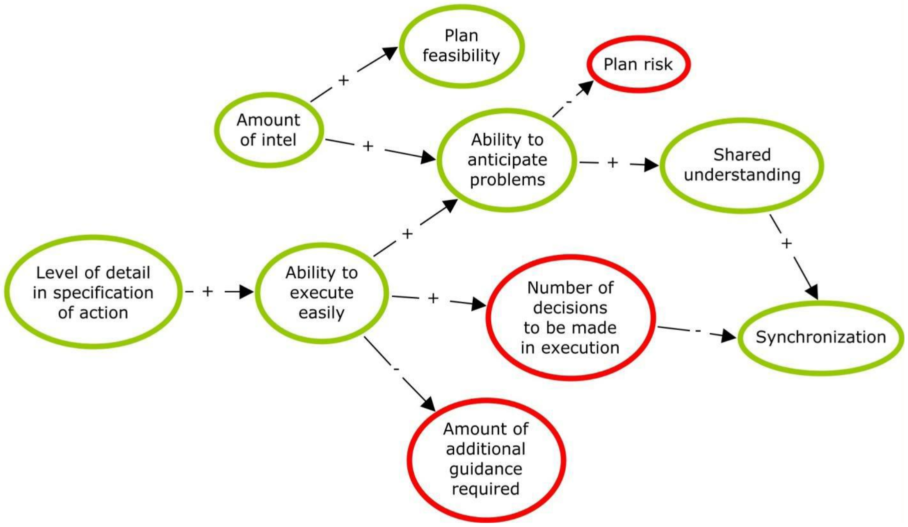

Fig. 2. Cultural model showing the dependencies between concepts in the domain of military coalition planning.

not just that they provide a means to assess inter-individual differences in shared understanding, they can also be used to assess differences in understanding between particular *groups*. This is important when it comes to a consideration of military coalitions. Because military coalitions feature multiple groups of individuals (e.g. from particular nations, military services or ethno-linguistic categories), we will often want to assess shared understanding at the group or collective level. That is, rather than focus on the extent of shared understanding between specific individuals (as we might do in the case of a small team), in a coalition context we often want to assess the extent of shared understanding between specific groups of individuals. This is a feature that is not easily provided by other approaches to measuring shared understanding (e.g. the approaches discussed by White and Gunstone [21]), and, as such, the use of cultural models to measure shared understanding in coalition contexts may have much to commend it.

An example of a cultural model (in this case applied to the domain of military planning) is shown in Fig. 2. The nodes in this diagram represent concepts and properties associated with the domain of planning, and the linkages between the concepts reflect the community's beliefs regarding the relationships and dependencies between the concepts. The links associated with a plus sign reflect a positive association between the concepts (e.g. 'Level of detail in specification of action' has a positive effect on ease of execution (i.e. 'Ability to execute easily')), whereas the links associated with a minus sign reflect negative associations between the concepts (e.g. 'Ability to anticipate problems' has a negative effect on the perceived riskiness of a plan (i.e. 'Plan risk')).

One thing that makes cultural models interesting in terms of understanding is that their content is often targeted towards an individual's or group's knowledge of causal contingencies in a particular domain of discourse. This establishes a natural linkage with previous attempts to provide a definition of understanding. Thus, recall that Smart et al [18] proposed that understanding corresponds to an ability to exploit bodies of causal knowledge. Inasmuch as cultural models can be seen to represent the kind of knowledge that enables an individual to manifest behaviours (e.g. explanation and prediction of system states) that warrant the ascription of understanding to an agent, then they may provide a potential realizing mechanism for at least some forms of understanding[5]. This is significant because it suggests that one way of measuring the similarity of understanding between agents (either individuals or groups) is to assess the structural isomorphism of the cultural models developed for the agents in question. If the models are identical, then the level of shared understanding between the agents concerned will be at its theoretical maximum; if the models bear no resemblance to one another, then shared understanding will be at its minimum. In between these two extremes, we will encounter variable degrees of similarity between the models, and such similarity will be reflected in the strength of the ties between the nodes of a semantic network.

What is required, then, is some way of computing the structural similarity of cultural models. This is where we encounter the first of three problems associated with the use of cultural models to assess shared understanding. The fact is that the technique used to develop cultural models (a

[5]Smart et al [17] propose something similar for the case of conventional mental models. According to Rouse and Morris [12] mental models are the "mechanisms whereby humans are able to generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future system states" (pg. 351). Mental models therefore seem to support the expression of particular abilities, such as those related to the description, explanation or prediction of certain things. As such, when it comes to individual forms of understanding, we may see mental models (like their cultural model counterparts) as contributing to the (partial) mechanistic realization of specific performances that warrant the ascription of understanding to an agent.

technique known as cultural network analysis [14, 15]) does not, at the present time, provide a means of assessing the structural isomorphism of cultural models. This problem might be addressed by turning to the literature on shared mental models [2, 3]. Shared mental models are mental models (see footnote 5) that are possessed by multiple individuals, and they are typically operationalized as the correlation between link-weighted networks using Pathfinder analysis [13]. The adaptation of such techniques for the comparative analysis of cultural models may serve as the basis for deriving future quantitative measures of cultural model similarity.

Two additional problems are associated with the use of cultural models to index shared understanding. Firstly, the process of creating cultural models is somewhat labour-intensive. This means that it might not be suitable for all cases in which shared understanding needs to be assessed. Secondly, it is not always clear that structural differences in cultural models necessarily indicate differences in understanding. The reason for this is twofold: firstly, a cultural model does not equate to understanding and, secondly, differences in cultural models need not result in different abilities. In terms of the former issue, there is a tendency, sometimes encountered in the human factors literature, to equate the notions of understanding and mental models. This equation is misconceived because understanding is akin to an ability [see 17] and abilities cannot be reduced to the things (vehicles) that explain the exercise of the ability. As Baker and Hacker [1] comment: "Science explains powers by discovering underlying structures, but it is a mistake to think that it reduces powers to the structure of their vehicle" (pg. 337).

The second reason why structural differences in cultural models do not necessarily indicate differences in understanding is because of what has, in the shared cognition literature, been referred to as equifinality [6]. This is the idea that two or more individuals may be able to generate the same expectations and explanations despite expressing differences in their respective mental models. This is important because it is typically the expectations and explanations that are deemed to be the main focus of interest from the perspective of team performance. As Cannon-Bowers et al [3] argue: "[the] function or benefit of shared mental models is that they lead to common expectations of the task and team, it is the expectations rather than the mental models themselves that must be shared." Something similar can be seen to be the case for cultural models. Thus, from the perspective of understanding, what counts are the performances that manifest understanding, not the mechanisms that make such performances possible. While similar cultural models may be highly suggestive of similar abilities, particularly when it comes to forming explanations and predictions in the target domain, it need not be the case that such differences will *always* translate to differences in inter-individual understanding.

Despite these caveats, the use of cultural models to index shared understanding may be of value in at least some contexts. Thus, while differences in cultural models need not always indicate a lack of shared understanding, some types of cultural model may be much more suitable than others in terms of revealing such differences. For example, if the content of the cultural model is focused on an individual's causal knowledge of some domain, then it seems likely that differences in the cultural models *will* reveal some differences in the explanatory and predictive abilities of the individuals concerned. Further research clearly needs to be undertaken in order to explore this possibility.

V. Relevance to Military Coalitions

We have already discussed a number of ways in which semantic networks might support the analysis and monitoring of shared understanding, and these benefits are clearly applicable to military coalitions. Thus, the identification of groups of individuals, distinguished on the basis of shared understanding, may yield important insights into how factors like nationality, training, language, attitudes and values contribute to shared understanding (or misunderstanding). Such groups also raise a number of interesting questions regarding the way in which coalition teams should be formed (for example, should the teams be formed based on the identified groups?) and the way in which communication policies are established (should special measures be taken to monitor the communications taking place between the members of different groups, perhaps as a means of dealing with the risk of miscommunication?). Other benefits to military coalitions include the ability to monitor the effectiveness of interventions designed to enhance shared understanding (an effective intervention is thus one that increases the overall connectedness of the network and increases the strength of network linkages); an ability to associate coalition performance outcomes with particular semantic network configurations (for example, do certain types of semantic network topology predict better performance outcomes?); and an ability to undertake network science simulations that reveal the potential effect of changes in social networks and physical infrastructure networks (e.g. MANETS) on the topological organization of semantic networks (see [4] for some initial simulation results in this area).

VI. Conclusion

Shared understanding is commonly seen as essential to the success of coalition operations, and current research efforts are attempting to develop techniques and technologies to improve shared understanding in military coalition contexts. As part of these research efforts, it is important to develop techniques that support the effective analysis, monitoring and visualization of shared understanding in a community of agents. Semantic networks, we suggest, provide one such technique. Although semantic networks were originally developed to support the analysis of shared interpretations of organizational message content, there is no reason why such techniques cannot be applied to the case of shared understanding. Undoubtedly, the most problematic aspect of this approach is the initial derivation of scores that reliably index shared understanding. Providing such difficulties can be overcome, however, the process of constructing a semantic network is relatively straightforward.

There are many advantages to semantic network representations of shared understanding. Specific examples include the use of network techniques to analyse changes in shared understanding across time (particularly in response to organizational and technological changes), the easy identification of individuals that may play special roles in coordinating action and enabling cross-community understanding, and the ability to undertake network science simulations that model how shared understanding is influenced by changes in other types of network (e.g. communication networks). Furthermore, by combining semantic networks with techniques such as cultural network analysis (which can be used to develop group-level mental models) we may be able to create network models of shared understanding at either the individual or collective level. In the latter case, the technique affords a means for representing and visualizing the degree of shared understanding between specific cultural groups, and it is therefore ideally suited to contexts, such as those encountered in the case of military coalitions, where the successful inter-operation of culturally- and linguistically-disparate communities is an operational prerequisite.

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