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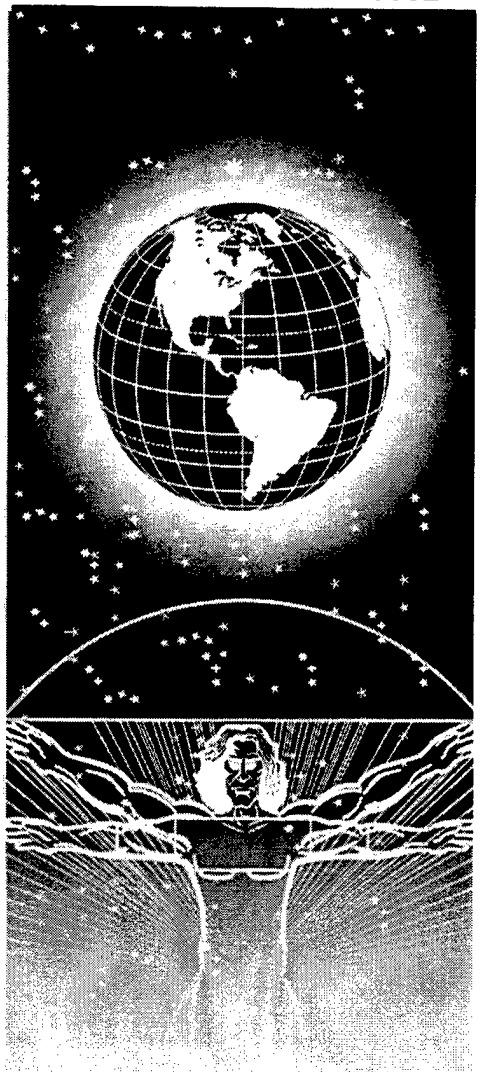

UNITED STATES AIR FORCE RESEARCH LABORATORY

AUGMENTING THE SOCIAL CONSTRUCTION OF KNOWLEDGE AND ARTIFACTS

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Human Effectiveness Directorate
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FOR THE COMMANDER

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Within many domains, complexity encompasses many nuances of ill-definition, fluidity, organizational variation, uncertainty, conflicting constraints, and multiple solutions. Responses to these areas of complexity necessitate the social construction of knowledge among various multi-disciplinary team members. Based on the literature, multi-theoretical foundations for augmenting the social construction of knowledge and artifacts were identified. These foundations include the recasting of such issues as task equivocality and task uncertainty, ecological and constructionist perspectives, and the inter-connectedness of cognition, intelligence, and knowledge (the capacity to act). Group Cognition is offered as the basis of all cognition, and is explained as a combination of Distributed and Coordinated Cognition that directly affects the creation/recreation of distributed and similar knowledge within a team. Based on these foundations, initial guidance is offered for augmenting the social contruction of knowledge and artifacts. It is important to remember that this report must be considered a work-in-progress, a "snapshot" of one exploration of a very complex subject.

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PREFACE

The Collaborative Systems Branch of the Air Force Research Laboratory, Wright-Patterson Air Force Base, Dayton, Ohio, conducted this effort. Logicon Services, Inc. (LTSI), Dayton, Ohio, provided support under contract F41624-94-D-6000.
Mr. Robert Stewart was the LTSI/Project Monitor, and Mr. Donald Monk was the Contract Monitor. Dr. Michael McNeese served as the government technical lead on the project. Under this contract, Mr. John T. Nosek provided support as the sub-contractor to LTSI in completing the project.

REPORT SUMMARY

This paper focusses on a review of literature in support of a multi-theoretical basis for group sensemaking in the social construction of knowledge. This review was conducted to inform the consequent development of information technologies as adaptive support systems for collaboration and highlights potential issues and solutions as related to actor-to-actor and actor-to-agent couplings.

This paper is divided into two major sections. The first section provides the foundations for understanding some of the major topics of exploration that are relevant to the social construction of knowledge, and will introduce new terms and concepts. Therefore, instead of the usual model where the literature review is strictly a summary of previous work, think of these subsections as building blocks that are based on the literature, but in which new terms and concepts will be introduced. There will be overlap in these topics of exploration, however, ignoring this overlap will be useful at times to help focus on the topic. Some of the topics explored include: sensemaking definitions and methods; cognitive engineering in complex dynamic worlds; decision making in messy problems; cognitive biases in information acquisition and processing; the need for teams in perspective making and perspective taking; constructionist and ecological perspectives in cognitive psychology; knowledge and artifact creation; group cognition and group knowledge; and techniques for perspective making and perspective taking. The second major section presents implications for technological support of the social construction of knowledge, including novel approaches that may be investigated to support identification of team divergence and convergence during operational missions.

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1. INTRODUCTION

Within many domains, complexity encompasses many nuances of ill-definition, fluidity, organizational variation, uncertainty, conflicting constraints, and multiple solutions. Responses to these areas of complexity necessitate the social construction of knowledge among various multidisciplinary team members. The process by which interpretation, meaning, decisions, and actions transpire is referred to as *group sensemaking*. This process is especially salient for understanding how to achieve a group-centered approach in the design of multi-person/team interfaces. Many of the current information technologies have not been designed from a group-centered approach, which limit their usefulness.

This paper will focus on a review of literature in support of a multi-theoretical basis for group sensemaking in the social construction of knowledge. This review will be conducted to inform the consequent development of information technologies as adaptive support systems for collaboration and will highlight potential issues and solutions as related to actor-to-actor and actor-to-agent couplings.

Based on the breadth of the topic, this report must be considered a work-in-progress, a snapshot of the exploration of such a complex subject. As a work-in-progress there has been no attempt to eliminate questions or problems that emerge in such an exploration to make the package tidy with no loose ends. To the contrary, we openly identify loose ends, pull them, and encourage readers to pull them, tuck them in, or cut them off if possible.

2. LITERATURE REVIEW/FOUNDATIONS/EXPLORATIONS

The literature review will be presented within major topics of exploration, which will include the introduction of new terms and concepts. Therefore, instead of the usual model where the literature review is strictly a summary of previous work, think of these subsections as building blocks that are based on the literature, but in which new terms and concepts will be introduced. There will be overlap in these topics of exploration, however, ignoring this overlap will be useful at times to help focus on the topic. This section attempts to introduce topics as sequential building blocks to explicate concepts important to the social construction of knowledge. The following section explores implications from this work to better support the social construction of knowledge and artifacts.

2.1 Sensemaking: Definitions and Methods

Sensemaking is "the process whereby people interpret their world to produce the sense that shared meanings exist [Leiter in Gephart, 1993, pp. 1469-1470." Researchers who engage in ethnomethodology, "the science of sensemaking," "view social actors, or members, as actively engaged in sensemaking, interpreting the social world through

conversation and textual accounts, explanations offered and accepted, and ongoing discourses that describe and make sense of the social world. A key assumption of ethnomethodology is that sensemaking occurs and can be studied in the discourses of social members – the intersubjective social world – rather than simply occurring in their minds. Further, the socially constructed objects, or facts, of the world exist through and are located in the discursive sensemaking of members [Gephart, 1993, 1470]."

2.1.1 Sensemaking Practices

From Gephart [1993]:

- *Reciprocity of Perspectives:* Members produce and attempt to sustain a *reciprocity of perspectives* whereby parties to a dialogue assume they could exchange places with each other and experience the same perspective on the world. This is sustained by acknowledging what each other say.
- *Normal Forms:* Expectation and use of recognizable words and terms to describe features of the world.
- *Etcetera Principle:* Sustain vague and incomplete aspects of conversation by assuming (1) others will fill-in or interpret, and/or (2) clarifications will come later in the conversation.
- *Descriptive Vocabularies as Indexical Expressions:* In a conversation, any given feature of conversation or action, such as a single word, may not be inherently sensible, but the speaker assumes that the hearer will use his or her general background knowledge and knowledge of the context of the statement or action to interpret it.

When these practices are disrupted, meaning begins to disintegrate [Garfinkel, Schegloff in Gephart, 1993, p. 1470] and repair practices can be demanded and evoked to restore the sense of shared social order [from Schegloff in Gephart, 1993, p. 1470].

2.1.2 Sensemaking Resources

People use schemes, sensemaking resources, to make sense of features of the world. Table 1 is taken from Gephart [1993].

2.2 Cognitive Engineering in Complex Dynamic Worlds

Much of this section comes from Woods [1988] commentary where he provides an excellent overview of some of the major issues facing cognitive systems engineering. He offers four dimensions that affect design:

- Dynamism
  - Problem solving incidents unfold in time and are event driven, i.e., events can happen at indeterminate times and the nature of the problem to be solved can change.

Table 1: Sensemaking Resources

Resources	Definitions	Examples
The Organization:		
• Model of functional integrity	Statement that shows, references, or constructs needs that must be met for the organization to survive or function well. May assemble seemingly unrelated phenomena and argue or imply these are related to organizational functioning.	Speaker one: "Given the **budget crisis**, what the University of California **needs** are some students from out of state paying high tuition."
• Model of compliance	Statement that mentions or uses features of an organization that demand compliance or action, including but not limited to rules, policies, official goals, hierarchy, authority, and responsibility.	Speaker two: "I can't afford what were **required** to pay!"
• Model of style	A scheme of proper forms and acceptable styles seen to be independent of formal rules	Speaker one: "At least we can **dress however we want**."
Selves:		
• Professional self	Statement that constructs aspects of a person's training, career, and professional characteristics and activities.	"My boss is an excellent leader."
• Social psychological self	Statement that describes a person's traits, motivations, personal styles, and habits.	"Jean is nice but unpredictable."
• Financial self	Statement that constructs a person's economic features, status, and needs	"Sue is very rich."
• Physiological self	Statement that constructs a person as a physical being with physiological characteristics and dispositions.	"John has asthma."

  - Results in cognitive demands associated with anticipation or prediction of the behavior of the world and one's tactical or strategic response.
  - Typical Failures: Failure to revise.

- Number of parts and the Extensiveness of Interconnections between the parts/variables
  - A disturbance could be due to multiple potential causes and have multiple potential fixes.
  - Can be multiple relevant goals which can compete with or constrain each other
  - There can be multiple ongoing tasks at different time spans.
  - The parts of the world can be complex objects in their own right.
  - Typical Errors:

    - Failures to consider side-effects, requirements, post-conditions
    - When simplifying to cope with complexity, mistake one factor related to the state of the world as the single explanation for that state – can delay or prevent identification of the set of factors that actually contribute the observed situation.
- Uncertainty ([Daft & Lengel, 1986]: Variables and interrelationships identified/known but data are unknown)
    - Requires inferential process
    - When high, some data always fit together into a correct assessment due to:
        - Red herrings
        - Sensor failures
        - Human reported data
        - Perceptual judgments
        - Irrelevant factors
        - Multiple failures
        - Typical Failure: over reliance on familiar signs [From Dreyfus & Dreyfus [1986]: acting as an expert inappropriately]
- Risk
    - Consequences/costs of actions

2.3 Decision Making in Messy Problems

From Strategic Planning, which is considered a domain with ill-structured problems, Hitt & Tyler in Schwenk [1995] found strong support for the use of the rational-normative model in strategic planning. This is counter to the prevailing thought that the rational-normative model is less valid than a more politically oriented model. Eisenhardt in Schwenk [1995] found that organizational politics were negatively related to organizational performance. Open conflict and frank discussion should not be considered politics and in a meta-analysis of past research, Schwenk [1995] found that the use of techniques like devil's advocacy and dialectical inquiry improved decision-making performance.

Prahalad and Bettis [in Schwenk, 1995] suggest that strategic decisions are guided by a *dominant management logic*, which is a shared understanding or *shared schema* of the factors relevant to the business's strategy and the relationship between these factors. They suggest that this shared schema sets upper limits on the diversity of technologies or markets in which a firm can participate. Lyles and Schwenk [in Schwenk, 1995, p. 479] suggest that when environmental changes invalidates existing assumptions, the dominant coalition of key decision makers articulate and communicate elements of a new knowledge structure to the rest of the organization.

Molloy and Schwenk in Schwenk [1995] found in a review of eight strategic decisions that the use of information technology increases the speed and quality of problem identification and decision making. They argue that information technology is less likely to be used in crisis decisions than in decisions with less time pressures and that

information technology allows for more complete communication about the strategic problem throughout the organization.

2.4 Biases in Information Acquisition and Processing

This section identifies biases that affect information acquisition and processing.

- Cognitive Simplification/Laziness/Expediency
  - Availability: Use of easily available information. Ignore not easily available, but possibly significant sources [Sage, 1981].
  - Data Saturation: Reaching premature conclusion on the basis of too small a sample of information while ignoring the rest of the data that is received later on, or stopping acquisition of data prematurely [Sage, 1981].

- Cognitive Rationalization
  - Escalating commitment: tendency to increase commitment to a failing course of action [Schwenk, 1995].
  - Recollection bias: limits the ability to learn and adjust – "Executives recall past strategies as being more rational and consistent with current strategies than they really were [Sage, 1981; Schwenk, 1995].
  - Causal attribution: "...executives tend to attribute good outcomes to their own actions and qualities while attributing poor outcomes to external factors such as environmental events and bad luck." Some argue this is a deliberate attempt to manage the perceptions of shareholders [Meindl in Schwenk, 1995], while others attribute this to an attempt of executives to make sense of a changing environment in which they operate [Clapham, Schwenk, Huff and Schwenk in Schwenk, 1995]

- Cognitive Lockup (Related to Conservatism): After continued experiential learning, people develop heuristic models that become almost unchangeable. When anomalies occur they desperately seek ways for the data to fit their models or ignore it [Moray, 1988, Weick, 1979].
  - Base Rate: The likelihood of occurrence of events, based on past events. The likelihood of occurrence of two events is often compared by contrasting the number of times the two events occur and ignoring the rate of occurrence of each event. Often occurs when there is concrete experience with one, causal base rate, and only statistical or abstract information, incidental base rate, with the other. When information is updated, the information associated with the causal base rate is given much more weight than it deserves. Also, it is easier for information to override incidental base rates than causal rates [Sage, 1981].
  - Conservatism: Failure to revise estimates as much as they should be revised, based on receipt of new significant information. Related to data saturation and regression effects biases [Sage, 1981].
  - Status quo: the longer the tenure of an executive, the more likely to keep the status quo and persist in strategies [Schwenk, 1995]. The better past performance, the more likely the persistence in the status quo.

- Adjustment and Anchoring: During times of information overloads, selecting a particular datum, such as the mean, as an initial or starting point, or anchor, then adjusting the value improperly to incorporate additional data [Sage, 1981].

- Data Presentation Context: For example, summarized data may have a much greater impact than data presented in detailed, non-summarized form. Different scales can change the impact of the same data [Sage, 1981]. Data presentation provides contextual cues that affect cognitive processing.

2.5 Expertise, Perspective Making, Perspective Taking and the Need for Teams

In complex environments, where not all variables and relationships are known, humans create rather than discover their future [See Figure 1]. They create the future by accepting stimuli from their environment, including others around them, and interpreting what these stimuli mean. The subsequent actions, including probing of the environment, leads to additional stimuli that must provide meaningful affordances to grab attention, and subsequent processing. A level of expertise must be achieved and maintained for humans to be attuned to relevant affordances, to interpret them, to act based on them, and to probe for additional stimuli. However, as the rate of technological change increases dramatically, the ability to achieve and maintain expertise decreases [See Figure 2].

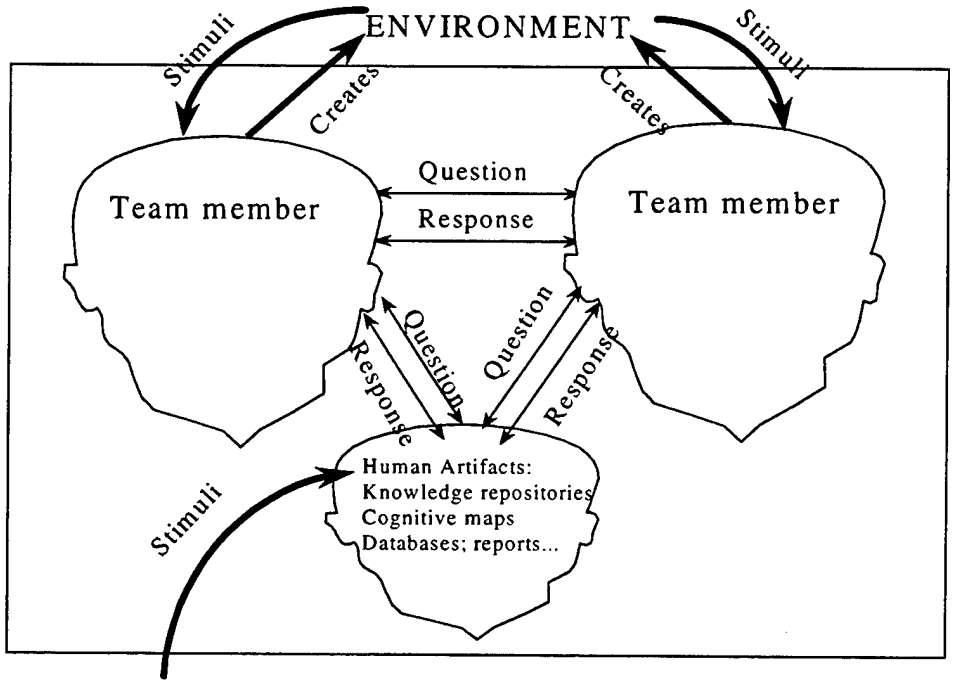

Figure 1

Group Sensemkaing in Ill-defined Situations

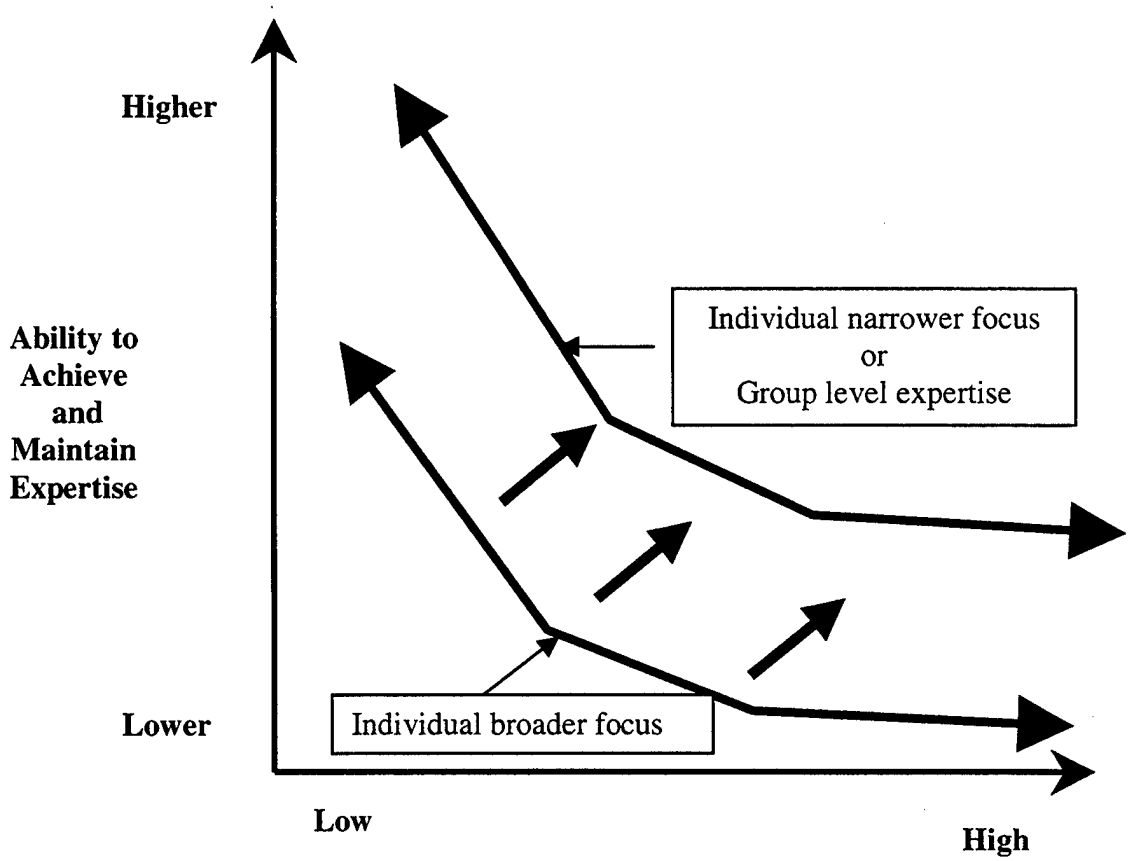

Figure 2

Relationship between Expertise Maintenance and Technological Advancement

Humans both narrow their focus to mitigate the problem of achieving and maintaining expertise and team with others to achieve and maintain a higher group level of expertise, i.e., the joint outcome of the team may represent the actions of a higher level of expertise than individuals may be able to achieve alone [Nosek, 1997]. While there is greater pressure to specialize in order to try to achieve and maintain expertise, at the same time, increasing problem complexity demands multiple-disciplinary/specialization activity. Larger teams of specialists, who possess a more narrow focus of expertise, must come together and take each other's perspective to interpret relevant stimuli and create futures that achieve their goals.

Figure 3 provides a visually dramatic representation of the problem in perspective taking, i.e., a member of one community of knowing must figure out how to take the perspective of the other community of knowing to achieve joint action. While essential, more perspective taking can absorb time and energy from perspective making, communication that strengthens the unique knowledge of a community. If we expand Figure 3 to double or triple the specialists, the increased interconnections would reduce the clear space of the diagram and increase the dark space of the interconnecting lines. Taking liberty with a space metaphor, with the trend towards both specialization and joint action by larger teams of more distinct specialties, how can one prevent perspective taking becoming a "black hole" that sucks in resources and energy.

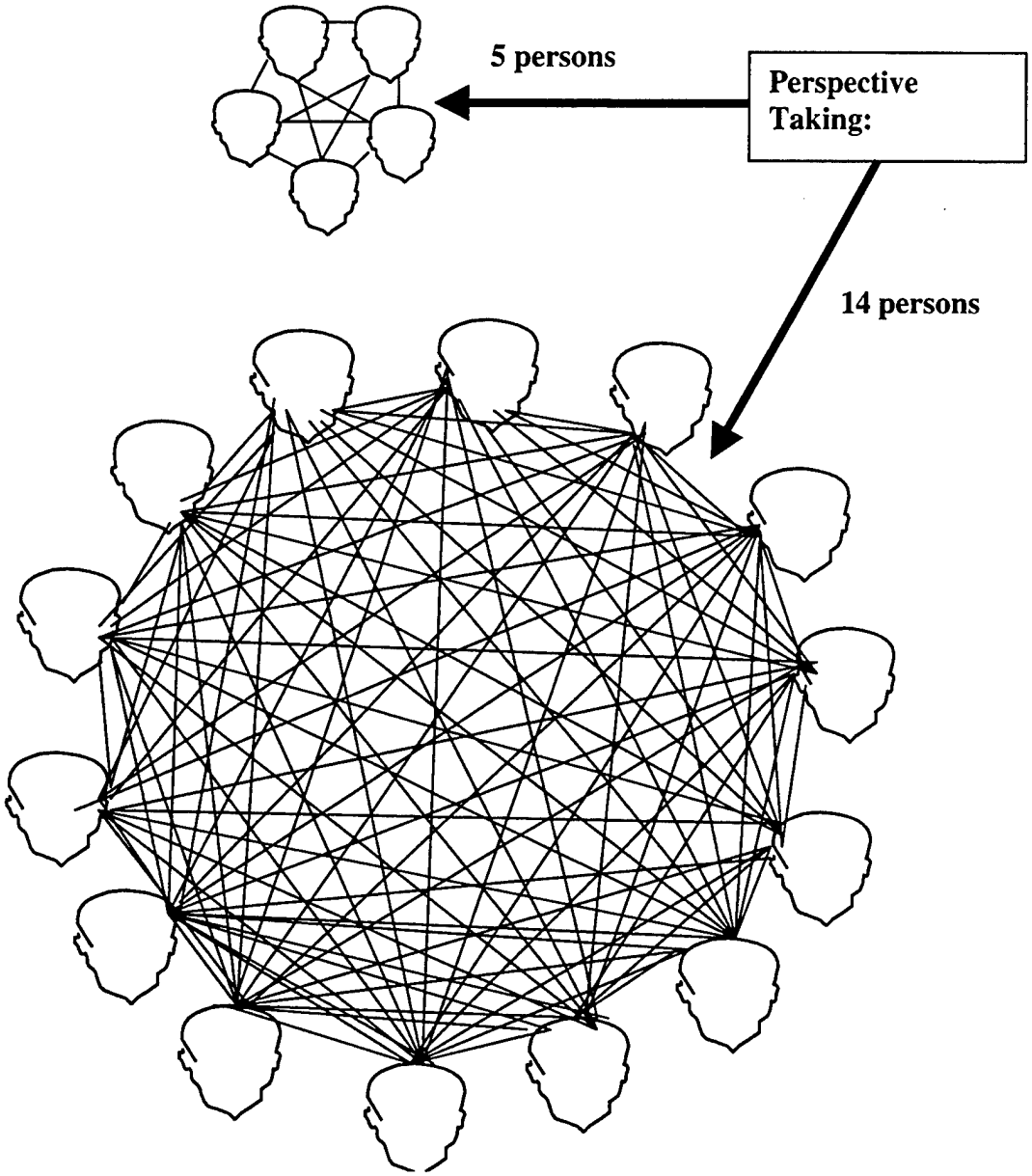

Figure 3

Perspective Taking: 5 versus 14 persons

2.6 Degree of Data Reliability: Task Variables and Their Relationships (Task Uncertainty versus Task Equivocality)

Daft and Lengel [1986] distinguish between task uncertainty and task equivocality. Task uncertainty means that the task variables and their relationships are known, but the data are not available or reliable. Low task uncertainty means that reliable data are mostly available, whereas high task uncertainty means that data are unavailable or unreliable. Task equivocality deals with the degree that task variables and their relationships are known. Low task equivocality means that some of the variables and relationships are unknown, while high task equivocality means that many of the task variables and their relationships are not known. For example, with high task uncertainty, one knows what the questions are and would know how to interpret the data, however data are unreliable or unavailable. In cases of high task equivocality, one is not sure of what questions to ask and unsure of how to interpret data, if available.

Figure 4 provides a visual depiction of the relationships among task uncertainty, task equivocality, and availabilty of reliable data. A key distinction within a given task is the availability of reliable data. Figure 4 demonstrates that if there is unavailability of reliable data for a given task, the unavailability of reliable data can be due to a combination of task uncertainty and task equivocality. Unavailability of reliable data due to task uncertainty means one knows what data are needed but it may be too difficult, too costly, or it requires too much time to obtain it. Unavailability of reliable data due to task equivocality means that if one doesn't even know what questions to ask or how to interpret the answers from questions, then the data related to task equivocality must be considered unreliable.

The cause of the unavailablity of reliable data is important to understand and acknowledge within a given situation. There is an implicit assumption with data unavailability due to task uncertainty that the one, correct, optimal decision is "knowable," i.e., if only the data could be obtained, the correct decision could be made. For tasks with a degree of equivocality, it is important to acknowledge that the one, correct, optimal decision is not "knowable," i.e., it does not exist. Instead cautious interpretation of data obtained is warranted as one chooses a reasonable fiction to pursue, the only optimality available.

2.6.1 Three Sample Multi-dimensional Scenarios

To illustrate some differences in the effect of task dimensions, this section briefly describes three scenarios along important task dimensions. Assume the dimensional continua in Figure 5:

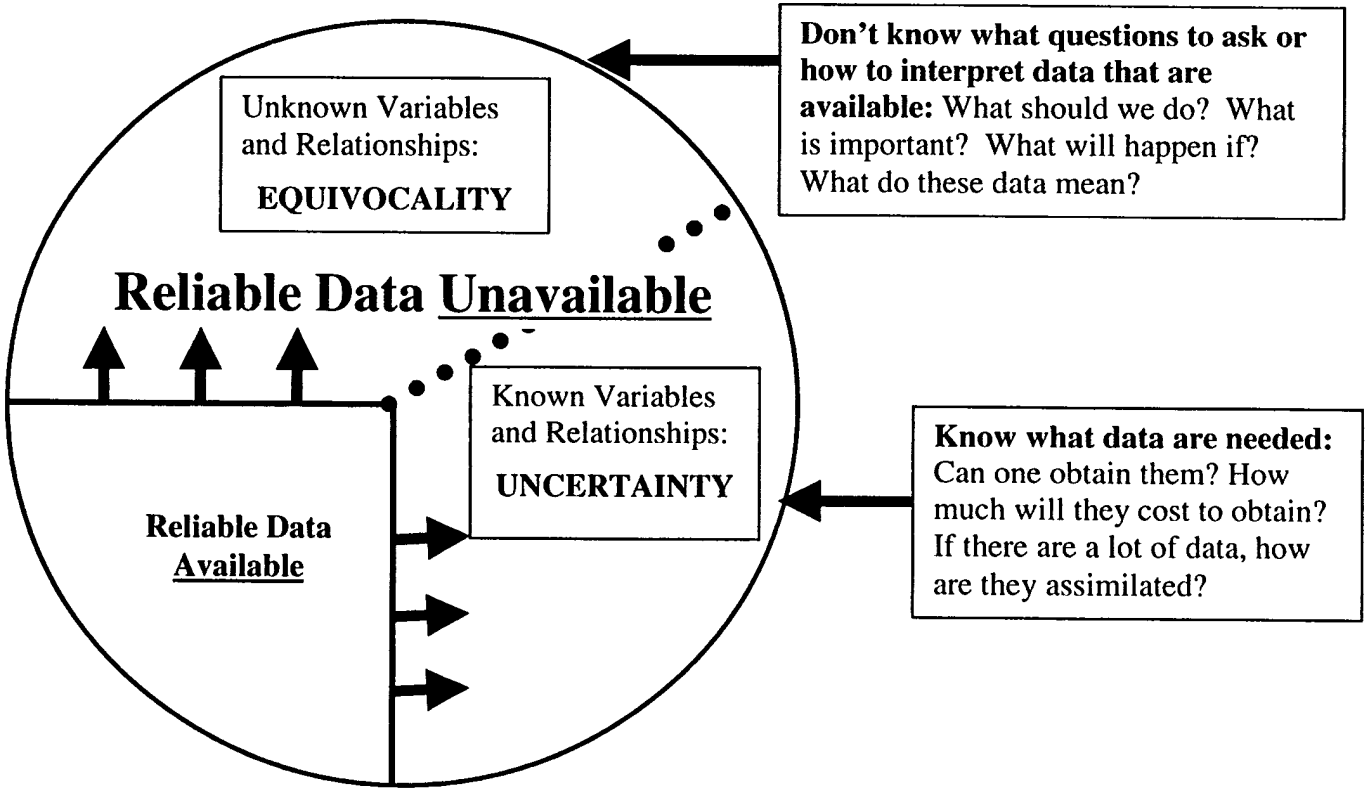

Figure 4

Degree of Uncertainty versus Equivocality in a Task

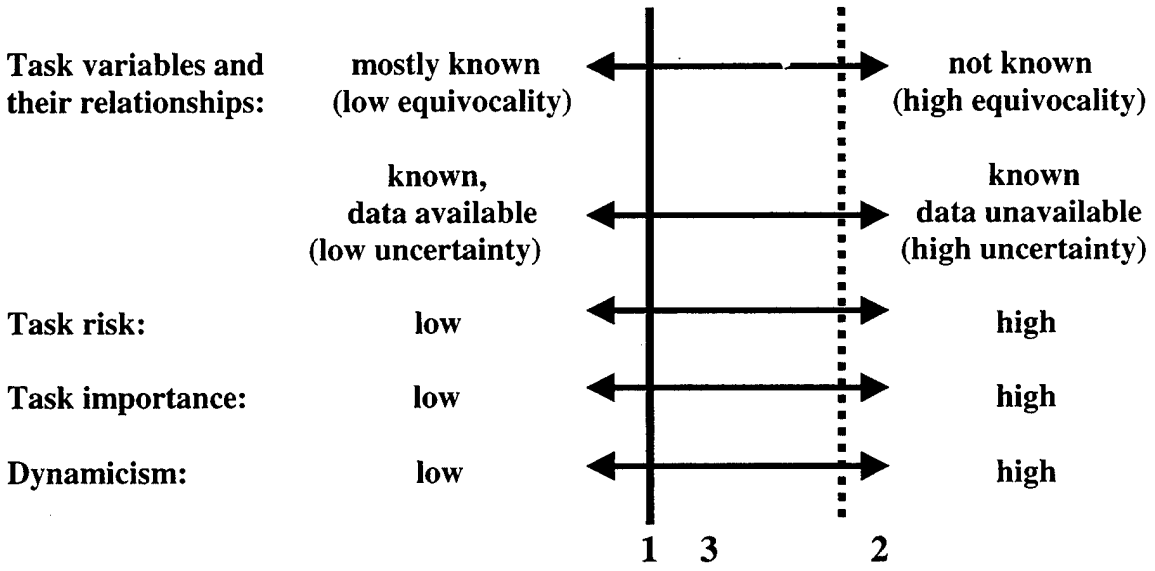

Figure 5

Task Dimensional Criteria

Task Risk: The consequences / costs associated with task actions and failure.

Task Importance: The value of the task to the participant/s

Dynamicism: As described earlier, events can happen at indeterminate times and the nature of the problem to be solved can change.

Data and Support Requirements for:

1. (Solid, Green Line – Line 1) Known task variables and their relationships and reliable data available (low uncertainty), low risk, low task importance, low dynamicism: computational, limited search for data, little need for social construction.

2. (Dotted, Red Line – Line 2) Not well known task variables and their relationships (High equivocality, and since variables and relationships not well defined, available, reliable data available are limited), high risk, high task importance, high dynamicism: This is basically a judgmental task and the important factor is mutual "trust" of those who are jointly constructing the knowledge/understanding of the situation. One needs to trust participants to assess this task and assist each other in a joint way. Look for early indicators of divergence.

3. (Dash and Dotted, Yellow Line – Line 3) Some portion of the task variables and their relationships are known (higher than average equivocality, and high uncertainty: since many of the variables and relationships are unknown, data can't be available, in addition for variables and relationships that are known, reliable data are not available), high risk,

high importance, but there is some time to perform more thorough analyses: Use of tools like concept mapping that permit exploration and facilitates convergence through consensus; identify divergences for focus points.

2.7 Constructionist and Ecological Perspectives

Both ecological and constructionist views offer useful aspects that help explain how actors interpret their environment [Preece et al, 1995]. Those who argue for the ecological view emphasize that observable objects afford their meanings in actors without conscious interpretation. Constructionists argue that actors observe stimuli and construct their meaning.

Figure 6 below provides a synthesis of these viewpoints and introduces some qualifications of terms to support this synthesis. One may argue that looking at the characteristics of the object alone within its background, one may say that the object projects an affordance, a "projected affordance." In figure 6, Stimulus A and Stimulus B possess characteristics that project their meanings. Stimulus A projects a weaker affordance, while Stimulus B projects a stronger affordance. The characteristics of the observer affect what affordances of the object are received, "received affordances." Focussing on Stimulus B, the actor on the left possesses characteristics that enhances the projected affordance, causing a stronger "received affordance," while the actor on the right possesses characteristics that diminishes the projected affordance, causing a weaker "received affordance." Depending on the situation, the received affordance can then be interpreted and a meaning constructed from the received affordance, "interpreted affordance." The actor on the left interprets the received affordance, further enhancing its meaning, while the actor on the right interprets the received affordance causing a diminished meaning.

For example, assume Stimulus A is a stick while stimulus B is a standard doorknob. Assume the stick projects a weaker signal of what to do with it, while the doorknob by its design affords that the object is to be grabbed. The doorknob projects a certain affordance regardless of the characteristics of the observer. However, let's assume the actor on the left has keen eyesight, while the actor on the right does not see well or is blind, then the "received affordance" is enhanced for the actor on the left while it is diminished for the actor on the right. The projected affordance of Stimulus B remains the same, but the characteristics of the actors affect the resulting affordance received by them. The actor on the left interprets the clear affordance of the object, perhaps compares it with previous situations, further enhancing the received affordance, the "interpreted affordance," and easily grasps the doorknob. The actor on the right can't see the doorknob or distinguish it from the surface around it so the received affordance is further dimished, and the "interpreted affordance" results in little or no thought to grab the doorknob. It seems reasonable to view resultant meanings of an object as relative to the object within its surroundings and relative to the characteristics of the observer within their task environment.

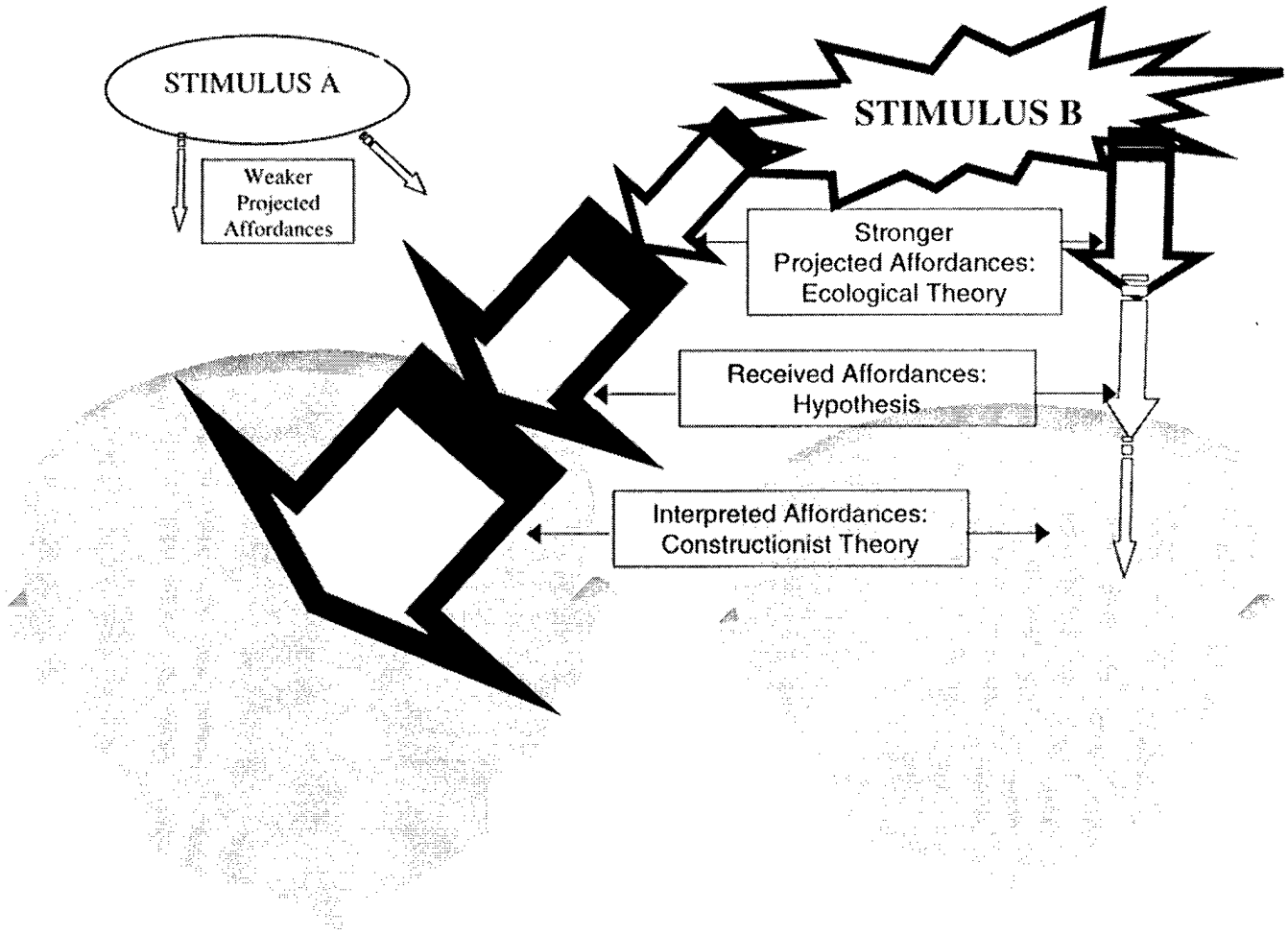

Figure 6

Ecological and Constructionist Synthesis

Extending these notions to the subject of the report, it seems reasonable to accept the ecological viewpoint when the projected affordance is strong, the situation is less ambiguous, and the actor does not possess characteristics that would prevent the reception of affordances. At the same time, it appears reasonable that when the situation is more ambiguous and the signal is weaker, that more interpretation is required and the constructionist viewpoint predominates.

Almost by definition, in ambiguous situations with high equivocality, the projected and received affordances must be weak. The situation is not well defined enough for the reception of signals in a non-ambiguous way. The actor/s must create a fiction in order to make sense of the world sufficiently. They hope this fiction created provides for a reasonable future. In these situations actors who perceive clear meaning and strong signals from stimuli are most likely being affected by cognitive and social biases. This could be a more dangerous situation and reinforce erroneous directions. In these situations it is more prudent to accept the notion of weak projected affordances that require cautious collaborative interpretations and vigilant scanning of the environment to interpret reactions to actions taken by relevant actors.

To summarize, stimuli meanings are relevant to the actors and the observable stimuli within a given situation. Ecologists and Constructionists both contribute to better understanding how meanings are ascribed to objects in a given situation.

2.8 Knowledge and Artifact Creation

This section lays the foundation for understanding how the term knowledge will be used in discussing the social construction of knowledge and offers some simplifications that will prove useful.

2.8.1 Boundary Objects

With greater shared context (shared beliefs, expectations, perceptions...) intent is casually communicated. Perspective Taking occurs through boundary objects [Boland and Tenkasi, 1995]. Boundary objects are "anything perceptible by one or more of the senses [American Heritage Dictionary, 1980]," i.e., anything that can be observed consciously or subconsciously. Ethnographers view sensemaking dialogs as a way to externalize thoughts and achieve a shared construction of meaning. These dialogs may be considered boundary objects that permit exchange of thoughts. Concept maps, as described earlier, can also be considered boundary objects.

Non-verbal expressions can be classified as boundary objects. These include such things as "body language," tone of voice, raised heartbeats, head movement, eye movement, gestures, brain patterns, etc. Boundary objects can be used to identify convergence and divergence related to a given situation. For example, in highly dynamic situations, early signals of divergence may emerge at a subconscious level, but may be of insufficient strength or inchoate form to surface at a verbal level. Real-time monitoring of non-verbal boundary objects may provide early warning of divergence. For example,

real time monitoring of speech patterns, eye, or head movements for members within a team may indicate early warnings of divergence and may be used to direct attention at a verbal level to consciously direct attention. The ease of capturing and screening boundary objects relates to the task characteristics.

2.8.2 Data, Information, Knowledge, and Wisdom

Knowledge is not about giving or getting [Senge, 1997]. Knowledge sharing is creating new potential/capacities for action [Churchman, 1971]. There are so many definitions for data, information, and knowledge that these terms provide little meaning for people. If a useful word conveys its meaning in a consistent manner, then many consider these words useless because there is no consensus on what these words mean. At the same time, great efforts are made in data, information, and knowledge management. Many times they are successful and many times not. Tom Petzinger Jr., an influential columnist for the Wall Street Journal pronounced the "end of 'knowledge management.' An oxymoron if ever there was one...[1998, p. B1]." He emphasizes that it is exchanging information that promotes creativity and quotes Malhotra, who has pooled a large collection of knowledge management literature: "sparse attention has been given to the human aspects of knowledge creation."

There is no difference in the physical nature of data and information. Informational value is relative to the capacity of an actor, human or non-human. The actor possesses the capacity to interpret the data so they have informational value for the actor. When data are interpreted as having informational value, they are labeled as information. As noted above, knowledge is the capacity to act, which includes conceptualizing. Therefore new knowledge is the increased capacity to act. This increased capacity to act may be situational; that is, the data that are interpreted to have informational value may provide an increased capacity to act for a given situation, but may not necessarily have increased the actor's capacity to act after the situation is over. On the other hand, actors that can learn may be able to increase their capacity to act in the future from these interpretive acts and may gain new knowledge that remains after the situational interpretation. For example, an airplane mechanic may be responsible for replacing a certain part when it shows problems. If this is a repetitive act and the mechanic is permitted to work on only one kind of problem, the mechanic may become automatic and his/her speed to perform the action may increase from this repetition. This would be an increased capacity to act; however, there could also be a point of declining performance if the repetition continued. Repeating the stimulus-response events may cause less attention to be paid to received affordances and the capacity to act may actually decline. Based on these definitions there are no differences between knowledge and wisdom and only knowledge will be used in this paper, i.e., like knowledge, wisdom is the increased capacity to act and an increase in wisdom is an increased capacity to act.

When one refers to information management, one means that data are organized in a manner to provide informational value to an actor who possesses the capability to act. Knowledge management is a broad term, however, at its crux, knowledge

management has as its goal a way to reduce the energy required to interpret data in novel but similar situations. Usually, each time it is required, an actor, the external interpreter, interprets data that provides informational value for the actor to act. To transition from data to information, an external actor provides the interpretation of data to determine informational value and achieves a higher capacity to act, knowledge. This means the external actor provides the situational assessment and interpretation. To transition from data to knowledge without an external actor, knowledge-based/management systems must adequately describe a situation and match a stored interpretation to correctly act in a new situation with new data.

A good analogy from Computer Science may be the difference between an interpreted and compiled program. An interpreted program must be converted to binary code every time it is run. A compiled program is interpreted once and then stored as binary code. Both interpreted and compiled programs can have variables that change with execution, but because the compiled program does not have to reinterpret its code, it executes much faster. Each time the compiled program executes, it uses the same code in binary format with different variable values that affects program outcomes. Knowledge management systems hope to store actor interpretations and use them again in the future to speed up action in new situations. Extending this analogy, some computer-based systems "learn" from interpreting new situations and modify their code with the hope that they increase their knowledge, their capacity to act, in future situations where data must be interpreted.

2.8.3 Individual responses to stimuli (Figure 7)

Figure 7, presents a diagram of an interpretation process. As discussed earlier, a stimulus projects a certain value of what it is, the projected affordance, the first arrow that emerges from the stimulus. Actors, with their own set of characteristics, subconsciously filter the projected affordances into received affordances, the second arrow emerging from the first arrow. Actors interpret the received affordances and create an "interpreted affordance," the third arrow emerging from the second arrow. The actor on the left interprets the received affordance, the interpreted affordance, as important, indicated by the larger arrow. This datum is interpreted as providing informational value, and this actor's knowledge, the capacity to act, increases. One could say, this actor has greater knowledge of the situation. The actor on the right interprets the received affordance, the interpreted affordance, as not important, indicated by the diminished arrow. This datum is interpreted as providing no informational value, and this actor's knowledge, the capacity to act, does not increase. One could say there are two "knowledges" of the same situation [Edamala, 1997], i.e., the actor on the left has increased his/her/its knowledge of the situation, and this knowledge of the situation is different from the knowledge that the actor on the right possesses.

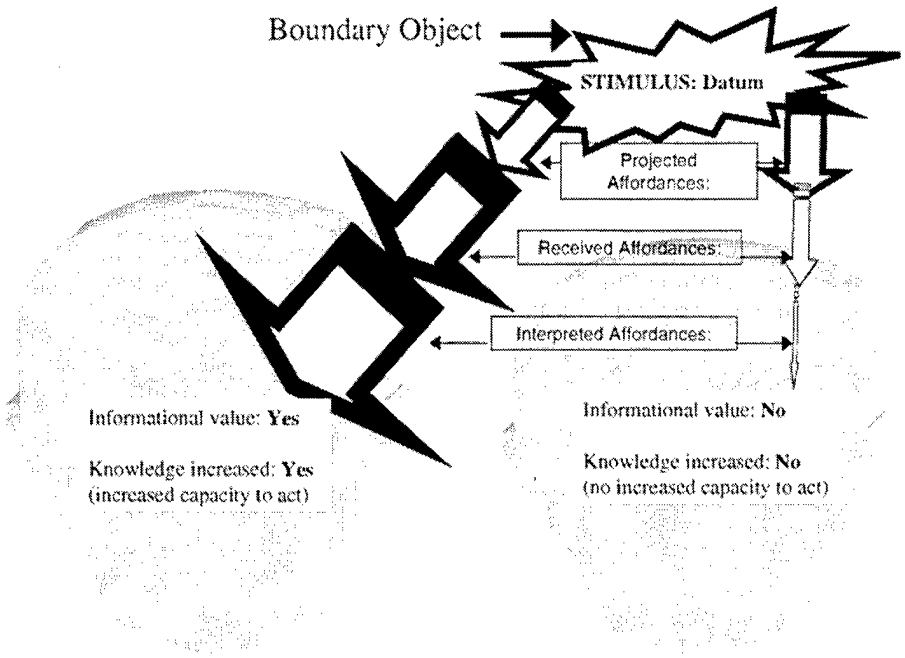

Figure 7

Individual Responses to Stimulus

Assumptions:

Based on knowledge as the capacity to act, one must ask whether it is always positive/correct? People can believe that they are knowledgeable about a situation, meaning they can act, but their actions could be wrong. How do we account for an actual capacity to act correctly, versus a perceived capacity to act correctly? This relates to the quality of the knowledge that is related to the situation and the task uncertainty/equivocality. For example, science builds upon temporary knowledge assumed to be correct, which many times is proven subsequently to be incorrect.

Once people act, especially at the more senior level in the organization, it is difficult to change their minds. As noted in the "biases section," they will rationalize failures as outside their ability to act, and will attribute successes to their action. For important situations with high information ambiguity, it is important to engage in sensemaking and delay positions to prevent negative social and cognitive influences that will interfere with revising actions based on subsequent understanding.

The skills, background, motivations... of actors affect interpreted affordance. People may selectively filter projected affordances and construct different meanings while converging on a similar way to act. Externally viewed, the convergence to act in a similar way may falsely indicate similar capacities to act (knowledge), or similar mental

models, however, multiple knowledges or mental models are likely to exist. For example, two people cast a vote for someone, but their mental models could be different, even inconsistent [Shaw and Gaines, 1994] with each other, however they act in the same way, casting the same vote. This relates to how much mental models need to be shared or how similar the knowledges of the situation must be to act in a similar, coordinated way. Shaw & Gaines [1994] emphasize the importance of coordination over consistency in team action.

The more important the action, the more dynamic, equivocal the task, the more unreliable the data, the more important group sensemaking to the emergence of knowledges in this situation, the emergence of the capacities to act, sufficiently coordinated to engender effective action. In these cases, knowledges are likely different, but the emergence of sufficient capacities to act in a coordinated fashion is critically dependent on the social construction of these knowledges.

Tacit versus Explicit Knowledge

Knowledge, the capacity to act, can be both tacit and explicit. Therefore the process described above regarding interpreted affordances by actors does not necessarily have to be a conscious act. In many cases, it must be a subconscious act. An expert is one who has, through many previous experiences of stimuli and responses, learned to react automatically, fluidly, subconsciously to stimuli [Johnson in Nosek and Sherr, 1984]. For example, in high-speed jet flight, pilots must learn to react automatically, subconsciously to varying stimuli to survive and excel.

This relates to the notion of "knowledge in the head" versus information in the world [Edamala, 1997]. Nonaka [1994] stresses that for organizations to make use of knowledge, knowledge must move from being tacit to explicit. He identifies tacit knowledge as consisting of mental models, beliefs, and perceptions that cannot be easily articulated and shared, while explicit knowledge is formal and systemic and easy to communicate. These ideas promote the somewhat simplistic and inaccurate notion that knowledge can be stored, transmitted, and reused. Nonaka and Takeuchi [1995] describe their views on how organizations can create and use knowledge.

2.9 Cognition, Intelligence, and Knowledge

In the previous section knowledge was defined as the capacity to act, and increased knowledge is the increased capacity to act. The following lists the American Heritage Dictionary definitions of cognition and intelligence along with the definition for knowledge from the previous section to show their interconnectedness. Please note the definition of cognition was slightly modified to include knowledge creation in addition to knowledge acquisition

Cognition: The mental process by which knowledge is acquired/created.

Intelligence: The capacity to acquire and apply knowledge.

Knowledge: The capacity to act.

New/increased knowledge: New/increased capacity to act.

Therefore, given a certain intelligence (capacity to acquire and apply knowledge (capacity to act)), cognition is the mental process by which capacities to act are acquired and created. Cognition is the process where capacities to act manifest themselves. Individual cognition is limited by working memory constraints [Preece et al, 1995]. Some researchers are mapping the brain and claim that people have different kinds of cognitive ability (multiple intelligences) [Gardner in Multiple Intelligences Approahces to Asssessment, 1997]. Gardner defines intelligence as "the ability to solve problems or fashion products that are valued in a particular cultural setting or community." He claims to have identified eight intelligences: verbal-linguistic, logical-mathematical, visual-spatial, bodily-kinesthetic, musical-rhythmic, interpersonal, and naturalist. He proposes that one is born with these intelligences, and that they can be modified by activities that manifest in brain activity. For example, researchers have found that musical training increases certain cognitive abilities.

Figure 8 proposes one way of looking at cognition, intelligence, and knowledge. At this stage, this is more conjecture than fact of how things work, and the relationship between intelligence and knowledge is presented for completeness rather than as a topic that will be explored further in this report. The important aspect of this discussion is to remember that cognition at a given moment in time is the process that determines what knowledge is being created/accessed, and that the capacity to act at a given moment is limited by the constraints of working memory. For example, when one speaks about one's mental model, for complex mental models, only a given subset of a mental model is recreated through the cognition process ("in" arrows from knowledge to working memory). In this cognition process, the next part of the mental model to be recreated and accessible is determined within working memory. In other words, when we talk about someone possessing a particular complex mental model, it never exists as a whole. Only parts of a model are recreated as part of the cognition process. As mentioned earlier, the cognition process can also create increased capacities to act in future situations ("out" arrows from working memory to knowledge of situation stored).

2.10 Group Cognition and Group Knowledge

Over the last several years, my view of cognition has changed from one where all cognition is individual to where all cognition is group cognition. When I speak of all cognition being group cognition, it is a subset of the ideas of Winograd and Flores [1987] who state that all cognition is social and emphasize the role of language and society in one's thinking. At the most elemental level, individuals use words within their own minds and with others to think about something. This reflects the views of several

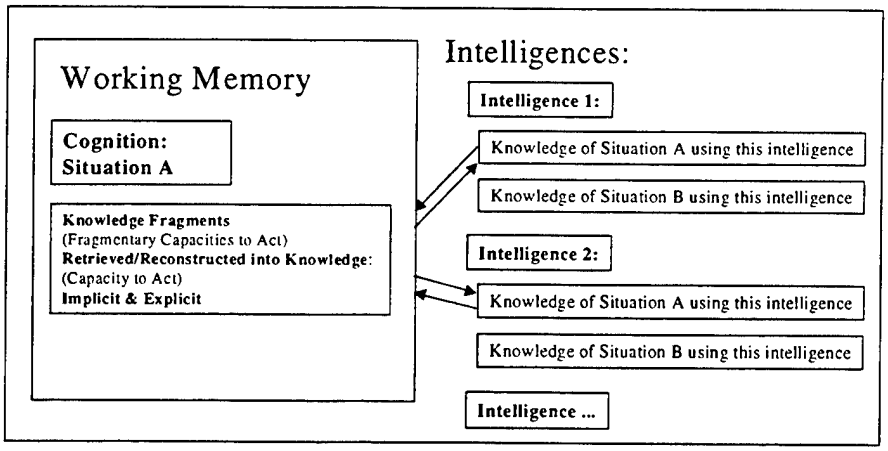

Figure 8

Cognition, Intelligence, and Knowledge

researchers who emphasize that language strongly and directly affects thought. Language is a social artifact created and employed by a community of actors.

To distinguish from these broad ideas that all cognition is social, Group Cognition deals with the actual thoughts that are generated within one's mind. What we think depends upon one's interactions with the world, a world of other actors and actor-created artifacts. It is the boundary objects (anything observable) as initial stimuli, and the reflection on these objects, that stimulate the generation of thoughts, the cognition process. It is the cognition process that recreates the knowledge (the capacity to act) available in a situation. Therefore, "what one thinks" is dependent on these boundary objects that originate with actors, both human and non-human. Knowledge that has not been previously externalized and recorded, only exists at the moment of activation/recreation (tacit and explicit), i.e., tacit knowledge is a capacity to act that is activated, only one is not aware of it. Explicit knowledge is knowledge that is activated, and the actor is aware of it. One can externalize both tacit knowledge and explicit knowledge – tacit knowledge emerges as observable capacity to act as a by-product of actions/behaviors, including open reflection of these actions/behaviors.

2.10.1 Distributed Cognition: Differences from HCI Literature

From the Human-Computer Interaction Literature, Distributed Cognition has been used to describe the coordinated actions within a group [Preece et al, 1995]. Each team member has specialized roles and knowledge. There is some overlap of knowledge needed to achieve smooth coordination. Many times this overlap in knowledge is

acquired and recreated tacitly through observation of boundary objects, which makes it difficult to discover. This definition of distributed cognition includes cognition and knowledges that need to be distributed (not replicated by individuals) and cognition that needs to be coordinated to effect similar knowledges. Therefore distributed cognition will be used here as including only cognition and knowledges that are distributed.

Cognition deals with the process of creating/recreating knowledge (capacity to act within a situation). Boundary objects and mental objects (tacit or explicit: one could be reflecting on objects subconsciously), affect cognition (the process to create/recreate knowledge (the capacity to act)) within working memory.

How do we coordinate cognition within a group to create reasonable knowledges of the situation? What boundary objects are needed and when and how do they need to be employed to create the knowledges of the situation to ensure effective action. Within a group there is a need for distributed knowledge and distributed cognition that are affected by boundary objects available to actors who receive projected affordances and interpret these affordances, tacitly and explicitly. There is also a need for more coordinated cognitive processing among group members that create similar knowledges of the situation. This is the essence of the social construction of knowledge and Figures 9a and 9b below depict this description.

Figure 9a depicts one end of the continuum where group cognition and knowledge is completely distributed. At Time 1 in Situation A, the received affordances of stimuli are different as desired, the cognition process is different for the actor on the left then for the actor on the right. As a reminder, actors can be human and non-human. There are some characteristic differences in the actors that cause the projected affordance of the stimulus, Datum 1, to be received differently. For the actor on the left, the received affordance is enhanced, while for the actor on the right the received affordance is diminished. The cognitive process for the actor on the left is different then for the actor on the right, with the result that the interpreted affordance constructed by the actor on the left is enhanced while the interpreted affordance for the actor constructed by the actor on the right is diminished. For the actor on the left, the result is that Datum 1 is interpreted as having informational value and he/she/it creates/recreates a capacity to act (knowledge). For the actor on the right, the result is that datum 1 is interpreted as not having informational value and he/she/it does not create/recreate a capacity to act (knowledge). As noted previously, this is sometimes necessary and advantageous for a group to work in a distributed way. Each member performs specialized roles and needs specialized capacities to act.

Figure 9b depicts the other end of the continuum, where group cognition is coordinated with the intent of creating/recreating similar knowledges of the situation for both actors. At Time 2 in Situation A, the received affordances of stimuli are similar, as desired, as a result of the intent to create coordinated cognition processes in both actors. Characteristics of the actors, relevant to receiving the projected affordance of the stimulus, Datum 2, are sufficiently similar to cause the received affordance to be the same for both actors. In this case the received affordance is enhanced for both actors.

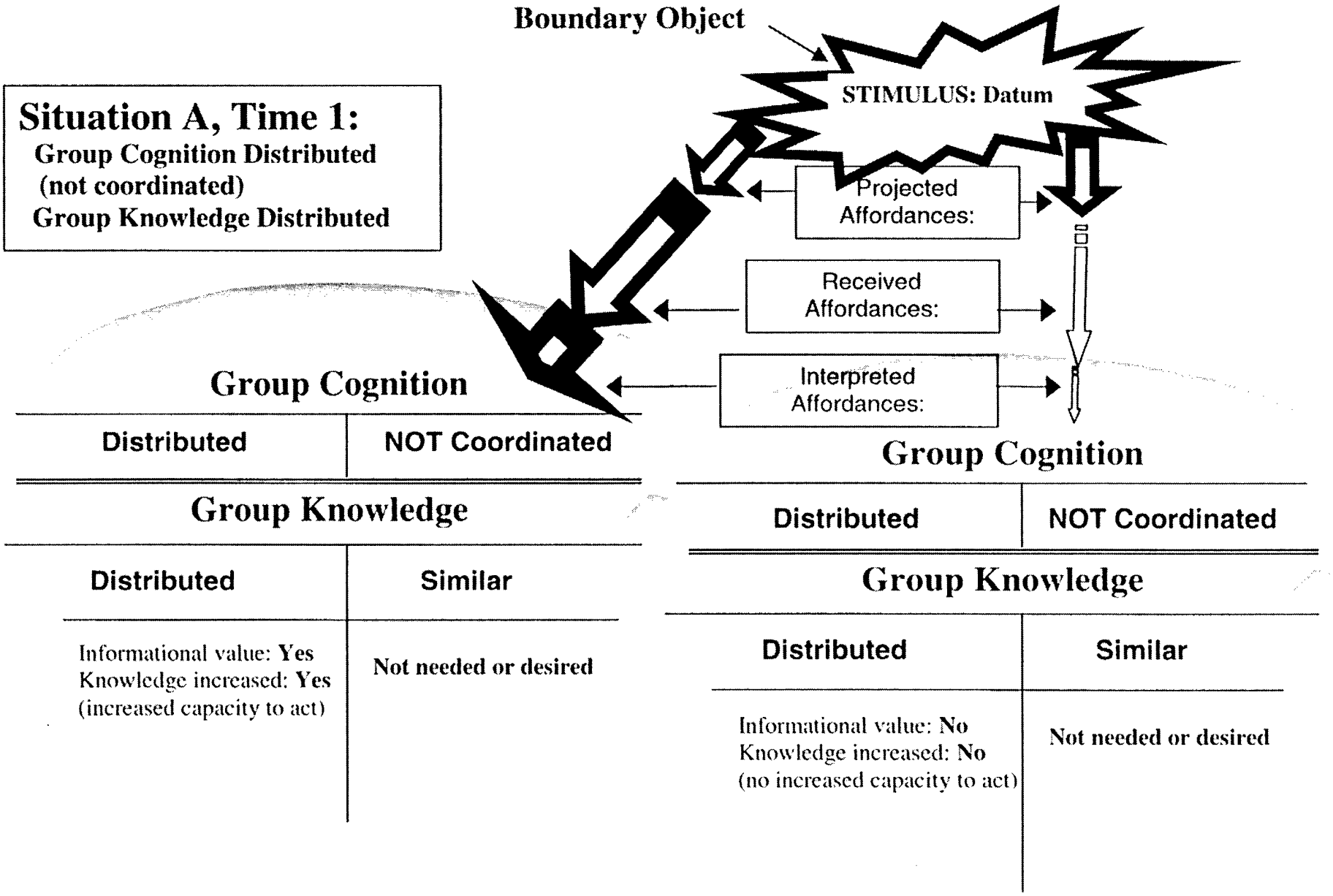

Figure 9a

Distributed Group Cognition & Knowledges

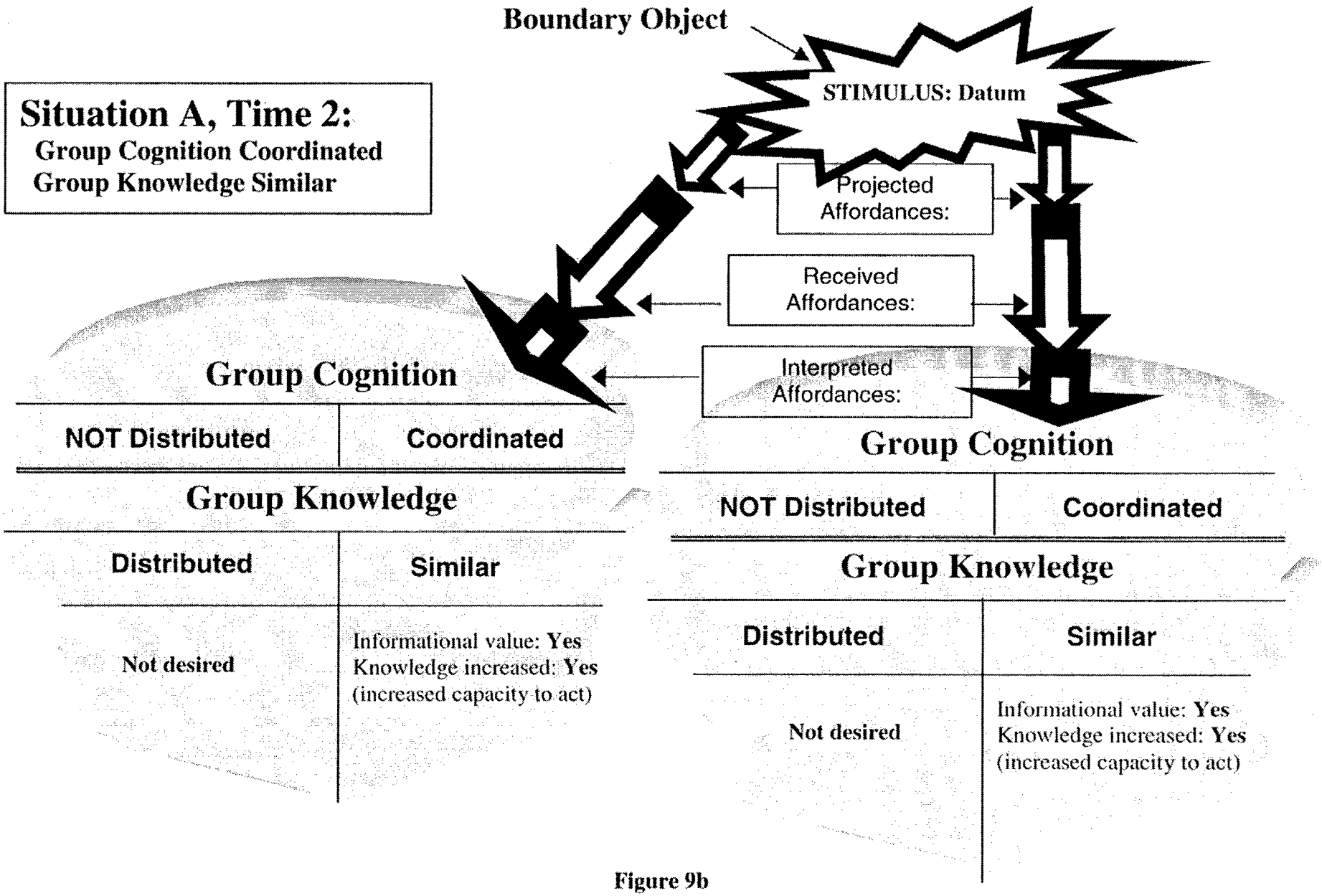

Figure 9b

Coordinated Group Cognition & Creating Similar Knowledges

The cognitive processes for both actors are similar with the result that the interpreted affordances constructed by the actors are similar. For both actors the result is that Datum 2 is interpreted as having the same informational value and the actor on the left creates/recreates a capacity to act (knowledge) similar to the actor on the right.

By viewing the social construction of knowledge in this way, there are a number of areas that can be addressed that will help us to better understand and support effective and efficient social construction of knowledges.

2.11 Techniques for Perspective Making and Perspective Taking

The social construction of knowledge supports perspective making and perspective taking (described earlier). This section briefly discusses ways, techniques, and tools that can be used to achieve this.

> "... perspective making and perspective taking are achieved by narrating our experiences as well as by rationally analyzing [them] ... they involve heightened levels of reflexivity [Boland & Tenkasi, 1995]."

Arguments, a means of rational analysis, are judged based on their factualness, while stories are judged by how interesting and believable they are [Boland & Tenkasi, 1995]. Metaphor has always been shown to be a powerful communications method [Finke and Bettle, 1996, Nonaka, 1994]. Arguments are more believable when there are positions presented that are counter to the position of the speaker [Sproule, 1980]. Believability also depends upon the originator [Sproule, 1980], "people discount for the biases of their colleagues [Cyert and March in Schmidt and Bannon, 1992, p. 32]," [Strauss et al, Cicourel in Schmidt and Bannon, 1992, p. 32], including motives of the originator [Schmidt and Bannon, 1992, p. 35]. Therefore, the listener/reader actively judges the believability of statements based on what they believe is the presentation of all sides to a story, and who the story teller/presenter is. Believability is also affected by who receives the message/story, i.e., their background and attitudes [Bostrom, 1989]. For example, those listeners/readers who have a greater grasp of the material are in a better position to judge the content of the material [Bostrom, 1989]. "Thus cooperative decision making involves a continuous process of assessing, and re-assessing, the validity of the information produced by the participants [Schmidt and Bannon, 1992, p. 32]." In discretionary decision making, the identity of the originator must be given with the information received [Schmidt and Bannon, 1992]. However, visibility must be bounded [Schmidt and Bannon, 1992, p. 35]:

> "The idea of a comprehensive, fully exposed and accessible database is not realistic. A worker engaged in cooperative decision making must be able to control the dissemination of information pertaining to his or her work: what is to be revealed, when, to whom, in which form? Deprive workers of that capability, and they will exercise it covertly."

2.11.1 A Collective Stance: The role of logical models and conflict

Wynn emphasizes the need and value in looking for the logic embedded in stories [Wynn, 1997] to guide analysis of the domains and their attributes within a given situation. Schmidt and Bannon [1992, p. 33, 34] report that Storrs, who developed "The Policy Application," provides a "logical model" of the domain to support a large group, widely dispersed in space and time, who have "a wide range of expertise and with widely differing perspectives." However, Shaw and Gaines argue that "neither individuals nor collectives need to be logically consistent or coherent in their knowledge structures to achieve effective performance [1994, p. 108]." They go on to note that "The notion of conflict arises in modeling individuals and collectives as a construct of the observer to account for inconsistency and incoherence. Conflict is significant because many diverse adaptive and goal-seeking activities may be modeled in general terms as conflict-resolution behavior... inconsistency alone does not lead to conflicts – effective coordination can occur despite major inconsistencies. It is failure of coordination ascribed to inconsistency that may be properly termed conflict – failure ascribed to the vagaries of the world or inadequate models of it is not indicative of conflict. This definition also relativizes the notion of conflict to the perception of failure. One observer may construe a group's activities as successfully coordinated even though another may see them from a different perspective as failing through conflict [Shaw & Gaines, 1992, pp. 108-109]."

2.11.2 Use of Diagrams/Mapping

Larkin and Simon [1995] provide the following reasons why diagrams can be superior to a verbal description for solving problems:

- Diagrams can group together all information that is used together, thus avoiding large amounts of search for the elements needed to make a problem-solving inference.
- Diagrams typically use location to group information about a single element, avoiding the need to match symbolic labels.
- Diagrams automatically support a large number of perceptual inferences, which are extremely easy for humans.

Placing related elements at adjacent locations reduces problems with short-term memory and places information needed for future inferences in a common location. While "every diagram supports some easy perceptual references, nothing ensures that these inferences must be useful in the problem-solving process [Larkin and Simon, 1995]."

Huff [in Schwenk, 1995, p. 478] found five approaches to mapping managers' minds:

1. Maps which assess attention, association, and the importance of concepts
   - Examine the *frequency* of use of words as a reflection of the importance of certain concepts to them.
   - Examine clusters of words, which indicate the importance of certain themes.

- Look at changes in word use as a reflection of changing patterns of attention.

2. Maps can show dimensions of categories and cognitive taxonomies. These maps show hierarchical relationships between broad concepts and more specific subcategories.
3. Maps can show influence, causality, and system dynamics. Often called causal maps, these maps represent decision-makers' beliefs about the ways that some cognitive elements affect others.
4. Some maps show the structure of arguments.
5. Maps can specify schemas, cognitive frames, and perceptual codes. These maps assess expectations and the complex hierarchical frameworks of which they are a part, using language as a sign of the underlying structure.

Analyzing the changes in causal maps over time, a number of researchers [in Schwenk, 1995] found that it was important for organizations that managers recognize new conditions created by environmental change, and more importantly, be able to link these changes to corporate strategy and modify these linkages over time.

2.11.3 Strategies for Reducing Biases

Slovic has proposed that humans are "intellectual cripples" and implies "humans may well be little more than masters of the art of self-deception [Sage, 1981]." The following lists some strategies for reducing biases in information processing.

- Identify bases for validity of information:
  - sample size, confidence intervals [Sage, 1981]
  - Schmidt and Bannon [1992] ask whether it's possible to record and convey the heuristics applied by a decisionmaker to permit the recipient of the information to assess its validity and other attributes. Explanation facilities in an expert system can change attitudes more and reduce the influence of the most influential member in a group [Nah and Kim, 1997].
  - Schmidt and Bannon [1992] ask whether it is possible to depersonalize contextual information that helps recipients of the information judge its believability, while achieving a level of anonymity.
  - Contextual knowledge of the conceptual frame of reference of the originator is indispensable to those who must act intelligently on information conveyed to them [Schmidt and Bannon, 1992]. Schmidt and Bannon [1992] report on work by Storrs who reported on a policy decision support system that provides a "logical model" of the domain. Policy makers may retrieve the "hidden" argumentation substructure of evolving policy.
- Sample information from a broad data base, include disconfirming information [Sage, 1981].
- Use models and quantitative aids to aggregate and make sense of the information [Sage, 1981].
- Avoid hindsight bias by providing appropriate information at critical times in the decision process [Sage, 1981].

- "Encourage decisionmakers to distinguish good and bad decisions from good and bad outcomes to avoid various forms of selective perception such as, for example, the illusion of control [Sage, 1981]."
- Encourage learning from experience: understand the decision methods and rules used in practice to process information and make decisions to avoid outcome irrelevant learning systems [Sage, 1981].
- Build semi-confusing information systems that destabilize organizations with planned confusion – "in times when they ought to be confused [Hedberg and Jonsson, 1978, p. 47]."
- "Use structured frameworks based on logical reasoning in order to avoid confusing facts and values and wishful thinking; and to assist in processing information updates [Sage, 1981]."
- Both qualitative and quantitative data should be collected and regarded with appropriate emphasis: neither overweighted nor underweighted in accordance with personal views, beliefs, or values [Sage, 1981].
- Periodically, remind decisionmakers the type or size of sample of data [Sage, 1981].
- Present information in multiple orderings to avoid recency and primacy order effects and data presentation context and data saturation biases.

2.11.4 Novel Approaches

Davenport and Murtaugh [1997] describe a novel approach for creating collaborative stories to co-construct meaning by selecting relevant story elements from a multimedia database and conjoining them into a narrative presentation. They claim that this approach is well suited for complex stories and that audiences become active partners in the shaping and presentation of the story.

3. IMPLICATIONS AND EXTRAPOLATIONS FROM RESEARCH

The scope of this project prevented any thorough review of all existing technologies to support the social construction of knowledge and lower level technologies such as shared screens and pointing technologies have been reviewed extensively by other researchers [See CSCW literature for detailed studies]. Instead this section looks at what guidance we can glean from the previous section to better support the social construction of knowledge. A table format will be used for this section [See Table 2]. In some cases, where guidance appears to be contradictory an effort will be made to identify these. Finally, some guidance will warrant more complete discussion, and where possible this will be provided. As noted earlier, this report should be considered a work-in-progress and this section should be considered a starting point for a more definitive review.

Table 2
Implications for Supporting the Social Construction of Knowledge

Guidance	Bases/Comments
1. Capture rationales	Boland & Tenkasi [1995] Schmidt and Bannon [1992] Sage [1981] Nah and Kim [1997]
2. Capture stories/narratives	Boland & Tenkasi [1995]; Wynn [1997]
3. Reveal originator	Cyert and March, Strauss et al, Cicourel in Schmidt and Bannon [1992] Sproule [1980] **Contradicts 4:** to maintain anonymity
4. Maintain anonymity	Dennis et al **Contradicts 3:** to reveal originator
5. Provide contextual information	Schmidt and Bannon [1992]
6. Provide deniability	Schmidt and Bannon [1992] **Contradicts 1:** capture rationales; Supports 4: maintain anonymity
7. Provide information about originator without identifying originator	Nosek[1998, this report] **Compromise of 1:** capture rationales; **3:** reveal originator; **4:** maintain anonymity; **6:** provide deniability
8. Support reflection	Boland and Tenkasi [1995] Dreyfus & Drefus Shaw & Gaines [1994]
9. Treat social constructions, such as facts, as objects	Gephart [1993] Boland and Tenkasi [1995] Wynn [1997]

10. Identify increased divergence and convergence of attention to stimuli: • help identify affordances that may be stimulating this • provide means for groups to help create divergence and convergence • provide means to identify divergence within groups	Ackermann [1997] uses a conceptual mapping tool to gain convergence through consensus. She feels the best way to achieve this is through recognizing divergences and exploring the reasons for them. Decision Explorer (a concept mapping tool) is based on Kelly's Personal Construct Theory [1955]. Personal Construct Theory states that people have "opposite" or "opposing" limits to their views relative to some scale, e.g., when one says hot, the person implicitly and perhaps subconsciously has an idea of what "hot" is as compared to what "cold" is. One person's hot could be 80 degrees when they are used to cold temperatures of minus 30 degrees, whereas another persons "hot" may be 110 degrees, when their "cold" temperature dips below "60." Conceptual mapping may be good for less dynamic situations, however as the speed of change increases, there must be some way to jointly calibrate quickly. Perhaps early divergences of team members could provide a means to quickly focus on affordances of importance, and adroitly move the group toward convergence. Individuals allow different affordances to be processed based on current hypotheses and/or focus, using their own personal scales [Kelly's Personal Construct Theory]. Team training could encompass understanding of personal constructs of importance, danger, etc. and could be useful in real-time interactions. Indications of early divergences could be, "To what affordances are team members attending?" Can these actions of attending to these affordances be automatically associated and presented so that patterns of these affordances indicate that the team members are focussing on separate issues? Extending possibilities, can participants be given different coding schemes/indicators based on expertise, closest to the problem, most recent information? For example, the most experienced evaluator, who is closest to the problem, and has the most recent information, his/her actions could be given prominence, indicating affordances that he/she is attending to. Comparisons could be made to provide early detection of divergences. Just as they have found that repeated speech and text patterns by strategic decision makers indicates a shift in attention, similar ways can be found for these shifts in

10. (cont)	attention. For example, speech and text could be sampled for team interactions in command and control operations and for tactical operations within combat information centers. There may be ways to extend this notion of what affordances in the environment for which one or more team members are searching? and what affordances are strong enough or resonate enough with participants so that they are accepted? For example, technology may be used to map eye glances and head movements. This pattern could indicate a change in attention. In highly complex environments that demand team role differentiation, what is the balance between group cognition and distributed cognition? That is, while there is a need to perform differentiated tasks, there is a need, as has been noted in distributed cognition studies, for maintaining an overlap of role understanding. At the same time, too much attention to the same or similar stimuli, "tunnel vision," may cause inadequate attention to a broad range of stimuli that are to be handled by a team with differentiated roles. As indicated above, this could be applied to command and control and in directing unmanned air vehicles. There are at least two ways where these ideas can affect process and development of support systems. From combat information centers with large groups with differentiated roles to unmanned vehicles where teams are located separately from the vehicle, there are multiple affordances of stimuli that exist in the task environment. Mechanical devices that record head and eye movement, coupled with computers that are analyzing these movement patterns, plus analyzing speech and visually displayed information (including text) could provide early information of divergence of importance and early signs of distributed cognition that might need to be shared with the group. Secondarily, within large and small teams with differentiated roles, there may be coupling of humans and machines that redundantly focus on single roles. In addition to mechanical recording of head/eye movement, speech, and text transmissions, other means that support more intensive creation and maintenance of shared understanding of the situation may prove useful. Any means that provides early warning of divergence and a simple means of calibration of shared meaning could be especially useful.

11. Time anonymity and open conversation: Support security and procedural protocols that provide opportunities for this.	For example, anonymously, one person can request during times of topic exploration that the discussion be anonymous. If this were allowed in the protocol for the task and the group, or for the phase of the task, then all would be anonymous. Other times, there may be a requirement along some range for a number of people to indicate the desire for anonymity, and then the system could respond
12 Provide means to quickly capture subsets of statements and categorize into domains and attributes of domains – provide relevant domains to ease selection	Wynn [1997]; Boland and Tenkasi [1995].

4. CONCLUDING REMARKS

This paper focussed on identifying multi-theoretical foundations for supporting group sensemaking in the social construction of knowledge and artifacts. Based on these foundations, some initial guidance to augment the social construction of knowledge and artifacts were identified. As noted earlier, because of the breadth and complexity of the subject, this report must be considered a work-in-progress, a snapshot of the exploration of such a complex subject.

5. ACKNOWLEDGEMENTS

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