Summer 2013

Micro to Macro Dynamics of Shared Awareness Emergence in Situations Theory: Towards a General Theory of Shared Awareness

Samuel F. Kavacic
Old Dominion University

MICRO TO MACRO DYNAMICS OF SHARED AWARENESS EMERGENCE IN SITUATIONS THEORY: TOWARDS A GENERAL THEORY OF SHARED AWARENESS

by

Samuel F. Kovacic
B.Sc. December 1988, University of Maryland University College
M.B.A. November 2001, Embry Riddle Aeronautical University

A Dissertation Submitted to the Faculty of
Old Dominion University in Partial Fulfillment of the
Requirements for the Degree of

DOCTOR OF PHILOSOPHY

ENGINEERING MANAGEMENT

OLD DOMINION UNIVERSITY
August 2013

Approved by

Andres Sousa-Poza (Director)

Adrian Gheorghe (Member)

Ghaith Rabadi (Member)

Van Brewer (Member)

ABSTRACT

MICRO TO MACRO DYNAMICS OF SHARED AWARENESS EMERGENCE IN SITUATIONS THEORY: TOWARDS A GENERAL THEORY OF SHARED AWARENESS

Samuel F. Kovacic
Old Dominion University, 2013
Director: Dr. Andres Sousa-Poza

Engineering Management is an interdisciplinary field of study. As such, Engineering Management must rely on the energies of its participants to integrate toward the problem being solved. Many techniques exist to aid the researcher towards a common goal; however, it can only be surmised on how effective the techniques have been. Not until the activity is over and the participants reflect back on their results can they know whether they shared a common understanding of the problem. This study explores the emergence of shared awareness based the interactions of disparate perspectives at a particulate level. The study builds from observations of a real-world problem and explores how shared awareness emerges.

Given the shared nature of multiple disciplinary approaches quantifying shared awareness would seem particularly important. It is not enough to say that shared awareness has occurred; more importantly it is necessary to know when shared awareness has occurred and with whom and what the conditions were for shared awareness *in situ*. Since any given project is longitudinal in nature, change is inevitable. With change comes different conditions for shared awareness; it cannot be assumed that shared awareness is sustained through change. Without knowing the prior conditions for shared awareness there is nothing to compare with when change has occurred. This study attempts to quantify when the emergent state of shared awareness has occurred and by extension the conditions where awareness is shared within a group of individuals. Most

importantly, this study will provide a method for studying shared awareness [probability threshold] using percolation theory. Percolation is one of numerous techniques being developed out of statistical mechanics. Statistical mechanics (reinterpreted for the use in this study) provides a framework for relating the microscopic properties of individual atoms and molecules [individual] to the macroscopic bulk properties of materials [whole] that can be observed in everyday life (Albert, 2002). An experiment is proposed to test the hypothesis formed within the study and canons to substantiate the findings of the experiment. Ultimately, the study proposes a General Theory for Shared Awareness that provides a foundation for further research.

All that I am and who I strive to be is for one person alone,

my soul-mate and wife Lynne.

She has shown me that beyond hubris and arrogance is humility

and it is from this position that learning and understanding is greatest.

I am in her debt as an author, a scholar, and a person

and dedicate the success of this work to her alone.

ACKNOWLEDGMENTS

To attempt to thank in this acknowledgement all those that have contributed or supported me in my academic pursuit would jeopardize or marginalize not listing all the many excellent contributors that were 'part-and-parcel' to this work. Suffice it to say it takes a village to raise a scholar and many thanks are extended to each and every villager. However, a special 'thank you' goes out to Dr. William Welsh, Dr. Chuck Keating, Dr. José Padilla, Dr. Nina Mun, and Mr. Richard Myers, for providing support 'above and beyond' that I could not have hoped to expect. Additionally, my deepest appreciation and gratitude goes to my committee members: Dr. Van Brewer, Dr. Adrian Gheorghe, and Dr. Ghaith Rabadi. Above all, I would like to thank Dr. Andres Sousa-Poza, my committee chair, for his support and insistence to follow my passion. Rather than guide me through a maze of all that is known, Dr. Sousa-Poza challenged me (continuously) to explore beyond what was known and provided focus for my passion for deriving an understanding of the unknown. His influence is imprinted in this work and will always be present on all my future work as a scholar.

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1. Background

Engineering Management is greater than the sum of its parts (engineering and management); it is a holistic interpretation of differing disciplines aligned along common perspective towards a greater understanding. The conflicted uncertainty generated by this merger (whether from the integration of disciplines, the paradigmatic tension generated from multiple perspectives, or the attempt at transcendence from a common framework) seems to hang like a shroud over the field of Engineering Management. Combining two or more disciplines, implying that an integrated discipline would emerge, may have caused more uncertainty than certainty. The ambiguity of purpose is apparent when interpreting current curriculum for Engineering Management. An analysis was conducted by the author on the definition of Engineering Management from five U.S. colleges that offered an Engineering Management curriculum:

- Stanford
- Massachusetts Institute of Technology
- University of Missouri/Rolla
- Old Dominion University
- Stevens Institute of Technology

After extracting themes from the mission statements and curriculum from each university the resulting comparison provided five thematically different descriptions. Although the themes were not grossly different it was sufficient to highlight the potentially different research approaches offered by each university. By definition integrating disciplines as an interdisciplinary study (Kollman, 2010) can potentially derive different approaches depending on philosophical disposition. It was apparent that each academic institute described uniquely different inferences toward research in the field of Engineering Management ultimately describing different research methodologies. While this may be viewed as a robust and wholesome approach to defining engineering management at an individualistic or institute level, as a whole engineering management [as an inter-discipline] suffers from an apparent lack of shared understanding.

The significance of this study is not to highlight discrepancies in the field but to study how shared awareness is formed within a heterogeneous environment found in complex situations such as Engineering Management. Critical to the study is the idea of complexity and its effect on understanding. In this study it is assumed when a situation is simple that any variance in the entities maintaining a shared perspective has little to no effect on shared awareness, this is due either to how the situation is being perceived or a natural or intuitive alignment of perspectives perceiving the situation. For example, a technical design or mathematical formula may be complicated but not complex in terms of the amount of variation between how the entities interpret or understand what they are working on (assuming the entities are versed in the topic). Clear and concise statements can be made, both empirically (for the technical design) or rationally (for the mathematical formula), that leave little room for misinterpretation or misunderstanding. Simple situations are governed by explicit rules or principles that obviate assumptions and allow for accurate predictions or statements of the future within the situation (Sousa-Poza, 2012). A simple situation is one where statements of reality and perspective are nearly identical. Participation in any situation makes the situation simpler, however, when dissociating from reality to study the situation, a more typical exercise, the situation quickly becomes complex.

Complex situations have a much greater probability of error in the knowledge stemming from uncertainty, non-linearity, disparate perspectives or lexicons, and/or culturally diverse value systems, all allowing for error in even the simplest of topics. A situation that requires one entity to infer from another perspective will create enough error to make the situation indefeasible. This dovetails nicely with Sousa-Poza definition of simple and complex situations:

> *'The distinction between simple and [complex] is thus defined by the degree to which comprehensibility and understanding of the situation can be established.' (Sousa-Poza, 2012)*

Ergo, the further the disassociation from reality the less comprehensible and understandable the situation.

Situations have a temporal and uncertain component that defies traditional methods for making definitive or integrated statements of reality. How shared awareness emerges in this environment is fundamental to the focus of this study. The scope is centered on the idea of 'together but separate' an autopoetic concept adopted by two organizations striving for integrating disparate but complementary functions and is the focus of *'the project'* presented in this document.

The purpose of this study is to explore shared awareness and the role complexity plays when shared awareness forms. Ultimately, the objective for the study is to hypothesis a General Theory for Shared Awareness.

Key to interdisciplinary approaches is integration and foundational to that is the belief that there exists a shared understanding of the situation assumed by each discipline coalescing around a common problem. Unfortunately this basic assumption rarely gets tested, yet its affect is the gold standard for problem resolution...that shared [situational] awareness exists for integration to occur.

It is not contended that Engineering Management deals with high levels of uncertainty, what is in contention is whether there is an effective approach for sufficiently determining whether shared awareness within these situation could occur. It also suggests that the dilemma that Engineering Management face is endemic to all disciplinary endeavors where two or more perspectives are merged. Invariably techniques for solving interdisciplinary problems generally are entrenched in one discipline and made to "fit" in the other for a satisficing solution or a cohesive group is formed with a subjective means for measuring a common perspective. Understandably, this is problematic when it can only be assumed that the participants have a shared situational awareness of the problem. This problem is greatly highlighted when one considers the implication of white space.

Science tells us that we share through knowledge, that philosophy defines the characteristics of that knowledge, and worldviews provide us the bounding parameters for that knowledge; yet they all are confounded when faced with the nuomenological dimension introduced by the individual participant. This dimension, which can never be made explicit, defies observation, can never be discussed, but must always be accepted when sharing is expected. In a reductionist approach such as science this dimension is white space, white space is everything that cannot be made known (Kovacic, 2007). It is within the nuomenological dimension that understanding is facilitated; understanding that is necessary for shared awareness.

Key to any research is the discovery of knowledge (Sousa-Poza, 2007), Knowledge can be divided into two categories: tacit and explicit. Explicit knowledge represents knowledge that the individual holds consciously in mental focus, in a form that can easily be communicated to others. At the opposite end of the spectrum, tacit knowledge represents internalized knowledge that an individual may not be consciously aware of, such as how he or she accomplishes particular tasks (Polanyi, 1966). Making the separation even more apparent is that tacit knowledge can be either transferable or cognitive (existing solely within the mind of the individual). The significance of this separation is that explicit knowledge can be captured, but not all tacit knowledge can. Critical to this research is the complementary nature of knowledge and its implication in shared understanding or shared awareness.

Critical for any research approach would be to provide a means to make sharable tacit knowledge explicit and for the internal tacit knowledge [white space], that cannot be shared, available to inform the process. The typical method for this is analysis. Analysis separates the whole into its component parts and their relationships (OED, 2010). Systemic analysis decomposes the parts and relationships to provide increasing detail while maintaining the integrity of the whole (Stanford, 2009); however, white space defies systemic analysis.

It is possible to explicitly represent knowledge in great detail; however, in systemic analysis the internal tacit knowledge can only be represented as white space. The intent of a holistic view is so the system can be viewed from the "30,000 foot perspective" and that generalities and broader understanding of the domain can be made; detail is less but understanding of the whole is greater. Analysis invariably starts at a holistic perspective and reduces down. At some point our understanding of the components and relationships are greater but the understanding of the whole is less because of the effect of white space. It becomes evident that the white space is non-linear and dynamic, critical for reconstruction of the parts back to the whole, and cannot be maintained. This implies that decomposing the parts from the whole will not necessarily allow reconstruction of the whole from the parts. The integration of the parts that resides in white space is lost as the parts were decomposed as time moves and the outcome no longer can be traced back to its initial condition.

This reductionist approach is in contrast to its complement, a holistic interpretation, which views the relationships of the elements behavior at a macro level. This approach also suffers the inverse problems as the reductionist approach, an understanding of the behaviors with little understanding of the details of the components within the system. This is an important distinction for studies in complexity where reducing confounds the implications of complexity and provides a false sense of casual understanding in an otherwise dynamic and disparate system (Bertalanffy, 1954). The white space of the macro level study is the absence of a casual chain between levels, creating a stochastic situation. Although methods abound for stochastic processes, they are lost in a situation that must interpret a situation that is closely linked to the continuous [temporal] nature of reality. The implication to shared awareness is that to affect sharing either one perspective or the other perspective must be adopted. At each bifurcation, its complement is no longer accessible. Insights can only be drawn from one side of the complementary perspective or the other.

This paper, and the focus of the study, posits as each bifurcation occurs awareness exists in both complementary halves however sharing can occur only in one or the other rather than across perspectives. In this interpretation shared awareness is an emergent construct where the particulate may have common variables that are represented as characteristics or qualities of phenomena common to the whole. But to share that understanding an individual must share a similar generative process and perspective of all the individuals that are sharing.

Interdisciplinary approaches attempt to overcome this issue with methods that focus strictly on the phenomena. Ultimately every approach relies on a shared awareness of the collective as a foundational component to overcome the reductionist effects in the pursuit of knowledge. This awareness is in no small part dependent on how predispositions of the environment are perceived. It is the predispositions and a willingness to rationally change dispositions that make shared awareness an emergent construct rather than a random one, and still within the purview of the scientist rather than the sophist. Regrettably, shared awareness, typically provided *posteriori*, can only inform in terms of best practices and lessons learned. However, emerging techniques in statistical mechanics have provided the researcher new tools to study the emergent phenomena of shared awareness in a more proactive means if not *a priori*.

1.2. What is Being Proposed

Have you ever been in a situation where, as a group, you are chartered to come to some type of a consensus so that a decision can be made? Sometimes there is success and sometimes not so much; it all depends on the situation. More specifically, it depends on the perspectives held by the participants and their ability to generate a common dialog to work through the situation. Actively participating in the group, working through issues, accepting compromises when necessary, reaching a point where all the perspectives have aligned sufficiently to articulate an integrated solution are all part-and-parcel of coming to a consensus. However, when executing the solution often it is discovered that all the hidden issues/agendas that were presumed to be have been resolved suddenly crop up again and reduce the solution back into separate dichotomous solutions. Workshops, integration centers, fusion centers exist to foster shared awareness leading to integrated action towards a common solution that ultimately can be executed by all participants. A primary objective is to unify around a shared awareness and integrate toward a common goal or purpose. There are a number of techniques to facilitate meetings for consensus; team building, mind mapping, concept mapping, and facilitated dialog to name a few; they are all based on the premise that the participants can be integrated. In some case where the perspectives all have common context and goals the shared awareness that is necessary to accomplish the goal is readily attainable, however, as perspectives become more diverse due to expanding context or ill-defined goals discussions quickly erode and shared awareness becomes less likely. A more likely scenario would be the emergence of a dominant perspective and shift from the other perspectives to the dominant perspective. This can occur naturally (external influence such as a mission that provides a rational reason to let-go of predispositions) or through sheer will of the dominant perspective (internal influence such as need that provides a rational reason to let-go of predispositions) (Friedell, 1954).

A project, conducted within a government agency, focused on providing the means and methods for integration amongst numerous agencies that shared a common goal is the impetus for this study. The observations from this project (specifically observations from three workshops) are inserted to provide context giving insights into the anthropological journey for the furtherance of this study. The observations (referred to as *'the project'* and italicized throughout the remainder of this study) are cast in the narrative form. The significance of this is:

1. Bias – how the *'the project'* unfolded and how it informed this study is part-and-partial of the biases that every individual holds when put into a position to collaborate or shared with another individual. Conveying these biases within the narrative provide the meaning for why the study is important – highlighting the 'so what' question that every research must and should answer.

2. Context – grounding the variables for sharing is critical and must be accomplished by capturing the context for how shared awareness may succeed or fail. *'The project'* provided the context for shared awareness towards the integration of the individual participants and the perspectives that were held by each individual.

3. Prose - meaning and understanding is lost within the technical and explicit structure necessary for this study, however, the emotional undertones of the project are necessary to convey the undertones that were at play within *'the project'*. Prose was used as a means to convey *'the projects'* undertones conveying a sentiment in *'the project'* that could not be conveyed in the study but critical for understanding shared awareness. It was not enough to quantify or qualify shared awareness but to also ground shared awareness within the practical boundaries for which it occurs.

The initial condition for *'the project'* found each agency providing a specific service to the collective goal of security; however, the brand of service and perspectives differed for each agency – different procedures, different processes, and different missions. The operational integration center that was developed for the organization was provided by an agency that viewed security in technical terms and obviated the expertise of the security operators as well as cultural behaviors and barriers within each security group, promoting an obtuse environment for sharing. Additionally, there existed a governing body that hampered the operators with both political and budgetary constraints. All these variables fostered mistrust, animosity, and resistance among the design team comprised of operators, program/project managers, engineers, and staff personnel. The conditions the participants found themselves in is referred to in this study as a complex situation, a situation so diverse that traditional methods for building a shared awareness of the problem and common purpose failed to meet the desired outcomes.

In 1994, the Department of Defense (DoD) set into motion a sequence of events that resulted in an unprecedented decision for change. The result of that decision was to stand up the Joint Forces Command (JFCOM or USJFCOM). The decision carried with it a mandate to change more than processes and doctrine, but more fundamentally, to change how the military thinks and behaves: a new paradigm, a paradigm that fosters 'jointness' or 'purple' behavior. The USJFCOM mission (to ensure all forces going into combat, anywhere in the world, would fight as integrated joint teams) was added to the command's existing Atlantic Ocean geographic mission (Kovacic, 2006).

Initial attempts at benchmarking USJFCOM, having professed to have had success in fostering 'purple behavior' showed limited value; purple behavior tended to have gross side effects (i.e. unique standards, one ups-man ship, isolation, etc...) that provided continued challenges for USJFCOM, eventually dissuading the team involved with *'the project'* to go with a mainstream technique for integration. Through a series of workshops and interviews the organization instead adopted a position of: "together but separate", a modality that allowed each agency to retain the necessary autonomy to apply their expertise while allowing for common resources to be shared by maturing a shared awareness of the problem. Although counterintuitive to integration and the idea of 'purple', this represented more accurately how they felt the mission could be achieved as a cohesive group. To facilitate this transformation an emerging construct 'complex situation' was introduced, and methods and techniques employed to assist the operator with evolving their environment into a syncretic whole. Accepting complex situations as paradigmatic shift had its benefits; the foremost was new methods (or re-interpretation of old methods) to solve integration of perspectives and the complexity that is engendered; complexity that was obviated through the maturation of a shared awareness.

Observations of the behavior of the individual agencies and the ensuing patterns toward a General Theory of Shared Awareness attributed to the key objectives for this study. It is the development of methods for facilitating shared awareness that is the focus of the remainder of this document through the methodical shift from a prevalent paradigm to a complex situations paradigm.

According to Thomas Kuhn, paradigm shifts are necessary to:

'Open up new approaches to understanding that scientists would never have considered valid before.' (Kuhn, 1962)

Brewer (2010) extends on this by putting forward a complex situation paradigm [later edited for accuracy and called PRISM, 2013] that provides a means for viewing the problem domain in a new way. With so many terms available to define the same thing, it would seem nearly irresponsible to introduce yet another term [complex situation, or complex situations paradigm] that appears to describe a phenomenological state [something systems already does]. However, complex situation infers both a broader meaning and imposes a differing perspective. *Complex*, in this context, is dependent on understanding and reality rather than observer and knowledge, and *Situation* imposes a gestalt that cannot be characterized within a singular perspective that relegates paradox to a hierarchically imposed primacy where the "squeaky wheel" gets the attention. This also infers that complex situation defies definition so much so that each attempt at a definition by a systems perspective is by default incomplete. Therefore the perennial derivations for system: complex systems, system of systems, federation of systems, stochastic, chaotic, dynamic etc… are no longer a sufficient descriptor for complex situation. Ergo, system and its genealogy lack the constitution to define complex situations. To wit, this dissertation provides the premise for a situation and describes the conditions that make it complex sufficiently for syncretic study by discipline(s), such as Engineering Management, in the proposed field of situations theory as implied by Sousa-Poza (2005) in Pragmatic Idealism and Brewer (2013) in PRISM, and the paradigm for which shared awareness is interpreted and studied.

1.3. Purpose

The purpose of this study is to demonstrate shared awareness, an emergent phenomenon, from non-linear, dynamic, and disparate perspectives. This is an inductive study based on the aforementioned project. Observations from *'the project'* are used to push the research forward along a coherent path as well as to put forth rational arguments that are substantiated using a modeling and simulation technique known as Agent Based Model (ABM). An ABM is a robust and universally accepted approach to conduct rational experiments where it is unrealistic or problematic to provide an empirical study, such as temporal constraints, magnitude of the population or subject under study, and non-probabilistic conditions affected by implications of complexity. The study proposes that the conditions of awareness at critical probability P(c) (referred to as the K-threshold), the state just before probability threshold [shared awareness] occurs, can be represented using techniques in statistical mechanics and studying the behavior just prior to and after K-threshold will provide sufficient insights for articulating a General Theory for Shared Awareness at the macro-level even though there is significant disparity in the differing perspectives at the micro-level.

1.4. Research Objectives

Does shared awareness occur within a nonlinear, dynamic situation? Whether it is an exchange of ideas, a joint project, or marriage, there is a presumption that each side has an understanding of the others perceptions, knowledge, or actions and that through this understanding sharing can take place, ergo, the ability to share is an implied attribute of the participants. Shared awareness implies more than the phenomenological nature that may be found in a common operating picture, or a dialog between a man and a woman. Shared awareness assumes sharing at a more intrinsic level as a participant; a level where the nuomenological nature of the individual has an influence on what is or is not shared. The objective of this study is to:

- Substantiate the K-threshold as a critical probability for shared awareness under pristine condition.
- Put forward arguments that hypothesize when shared awareness occurs between complementary perspectives.
- Articulate a General Theory for Shared Awareness.

1.5. Significance of this Study

Imagine, as a program manager, a governing member of an organization, or project manager of an IPT being tasked with unifying and leading a diverse group of individuals toward a common goal or mission. Imagine a perspective toolkit being available to that manager that predefines an individual's predisposed perspective as well as those perspectives that are readily accessible to the individual, to include a number that depicts the individual's propensity to shift among perspectives. The chances of the manager successfully navigating through the morass of perspective to form a common or shared awareness would increase significantly.

The value of percolation for shared awareness and understanding is that it shows the macroscopic potential of the particulate [ultimately emergence] and the critical state just prior to emergence. By observing the super-cluster as the whole based on the flow of information of the particulates two key studies can be conducted from this method. The first study would be the state of the Cognitive Representation of Reality (CRR) at P(c) and the second is the nature of the emergent second phase transition [emergence] that occur as P(c) is exceeded. The implication for awareness and shared awareness is it allows a simple and visual study of the state of CRRs just before probability threshold and the implications towards integration illustrated in the abrupt behavior change as a parameter value crosses a threshold. This study provides a pseudo case study [loosely followed steps for a case study] from a border security project. Each phase of '*the project'* is depicted in the study to convey concepts being proposed. The struggles encountered in '*the project'* serves as a means for highlighting the merits for this study, and more importantly a means for affecting integration in Engineering Management studies.

CHAPTER 2

LITERATURE REVIEW

2.1. Anthropological Journey on Shared Awareness

Humpty Dumpty sat on a wall

Humpty Dumpty had a great fall

All the Kings Horses, and

All the Kings Men

Couldn't put Humpty Dumpty back together again.

(An Introspect on the Nature of Nature, Sam Kovacic 2011)

Understanding complex situations is a journey into the history of the major influences on nature: science and philosophy, and the correlating premises that act as an anchor for this study. The journey is necessary for any chance of a shift in the paradigm to situations theory proposed by Brewer (2010, 2013), and Sousa-Poza (2013). The practical utility for providing this theoretical jaunt into reality and perspectives is to provide a generalizable meaning to the term complex situation and remove any historically contentious definitions that may be found within individual disciplines. Most importantly it is necessary to substantiate the propositions of a complex situation and how shared awareness would be defined and occurs within this paradigm.

Complex situations can best be represented as a narration of the influences on science and philosophy and the correlating propositions that can be extracted to describe complex situations. As such, a complex situation is a study of duality. It is these propositions that help bound and define the domain for a discussion. A review of literature in complex situations is more akin to an anthropological find than a systematic exploration stemming from a key concept or word. Complex situations as a subject for study is in its adolescent stage, however, its birth was nearly three thousand years ago. This is a narration of this history that provides a foundation for further discovery in complex situation and is core to the paradigm for which this work has been accomplished. Figure 1 provides the road map for which complex situations has traveled; pictorially describing the emergence of a paradigm meant to fill a gap that was created nearly three thousand years ago by one of the great Greek philosopher's: Aristotle.

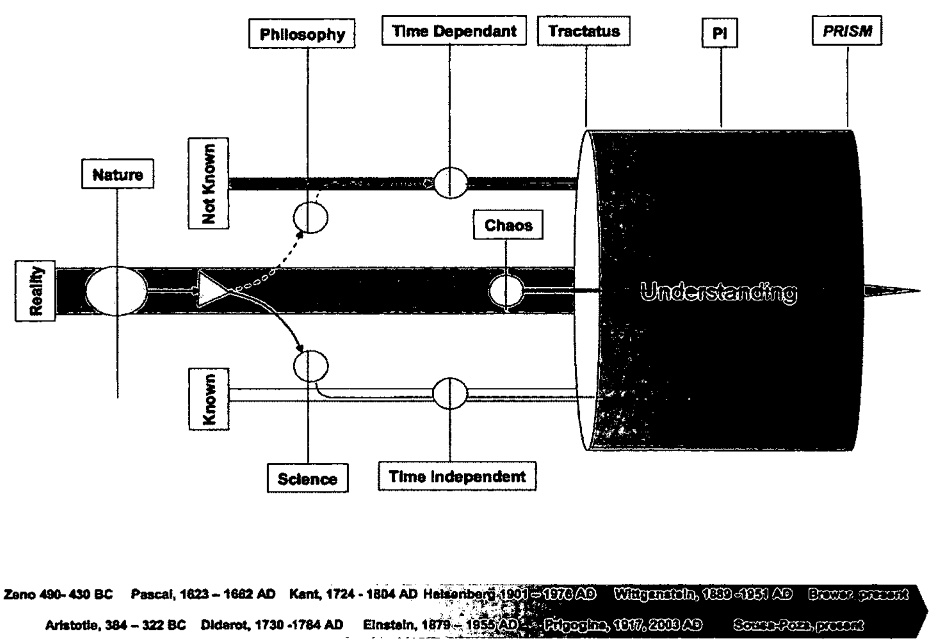


Figure 1. Anthropological Journey

A complex situation is a paradigm shift that was described nearly three thousand years ago by the Greek Philosopher, Zeno of Elea (Owen, 1957). Zeno proposed three paradoxes that illustrated the nature of the disassociation of the observer from a mind independent reality. These paradoxes illustrate that, as observers, we, in effect, dissociate from the continuum of 'reality' in order to study and understand the representations created by that being observed. In effect creating a duality, which will be describe later, in many cases, complements within the duality, and in so doing, this dissociation generates inconsistencies in the subsequent perspectives. These inconsistencies were highlighted in the paradoxes offered by Zeno. The paradoxes emphasized a duality in any perspective that provide the observer two equally correct solutions, in effect, creating inconsistencies in the generation of knowledge – or error. The flaws focused on the discrete nature of the perspective and the approximate distance created by the observation from the continuum [reality].

One hundred years later, Aristotle's proposition of science [a direct refute to Zeno's paradoxes] quickly dominated the discussion and set the condition for obviating the continuum and its implications as constants within the bounded domain (Wolf, 1989). Aristotle, however, found the universal in particular things, which he called 'the essence of things', For Aristotle, the philosophic method implies the ascent from the study of particular phenomena to the knowledge of essences (Sedley, 2003). This was so compelling that it dominated the dialog for hundreds of years - in fact it would be over two thousand years before the insights of Zeno were once again brought under the spotlight. It is from this starting point [the dialog of the Greek philosophers] that this anthropological find takes place, but not before acknowledging that Aristotle's interpretation of universals has dominated the dialog throughout history. This dominant discourse is nearly irrefutable empirically, and pervasive rationally, and is a main theme extracted from the observations of the project that this study builds from and the initial interpretation for working towards a general theory of shared awareness

In their book '*Order out of Chaos*' Prigogine and Stenger (1986) provide a chronology of nature and speak to the instability of science (in western culture) with regard to the loneliness of science as described by Pascal. "Science can only speak in terms of science and as such fails to elicit conversation in that which is not described in nature by science" (Prigogine & Stenger, 1986, p. 3). The authors use Pascal as a starting point to describe the bifurcation of nature: science and philosophy. From Pascal's work the authors turn to Diderot's radical attempt to limit or supplant science with a new perspective. Diderot provides the lens for how life can be explained. His contribution to the dialog was not to refute science but to suggest that science is not sufficient for understanding life [nature] (Prigogine & Stenzer, 1986, p. 80), which is informed by something more than science. This is highlighted by an imaginary conversation with the physicist d'Alembert.; that a notion of life as depicted in the process of an egg evolving to a chicken. His point is that evolution cannot be explained solely through the organization of living matter (replacing inert matter with active matter), Diderot states that "nature must be described in such a way that man's very existence becomes understandable" (Prigogine & Stenzer, 1986, p.83).

By defining knowledge in its own language, science loses its discourse with nature. Science is but one of the languages necessary for understanding; ergo objective knowledge is incomplete. It must be assumed in a situation that a discipline's ability to explain phenomena within the aggregate of its own boundary is myopic and integration with another discipline is problematic. Whether the failure is from the intractable nature of the individual disciplines or through the efforts of integrating misaligned perspectives generated from each discipline, the dialog will suffer from the ensuing uncertainty and the complexity that challenge decision makers. It is assumed that there is sufficient overlap between the two disciplines to overcome any integration issues, however, the gaps are generally obscured rather than addressed by the overlap.

This aggregation in disciplines leaves gaps in terms of understanding, each discipline is immersed within its own lexicon and axioms that is either subsumed by the other discipline or obviates it entirely. Within these gaps lie uncertainty and with it emergent and dynamic properties that constantly change the nature for how the problem is framed.

Emmanuel Kant took an antagonistic position in regards to science stating that: "*science is nothing more than metaphorical statements to include ideas of life*" (Prigogine & Stenzer, 1986, p. 86). The nature of his work was identifying two levels of reality as phenomenological (all that is accessible by the human mind) and nuomenological (all that is not accessible but transcends from spirituality). Kant supplanted science with philosophy as true knowledge. Kant's contribution of rational thought was depicted in the Copernican Revolution which stated: "*objective knowledge cannot be anything more than what it perceives*". Kant reverses this by stating the subject does not revolve around the objective but rather the object revolves around the subject ergo philosophy [transcendental] is the truer form of knowledge" (Prigogine & Stenzer, 1986, p. 87). Establishing philosophy as the dominant position in respect to science Kant was effectively able to stem the domineering momentum of science's grasp on understanding, however, although this parsimony violates Diedrot's point: '*there is no one language for nature*' – it speaks more to the primacy of participation towards understanding than did the ongoing discussions of his time.

Kant asserts a generalizable dialect in the transcendent state and effectively shifts the conversation to the gestalt but at the expense of actionable knowledge within the epistemic dualities. Again, the dyad of philosophy and science is lost within each language. It must be assumed that primacy be subscribed not from the knowledge gained by the individual ontology but through the understanding gained from an overarching goal [value premise] by which an evaluation for obtaining the goal can be made. A value premise unlike an attractor becomes the focal point for dialogs of all dialects to judge the merits of how they obtain the goal. A perusal of decision theory indicates that understanding while less empirical has a domineering role in decision making. Primary methods of utility theory and/or game theory exploit understanding as the mechanism for action rather than solely depending on empirical data in complex problems.

Whitehead (1947) turned the subjective experience to one of process; he accuses the math of science as being confused and wavering amidst the paradigm of three extremes: dualist, positivist, and the constructivist. Whitehead took a personal stand against science and suggests: "*the conceptual field within which the problem of human experience and physical processes could be dealt with consistently and to determine the conditions under which the problem could be solved*" (Prigogine & Stenzer, 1986, p. 94). Nicholas Rescher (1996) builds off of Whitehead and provides the foundational tenets for a process philosophy. Rescher states "*that a person can see reality as individual elements (substantive reductionist approach) or as a collection of elements (process holistic approach)*" (p. 19). He puts forward the laws of science are a process and we understand the laws because we are a part of them. This approach simplifies the need to digress back into a modality of science for a coherent view of nature (Rescher, 2000).

Rescher's (2000) approach speaks to the condition of the dichotomous existence of discrete and continuous variables within the same bounded construct. This affects how to study such a dualistic condition; a common approach, analysis, is to remove the variability within all entities but one and affect change only in that one entity. A process approach avoids the intransigence of perspectives, providing a temporal path that does not rely on deterministic modalities to affect sufficient causation to allow for understanding to occur. Instead of requiring a sequence of events to maintain a coherent perspective, or an amorphous boundary to capture unlimited random possibilities, a process inserts understanding through intuition as the means for causation to an end goal. Numerous methods for process engineering have been created recognizing the limitations of just a hard science approach to wicked problems.

Einstein introduced his idea of the wave and particle duality of light – that light can be both a particle and wave providing the impetus for Heisenberg's Uncertainty Principle and its devastating impact on efficient cause – re-addressing science's notion on causality and certainty (Wolf, 1989) - and inserting back the notion of final cause. In fact it was Heisenberg's (2001) theory that reached back two thousand years to validate Zeno's (as cited in Wolf, 1989) position of the disassociative nature of the observer with reality coupled with Bohr's (1949) idea of complementarity - that there is not a complete description of the system 'as is' independent of how it is observed that exemplifies Zeno's paradoxes. Wolf (1989), Sousa-Poza et al. (2005), and Brewer (2010) add their voices to the discord building a unified voice that speaks to the idea of a separation from reality. When observing there is a separation from the continuum and the disassociated construct of the domain (that which we perceive) – making statements across disciplines of the domain probabilistic.

These discoveries speak to the nature of holistic [as defined by systems theory] and the relationship of the observer to a mind independent reality. In the pursuit of knowledge disciplines are born and evolved. The evolution of each discipline is predicated by bounding assumptions that invariably insist on omissions necessary in other disciplines. Each discipline can also be complementary in nature. In an interview with Neils Bohr (1949). he advocated that:

"Evidence obtained under different experimental conditions cannot be comprehended within a single picture, but must be regarded as complementary in the sense that only the totality of the phenomena exhausts the possible information about the objects." (p. 2)

The mind-independent assertions of the positivist, and the mind-dependent assertions of the constructivist, are bounded by the paradigmatic imposition of the worldview or discipline of an observer. Each assertion speak to Godel's (Wolf, 1989) theorems of completeness and incompleteness providing insights into the idea the holism or particularism in itself cannot represent the total picture. Holistic approaches are fundamentally contained within a discipline. The ability to function in an interdisciplinary manner is contingent on the degree to which shared awareness or understanding can be established from perspectives that are derived from different disciplines. However, the implications would assert that to affect sharing in an interdisciplinary study would require acceptance of the potential bifurcating nature of interdisciplinary studies. In simple conditions where the axiomatic limitations of complementary perspectives are not challenged a high degree of shared awareness is possible. The necessity of an interdisciplinary approach is, however, obviated by the correspondence of the conclusions that may be drawn by any one discipline. However, in complex conditions where uncertainty becomes more prevalent, the axioms that dictate the bounds of knowledge are challenged across interdisciplinary approaches and shared awareness suffers, creating a bifurcation that is reflected in Bohr's (1949) complementary principle.

Continuing with the narration, it becomes apparent that much of the discord can be subscribed to complexity. Hegel (as cited in Prigogine & Stenzer, 1986,p. 90) obviated the reductionist theme of science and the arrogance of speculation found in philosophy and proposed levels of complexity that correspond to the complexity in nature and to the concept of time. Hegel put forward levels that reflect the increasing complexity of nature and a concept of time that would make each level richer. Although his philosophy never gained traction it was not due to the philosophical notion but rather the conditions that he builds his philosophy were made obsolete with the discovery of an alternative to classical physics – quantum. Bergson (as cited in Prigogine & Stenzer, 1986), however, maintains Hegel's (as cited in Prigogine & Stenzer, 1986) theme when he put forward the idea of speculative knowledge. Bergson posited that science is a whole (vice Diderot) that must be understood through rational intelligence, he states that, "rational science is incapable of understanding duration since it reduces time to a sequence of instantaneous states linked by a deterministic law" (as cited in Prigogine & Stenzer, 1986, p. 92). Bergson chose to avoid the conflict between philosophy and science in favor of something new, a philosophy that chose to address the problem of time and complexity in favor of intuition.

The necessity of simultaneously maintaining multiple disciplines can only be argued from the position of their indispensability to address a [complex] problem. For this, we must establish the limitation of the tendency towards an orthodox [single discipline] position when challenged with the complexity of perspectives within a problem.

Within a discipline, the bounding of a problem is dictated by the principles and axioms that underlie the discipline itself. This act of bounding, however, not only influences the perspective(s) that can be supported, but the very manner that the problem and reality are perceived. The discipline in this sense will become "the hammer that makes everything look like a nail". The highest degree of comprehensibility will be marked by the nature of the bounding. Optimizing within this bound will maximize the understanding that is generated by a perspective, but will, based on the theory of complementarity (Rosenfeld, 1961), become increasingly polarized and inaccessible by other perspectives. In the problems where a satisfactory solution is identified within the comprehensibility that a perspective can provide, an orthodox position is warranted. If such a solution is however not possible within the constraints imposed by the comprehensibility of a perspective, adopting an alternate perspective, as is the case in reframing, might be possible. For truly complex problems any perspective will provide a local perspective, but will be unable to generate a sufficiently global construct to generate a suitable basis for further action. Thus, a paradoxical condition is set where multidisciplinary approaches can be enacted where they are not required (simple problems), and become impossible to adopt where they are necessary (complex problems).

It can be argued [effectively] that the term complex situation is redundant; however, in so doing much of the history and insights [context] that were generated to reach this state of awareness is lost. To go from the dictionary to a complete understanding of complex situation is incomplete without making the journey into the history. It is anticipated that over time the two words will become a term that, although redundant, speak to the many challenges that were overcome to recognize this nuance. Until then a discussion of complex and situation are provided as if they were not redundant words.

2.1.1. Theories of Awareness

Isn't it strange how this castle changes as soon as one imagines that Hamlet lived here? As scientist we believe that a castle consists only of stones, and admire the way the architect put them together. The stones, the green roof with its patina, the wood carvings in the church, constitute the whole castle. None of this should be changed by the fact that Hamlet lived here, and yet it is *changed completely. Suddenly the walls and the ramparts speak a different language...Yet all we really know about Hamlet is that his name appears in a thirteenth-century chronicle...But everyone knows the questions Shakespeare had him ask, the human depths he was made to reveal, and so he too had to have a place on earth, here in Kronberg (Werner Heisenberg, 1972, on the occasion of a visit at Kronberg Castle)*

The Oxford English Dictionary (OED) defines awareness as:

'having or showing realization, perception, or knowledge' (OED, 2010).

The benefit of a good definition is that it is specific enough to provide usefulness in practice, yet generalizable enough to be applied in all applications. This definition of awareness is a good one. Hence, it is incumbent of this paper to establish the context of the use of awareness, to wit the bulk of the anthropological findings [propositions] provided previously in this document are applied toward arguments that can be tested.

If the context of this definition is 'complex situation' then the theoretical application can be found in the culmination of the works from Henderich (1995), Sousa-Poza (2005), and Brewer (2010). The following is an interpretation of the three seminal works on situations theory relevant to this paper. The principles cited are not sequential in nature of their work but extracted for their relevance for establishing how awareness is used in the context of this document.

Wittgenstein (1995) posits that: 'the world is all that is the case' which is echoed in Brewer's (2010) work as the 'Reality Principle' This principle set the axiomatic undertone for the ontological depiction of Brewer's (2010) Complex Situation Paradigm (CSP) and subsequent PRISM. Its significance emphatically states that reality "exists in and of itself"..."which is both separate and part of the observer and is beyond the observers full understanding" (Brewer, 2010, p. 60).

The second principle from Henderich's (1995) contribution: "What is the case—a fact—is the existence of states of affairs." Mirrored by Brewer (2010) as the Awareness Principle, which sets the notion that time and change are common to awareness and adds/contributes an additional principle of self-awareness which introduces awareness as a unique perspective embedded within the whole (Brewer, 2010, p. 61).

Brewer (2010) goes on to discuss the limitation of knowledge and the duality of cognition; that knowledge cannot exist *in toto* within awareness and as it exist within reality. This suggests an error in all knowledge that is always present but cannot be completely bounded.

Both Henderich (1995) and Brewer (2010) speak to the truth in knowledge in Wittgenstein's third principle "A logical picture of facts is a thought" or Brewer's CRR Principle, 'the result of awareness is a cognitive representation of reality (CRR)' (p. 64). The significance is the acceptance of a mind independent reality where a 'CRR is reflective of reality and is therefore reactive to changes in reality which is contained in the domain of awareness' (p. 66).

Brewer (2010) further discusses the limitations of the domain of awareness as its imposition of those limitations on the CRR which again establishes its fallibility. All this boils down to accurately representing reality in relations to awareness and domain of awareness as "the portion of reality that is accessible to the self-aware entity (p. 64). This suggests that understanding exists not only within the domain of awareness but also within the CRR [CRR ϵ awareness] within the domain.

Throughout this diatribe little has been said of Sousa-Poza's contribution to awareness and yet it is reflected in the work of Brewer (2010) as well as reflects Henderich's (1995). Where the latter authors argue effectively of the nature and relationship with reality it is Sousa-Poza (2005) that provides the ground work for framing knowledge and understanding within this framework. Brewer (2010) alludes to knowledge being incomplete this is seen in Sousa-Poza's (2011) duality of understanding where understanding is a condition of knowledge and not-knowledge (Fig 3).

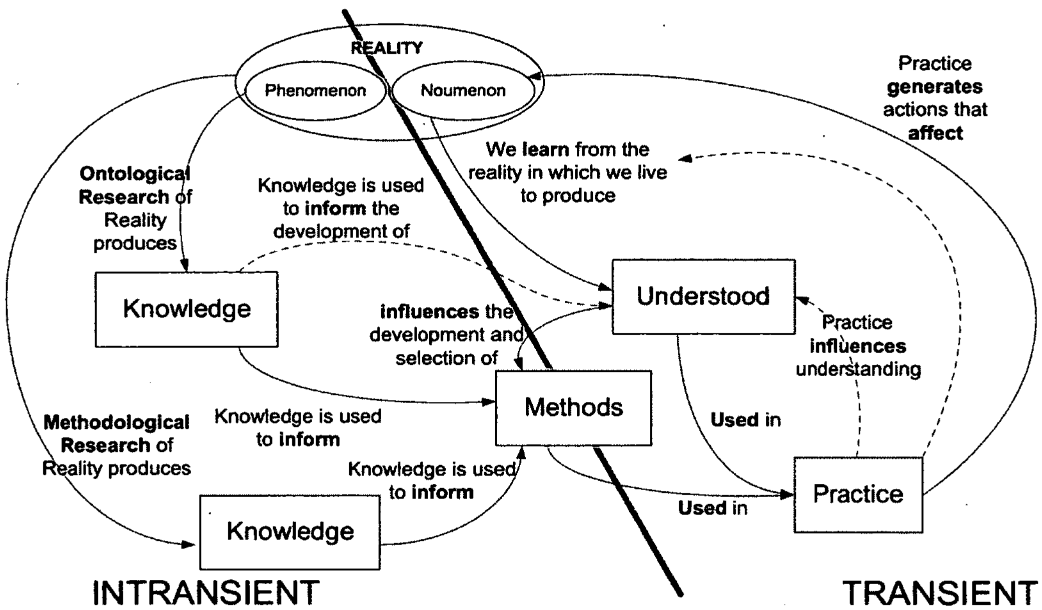


Figure 2. Duality of Understanding

Sousa-Poza's and Brewer's work establishes awareness within the concept of a mind-independent reality for which self-awareness contains all that can be known and not-known within the generative process of awareness. It also commutes structure from this cognitive awareness to the Domain of Awareness.

Bootstrapping this dialog back to the OED's definition of awareness provides the context of how awareness is being used in this dissertation:

"having or showing realization *[a self-generative process and structure],* perception *[that forms a picture of reality],* or knowledge *[for which understanding can be established]"*

The duality that is suggested by Sousa-Poza (2013) and Brewer (2010) is mirrored by Einstein and the treatment of the observer by Heisenberg (as cited in Wolfe, 1989) and Bohr (as cited in Wolfe, 1989) become significant in the construct of situations theory. This thread necessitated a construct of knowledge that has a corresponding component to 'not-'. Padilla (2010) elaborates on the complex situations model described by Kovacic et al. (2006) that in effect: "reflects the entity of the situation in a temporal and spatial scale, but also associates the solution form to the capability of understanding through the observer's personal profile" (Padilla et al., 2007, p. 2).

The difficulty in awareness is its close ties to knowledge that is to say that if one has knowledge of the state of an environment he has an awareness of himself and those around him within the environment. (Greenberg, 1999; Gutwin, 1999). This is problematic for a complex situation; this is supported by both Henderich's (1995) dialog and Brewer's (2010) principles of awareness as the dissociation of self-awareness and Sousa-Poza's (2013) approximate distance from a mind independent reality. For Gutwin (1999), awareness is based on a state that maintains a relationship with its environment and Brewer (2010) it is more on the recognition that the act of awareness and self-awareness that generates the bounding of a domain and subsequently recognizing the duality in understanding that this creates. By default any knowledge statements will have a degree of fallibility due to this disassociation.

The value for characterizing awareness and self-awareness in terms of shared awareness is:

1. Paradigmatic new worldview – accepts the fallibility of its own perceptions and knowledge and allows for the acceptance of a differing perspective.
2. Generalizes concepts such as complexity. Complexity is no longer commuted to the positivist or constructivist observation rather to the cognitive act of self-awareness. This concept provides a more universal application of complexity because it is the act of cognition, that sets the condition of complexity rather than the observation and analysis of a state, which can vary greatly among perspectives.
3. Tackles the ontological concept of the whole as a representation of reality, and the domain of awareness as that part of the whole available to the entity.
4. Places the observer into the situation as well as outside.
5. In this context the interactions of the particulate (ΩCRR) becomes the medium for shared awareness to occur and the flows of information that are commuted through dialog and purposefulness.

This suggests that knowledge, as an irreducible and transient condition, is imposed by predispositions of the observer in complex situations. It is the knowledge from the domain combined with the non-knowledge of the observer toward a value premise that creates the condition for understanding. This reinforces Sousa-Poza's (2013) duality of understanding and that knowledge and not-knowledge form the basis of understanding.

Complex Situations Paradigm (CSP) is an internally consistent philosophical foundation for complex situations (Brewer 2010). Brewer threads Pragmatic Idealism, proposed by Sousa-Poza et al (2005), inextricably into the foundations of the paradigm. CSP later expanded under the banner of PRISM provides the epistemic, ontological, axiological and methodological principles necessary to be labeled a [emerging] paradigm Important within Brewer's (2010) work is the definition of Cognitive Representation of Reality (CRR). CRR is: "a representation of reality in the cognitive domain that acknowledges knowing refers to something known and fundamental in comprehensibility of reality" (p. 64) The value premise principle forms the basis of action based on comprehension. Brewer (2010) also provides a definition of a situation specifically: "that a construct to frame discussions of complexity relative to reality, or a portion thereof; a self-aware individual (one or more), and the individual's CRR" (p. 64). The CRR becomes foundational to the study of situations theory and how the duality of understanding can be leveraged for sharing between CRR's. Fundamentally the CRR provides the mechanism for entities to shift from one perspective to another and affect sharing.

2.1.2. Workshop 1

The attendees for the first workshop were a mixed bag of 'staffers' from a program office, system integrators, and operators. The obvious isolation imposed by each group was noticeable based on where each member (or in this case group) sat in the room – each group segregated themselves from the others. This anomaly alone was significant in addressing the issue of integration. Key to the idea of integration was the transformation of an individual or group into an amalgamation of all the parts necessary to make the whole. This process resisted emergent conditions by projecting an end-state, or series of states, and making corrections along the path towards the end-state. These corrections extenuated the emergent effect rather than obviate it creating a dichotomy within the purple construct – a tension between identity of the past and that of the future. The fact that the groups (all familiar with each other over an extended period of *time) had isolated themselves and expected to coalesce along a common goal was very optimistic. Communication amongst the disparate groups was as disjointed as the groups themselves – each framing the problem within their own axiological conditions – creating misinterpretation of the simplest terms. The first workshop was a bottom-up exercise of 'climbing the slippery slope'. That integration from the particulate was going to define the whole; a top down approach within the same group would have been just as problematic. Ultimately, each agency recognized the complementary nature of their perspectives towards providing security and choose to pursue a method that would allow for them to share, as needed, while allowing for the ability to 'shift' back to their predisposed worldview as necessary – a syncretic effort of together [the whole], but separate [the particulate].*

The purpose of the first workshop was to convey the foundation for which a complex situations paradigm could exist. The evolution of "together but separate" could only be accomplished if the participants could let go of close hold beliefs that they could design integration through careful reconstruction of each reduced perspective. Emphasis was put on the random nature of the environment and its ill-effect on explicit pursuits of analysis. The workshop focused on the primacy of time dependent process approaches to define their actions in order to respond to the emergent conditions they found themselves in. This led the operators to reconsider the need for transforming their identity in lieu of a more uniform perspective that they felt necessary to view their purpose [together] while at the same time maintaining their autonomy [but separate] so they could exploit the unique talents that they were trained for. This was a critical break-through in their shift to a CSP. They no longer looked at the sequential nature of getting from point 'a' to 'b' as a collective but adopted a 'phased space' that accommodated learning within a shared domain populated by the disparate groups using a common lexicon: action – the catalyst for this learning *was through the participation and actions of each separate agency as they worked together – facilitated by a ecosystem that enhanced such activities. This construct would allow for the interactions of implicit behaviors and change across the group in the form of learning through algedonic feedback. This acceptance of complex situations as paradigmatic shift reflected in their ability to shift from a rigid protocol for utilization of tools to a less rigid protocol that dealt with adopting the idea of 'freedom of adaptability' – selecting tools as they are needed rather than when they are imposed. The decoupling modality restructured their old methods as well as introducing new ones. Use of lightweight technology ensured flexibility and increased the acceptance of tools by individuals allowing integration to occur over the process rather than the data. A process driven approach that supplanted the system process with a human process making technology a slave to the operator rather than the other way around was proposed. Additionally, a time dependent meta-construct for group planning was devised to foster togetherness while allowing for the individual planning activities to occur independently.*

2.1.3. Framing the Problem from Deterministic to Situational

The value of complex situation is realized in how a problem is framed. Brewer (2010) speaks to the positivist and constructivist problem framing approaches towards resolving complexity. The positivistic approach, often seen in empirical studies, assigns complexity to the objects being observed, allowing for measurable experiments with quantifiable results. The constructivist approach, found in rational studies, assigns complexity to the observer him or herself. Although no less quantifiable the methods employed are often a source of controversy for positivistic approaches both approaches, however, address the problem in the same way. Within any given discipline the technique is to reduce from the whole a state with elements and 'lock down' all but one of the elements (an example would be to freeze the observer and solution form to remove any effects from variability [change] within those elements). All variability is derived from the entity (the remaining element). By doing this a method can be executed that will give a realistic analysis of the accuracy of the knowledge generated from the entity. The limitation of this approach is that by removing variability from the other two elements the knowledge of the whole becomes dichotomous and incomplete to the elements and the results open for debate. However, by changing this criterion so that variability is accounted for in all three elements new ways for dealing with the problem can be addressed, particularly in wicked problems (problems with no apparent solution (Kovacic, 2006; Webber, 1973) which are typically found in complex situations.

In a wicked problem, each perspective provides a differing way to view the problem and subsequently differing methods and processes to solve them. The dichotomies that are generated from these disparate perspectives can no longer be assessed using conventional definitions of complexity. A generalized definition of complex must be postulated to address the issue of wicked problems in complex situations. This can be effectively illustrated in how to address complexity within a situation.

2.2. Complex[ity]and Awareness

As stated earlier in this study the term 'complexity' proposes its own unique challenges. It is uncertain how many uses the word 'complexity' has found in the English language; as such it would be remiss not to frame how complexity is currently being used.

> *"A key difference between current cybernetics and complexity theory is the use of different epistemology. Complexity theorists use a realist epistemology and assume that complexity exists in an observed system, or perhaps in a computer model. Cyberneticians use a*

constructivist epistemology and assume that the system of interest is defined by the observer." (Umpleby, 2010)

This theme for how complexity is perceived and dealt with resonates within the research communities of many research and academic institutes, Umpleby's (2010) comments are foundational in BarYam's (2010) New England Complex Systems Institute (NECSI) where research explores both facets unilaterally. Complexity, a major division within the Santa-Fe institute has taken a multidisciplinary collaboration approach, and the University of Michigan's Center for the Study of Complex Systems encourages research in nonlinear, dynamical, and adaptive systems. Additionally, complexity is an integral thread in many centers: the National Centers of System of Systems Engineering (NCSOSE) invokes complex systems in their mission statement as does the System of Systems Center of Excellence (SOSECE). Sousa-Poza et al. (2006), however, opens a unique door and suggests that complexity is tied not only to the observer and how he or she perceives but that the observer, as a participant, is a major contributor to the complexity, insinuating both a pragmatic and fallible component to complexity.

Sousa-Poza et al. (2005) introduces complex situation in the seminal paper titled 'Pragmatic Idealism'. The paper was the first instantiation of a budding idea that was germinating at a time with a small cadre of researchers when system of systems was gaining traction in the research community. The paper's intent was to set the philosophical foundation for how to "understand and address complex situations" commuted from the idea of System of Systems. It accomplishes this by establishing the relationship of what can be known (the domain) from all that is (reality) and follows up with the systemic perception of what is perceived of the domain. Sousa-Poza et al. (2005) postulates that the increasing attention given to new methods is due to the increasing complexity of the situation being addressed (Figure 2.3). This postulate provided the segue necessary from complexity as a condition of a mind dependent reality to a more generalized concept of complexity as a mind independent reality – essentially complexity exist from our attempts to understand rather than how we perceive our environment.

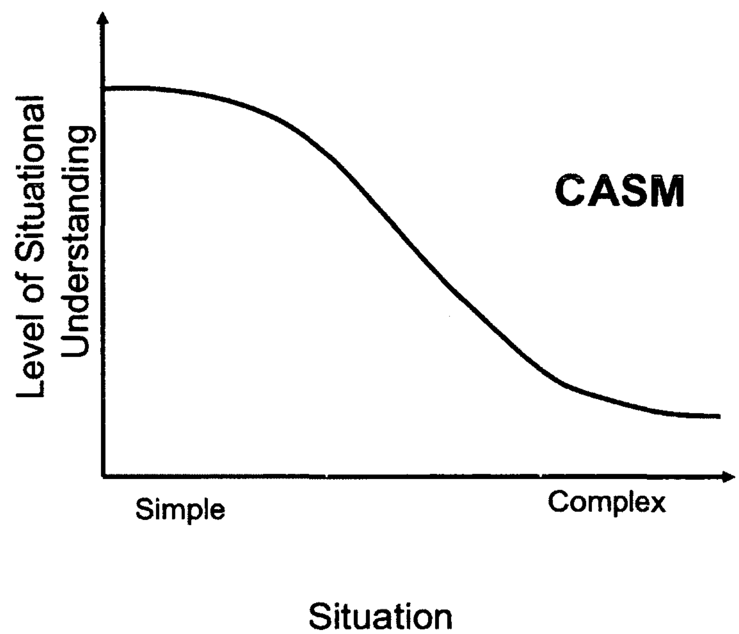


Figure 3. Understanding and Complexity

This was the first attempt to treat complexity as a condition of understanding rather than observation. Pragmatic Idealism (PI) provided a keystone component, subsequently used in the study of situations theory; a working definition of complexity – *...complexity is proportional to the probability of having/making and erroneous knowledge claim. ($\rho(\varepsilon)$)* (Brewer, 2010; Kovacic, 2006; Padilla, 2007; Sousa-Poza et al., 2005). This definition recognized the edict that a systemic perception is a function of the domain, not reality, and that the approximate distance between reality and the perspective is due to the less than perfect perspective of reality through the domain, including the error in the knowledge claim as a result of this separation. This concession imbibes the idea that ..."complexity is defined as a construct associated with the fallibility of understanding" (p.2).

> *"Drawing on the concepts of Pragmatic Idealism Brewer (2010) establishes that there is a reality which cannot be known. Within this reality we must define a domain on which we focus. The bounding of the domain, becomes a crucial step to reducing A(d') The distance between the domain and reality ,A(d") the distance between the domain and the perspective, and consequently A(d) our perception of reality." (Sousa-Poza et al., 2005, p. 2).*

Brewer (2013) continued to build on this theme and introduced CSP and later PRISM as a philosophically grounded paradigm and worldview. In Sousa-Poza's (2005) Pragmatic Idealism and Brewer's (2013) PRISM, complexity is commuted to fallibility and the error that is generated as we try to understand a complex situation. Statements of reality are possibilistic and commuted onto the domain. In affect complexity is studied not in terms of entities and relationships but in terms of the amount of error created and its effect on understanding.

2.2.1. Workshop 2

The operators in Workshop 2 brought a different tone from the group than was expected – the enthusiasm generated in the first workshop had eroded over the time-span separating the second workshop from the first. With the difficulties of conveying simple principles across paradoxically regulated agencies – there was no compromise, nor, had there been any give and *take between the service providers and the operators – the positive results from Workshop 1 crumbled under the dominant discourse. The purpose of Workshop 2 was an aligning of CRR's such that a holistic awareness could be fostered. Considerable effort was placed on defining scalar laws by addressing issues and challenges associated with strategic, operational, and tactical perspectives. Reconciling the perspectives with the documented assumptions from the group as a collective was intended to insert another nick in the dominant paradigm and insert new insights from CSP. The result was less than stellar, by the time we had realized the tone had taken a belligerent shift between the participants it was too late. The presentation itself was used as a catalyst by the participants for taking 'pot-shots' at each other – 'a he-said, she-said' argument.*

The silver lining in the entire workshop was the discussion of tools that were being developed necessary to adopt their integration philosophy of 'together but separate' were still deeply rooted within the CSP and was about the only thing that the entire group could agree. However, the tools were not without receiving their own battle scars, as the evolutionary development process (conducive to a CSP) was enforcing its own dichotomous requirements that threatened to denigrate the news tools to the standard tools.

Ultimately, the workshop ended in a resounding yes for the tools – with an even more resounding threat to the developers to "get it right or get out" by the next workshop. This was disheartening in the sense that using an evolutionary protocol for aligning paragraphs assumed gross amounts of error in the beginning and as the process evolves sufficient error was removed for alignment to occur. Compressing this process was going to be a major hurdle not only technically but as in terms of maintaining the synergy from the group to continue on.

2.2.2. Premise of a Complex Situation Paradigm

So long as I keep before me the ideal of an absolute observer, of knowledge in the absence of any viewpoint, I can only see my situation as being a source of error. But once I have acknowledged that through it I am geared to all that it is gradually filled with everything that may be for me, then my contact with the social in the finitude of my situation is revealed to me as the starting point of all truths, including that of science and, since we have some idea of truth, since we are inside truth and cannot get outside it, all that I can do is define a truth within the situation. (Merleau-Ponty, as cited in Prigogine & Stenzer, 1986, p.299)

A complex situation is a paradigmatic worldview that necessitates premises that allow for sufficient boundaries to explore within situations. These perspectives can be found in the recent exploration of the history of complex situation and are extracted as propositions for this study of awareness within situations theory.

Proposition 1: Mind independent reality necessitates self-awareness, and the awareness of others and a disassociation of the observer from reality. White space is an irreducible concept that is commuted to the whole throughout the scales of perspectives, imbibing universality from the scalar issues associated with perspectives. Study within a holistic perspective cannot be parsed to differing disciplines such as trans-disciplinary studies with the intent of integrating later.

Awareness is the condition within a mind independent reality.

Proposition 2: Knowledge and not-knowledge form the basis of understanding. As such knowledge, by default, as a bounding construct imposes error in terms of what can be made known. Understanding is process oriented that considers beyond the epistemic and ontological tenets of a mind dependent reality. Complexity is commuted to fallibility and the error that is generated as we try to understand a complex situation. Statements of reality are possibilistic and commuted onto the domain.

Awareness implies the dissociation from a mind independent reality.

Proposition 3: The observer in context with reality is not a zero-sum solution. Change is a condition of a situation motivated by a purposeful end [value premise]. Situations include the observer, the domain, and the solution form. This speaks to the propensity to obviate variability that exists within two or more dimensions. It infers an influence of the continuum that cannot be ignored within the study of the substantive object, and speaks to a process approach towards solutions within complex problems. When observing there is a separation from the continuum and the disassociated construct of the domain (that which we perceive) – making statements across disciplines of the domain probabilistic. Participation and dialog are key to shared awareness and understanding and must be accounted for within the holistic construct of a complex situation.

At the heart of the dialog there is an assumption of an ultimate purposive end that creates the need for a self-aware individual to make a choice.

2.2.3. Implications of Complex Situations Premises on Awareness

There is a reality that is external and yet given immediately to the mind...this reality is mobility. Not things made, but things in the making, not self-maintaining states, but only changing states, exit. Rest is never more than apparent, or, rather, relative. The consciousness we have of our own self in its continual flux introduces us to the interior of a reality on the model of which we must represent other realities. All reality, therefore, is tendency (Henri Bergson, an Introduction to Metaphysics, 1912, p.65)

PRISM is an axiological consistent perspective of reality [value premise] that subsumes individual perspectives and languages within it. PRISM deals with Complex Situations, both philosopher [Wittgenstein] and physicist [Brewer] would agree that the value of PRISM places value on understanding over knowledge and the understanding is increased through dialog and participation, rather than the engineered integration of methods and axiology (Adams & Keating, 2011) where in a broad sense, axiology is dependent upon an ontological foundation - whether its derivative of this same foundation remains to be examined.

Within the construct of situations it is less a matter of taking all perspectives into consideration as it is recognizing that each perspective generates its own situation.

Summarizing the relationship between the fore mentioned correlated propositions to CSP and the implications to shared awareness are:

Proposition 1.1: CRR a self-generative process and structure. CRR € Awareness. The output of the generative process is perspective and resolution (Brewer 2010). Further, it provides the pragmatic assertion of a mind-independent reality in order: ...to serve as a basis for inter-subjective communication...to furnish the basis for a shared project of communal inquiry... (Rescher, 2000, p. 100). As CRR's increase disparity is introduced into each perspective. However, it is the mutually generative nature of process and structure that create an algedonic response from reality that asserts an understanding beyond that which is known within the structure.

Awareness is shared via a common generative process and the willingness to change perspective within the CRR's.

Proposition 2.1: Action is derivative of understanding. What is understood is derivative of knowledge and not-knowledge. Knowledge can only be formed of intransient aspects of reality (phenomena). Not knowledge captures transient aspects of reality (noumena). Universals form the element from which knowledge is defined and non-knowledge can be commuted.

The effect on awareness is a perspective that accounts for both knowledge and not-knowledge as understanding and a framework for sharing.

Proposition 3.1: What is understood is conditional on the inclusion the observer and the action orientated construct of participation. Understanding is the change of the whole as change is generated within the entity and how the domain of awareness is perceived, as well as change reflected in the amount of error represented in the domain of awareness of reality.

Awareness can be shared through purposeful action commuted via inquiry amongst entities.

2.2.4. Workshop 3

By the time Workshop 3 of 'the project' had begun all discussion towards working for a better solution for 'together but separate' had ceased. The group had split among two factions. On one side stood the operators, all willing to evolve the concepts into workable solutions. The purpose for the workshop was to begin work on analytical tools to provide insights into the dynamics of their daily lives. What actually occurred was a reckoning – justifying the problem, the paradigm, and the development to the opposing camp – the program office. Since the program office was predominately unavailable from the beginning and there was no opportunity to evolve a common dialog and vocabulary with the group – the discussion became contentious from the start. Coupled with the inherent disparity created from the development process it quickly neither became apparent there was no shared communication nor shared ground from which to have a *discussion. The two sides parted, bristling with indignation for time wasted over the span of 'the project'. Workshop 3 never began, a line in the sand had been drawn and a date set to make a decision whether the project was to continue and the metrics for the decision clearly sat in the opposing camp. From this point an intentional disassociation from the program office began putting the operators into the role of ombudsman for the future of their newly acquired understanding of a complex situation.*

2.2.5. Situations Theory

In an attempt to formalize that which has only been addressed in a haphazard and uncoordinated approach Sousa-Poza (2013) captures the essence of situations theory hinted at in other articles. Sousa-Poza defines situations theory as:

> *"A set of conditions that we expand on with the requirement that an individual 'is' or 'becomes' cognizant of the set of conditions" (Sousa-Poza, 2013)".*

Situation theory makes possible the study of shared awareness in the context of not only awareness of the domain but also the impact of participating in that domain providing for the markers to determine when sharing has occurred.

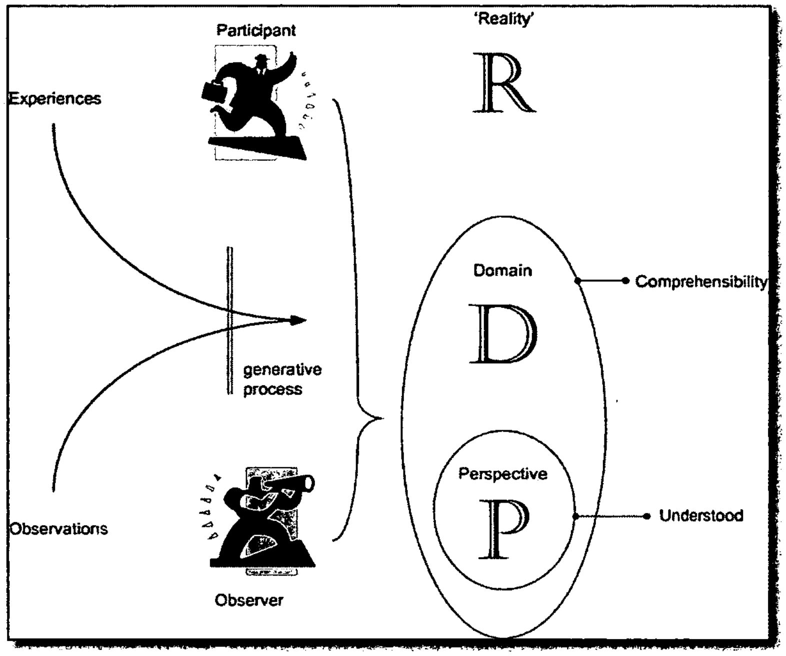


Figure 4. Domain

The domain in this sense represents what is comprehensible to the individual, given a specific point of view. The combination of experiences and observation of a problem resulting in a perspective of the problem form the elementary building block of the environment (Sousa-Poza & Correa, 2005).

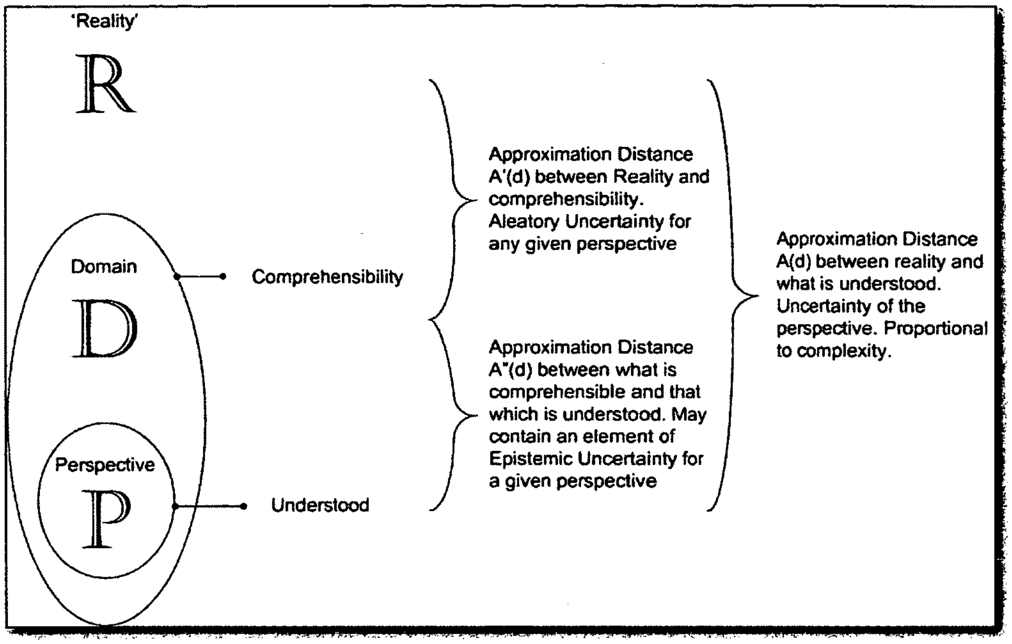


Figure 5. RDP – Reality, Domain, Perspective

Actions (very generally defined) are the result of what is understood of a problem, not what is known. What is understood is dependent on knowledge and not-knowledge; as well as the sense-making approaches that are applied. The manner in which the perspective is formed will dictate the degree to which a problem is understood. The formulation of the problem domain (problem frame) by the individual will constrain what is understood.

2.3. Shared Awareness

'[T]he project' was on a rapid decline towards self-destruction. Failure to generate a shared awareness of the problem, a common value premise, and a contextually robust open communication marked the demise of the 'the project". In hindsight, what was perceived as shared awareness was merely presumed acceptance of a path ahead that ultimately turned out to be only accommodations for future posturing. Failure to align perspectives resulted in the

cannibalistic frenzy for ravaging any bipartisan effort, within the groups as well as across the groups. A shared awareness and purposeful end was supplanted with subterfuge and rhetoric. A proposition was put forward that clearly split the group along two factions, the lack of common purpose generated animosity and distrust (nearly contempt) from each crowd. The method of choice for a decision was power-plays and threats. Although a subsequent meeting was held to attempt to gather support for the project once again, it was participated only from one faction of the group (with a token representative from the other). This was mistaken as victory and in the ensuing couple of months a misplaced truce was called, in the end this was the downfall, while one side waited the other side set the condition for the coup de grace *and the project was cancelled without any more fanfare than an email at the eleventh hour.*

The earlier definition of awareness and the poignant failures within 'the project' form the basis for the remained of this study and inform how shared awareness is defined.

The definition of awareness effectively establishes the criteria for shared awareness as change; the willingness to adapt to the situation and change perspective to maintain a common understanding. Brewer (2010) suggests that awareness is shared based on a common [value] premise. Sousa-Poza (2013) would contribute that the value premise is conveyed both in the particulate of knowledge as well as the universals of understanding, and Henderich (1995) would posit that shared awareness is achieved through dialog. This leads to an articulation of the characteristics for sharing to occur within awareness.

Friedell (1960) suggest common sense [found in the larger homogeneity] of the situation as a cornerstone for understanding through shared awareness. A problem with knowledge statements (confounded by the duality of understanding) is the complexity of the propositions put forth, the bigger or more complex the proposition [given the exponential uncertainty of white space] the more difficult it is to be said it is shareable knowledge. Understanding by virtue of awareness assumes an alternative proposition of common sense; Friedell (1954) postulates that propositions that are logically believed [common sense] form the basic structure of shared awareness and understanding. Brewer (2010) postulates, a comprehensible systems perspective requires a shared domain of awareness between two comprehensible resolutions operating at the scale of the whole and at the particular.

Finally, the idea of shared awareness - a putative quality of organizations – is seen from the CSP perspective to represent several intersecting domains of awareness across multiple CRR's (Brewer, 2010). Regardless of how it is captured it represents potentially a shared method and context. This resonates with Friedell's (1954) interpretation of common opinion or to generate sufficiently compatible domains of awareness across individuals. This approach would emphasize research into the desired structural characteristics of the entity (Ω CRR's) within the shared domain, including the representation of organizational value premises, in order to facilitate concerted action (Brewer, 2010) and becomes the momentum for this study and proposing an interpretive framework for understanding.

The relevance to the discussion at hand is simply that awareness can be shared and measured. Brewer (2010) proposes resolution and granularity (as its inverse) as the characteristics of structure as a means of denoting shared awareness and that an interpretive framework for understanding (see Figure 4) is such that within the space for understanding exists the potential for a second order phase transition (change in reality through multiple CRR's) to occur where awareness exceeds the critical probability of maintaining its own awareness in exchange for an emergent construct of shared awareness based actions of the entity, movement towards a value statement as noted in action science (Argyris, Putnam, & Smith, 1985).

Individual actions that are executed with the purpose of establishing across individuals: respective CRR's; respective generative processes for CRRs; respective structural characteristics of CRRs, and reliable method and context asserting they are reflective of reality may be broadly grouped within the general notion of information/communication (Brewer, 2010).

The construct for knowledge requires mutually intersecting domains of awareness, essentially generating respective representations of reality that are sufficiently congruent to establish a shared context (Brewer, 2010). This leads us to the stipulation of assumptions for which shared awareness can be studied.

- Awareness can be shared between individuals.
- Information flows between individuals.
- An entity can have numerous CRRs.
- The result of the flow of information amongst individuals is the potential for shared awareness.
- Shared awareness establishes shared context and subsequently understanding.
- Spatial and temporal interpretations form the basis of understanding.

CHAPTER 3

CONCEPT

3.1. Nature of Shared Awareness

There is a notable lack of literature on shared awareness beyond the definitions in dictionaries; journal searches yield limited descriptive text. However, other possible topics synonymous with shared awareness were retrieved that allowed for a robust synthesis for developing variables for shared awareness. At the top of the search were topics in common opinion, sense making, situational awareness and situational theory, each provided insights into the factors that make shared awareness.

Adams (1995) defines situational awareness as: "the top up-to-the-minute cognizance required to operate or maintain a system" (p. 85). Although granular in its conception, this definition serves as the means for further study. Endsley (1995) provided generalized stages of situational awareness that resonate with shared awareness and provide insights into variables.

Endsley (1995) suggested three stages of situational awareness:

1. perception of relevant elements of the environment,
2. comprehension of those elements, and
3. prediction of the states of those elements in the near future.

The relevance to shared awareness is the role of the individual and how s/he is informed toward action. As stated earlier in this dissertation, shared awareness is actionable through understanding, prior to action there must be an initial state or perspective to act upon. Brewer (2010) speaks to comprehensibility and understanding and the notion that reality is comprehensible or capable of being understood. He articulates his Action Theorem *Within a CRR, establishing comprehension* a posteriori *defines a justifiable basis for action* a priori (p. 85). Action research resonates within Brewer's Theorem; "The basis for action is assumed to be movement from the descriptive CRR to a desired CRR; this is used in the sense of direct action towards a value premise as opposed to indirect action such as learning and adaptation including, for example, concepts such as Action Research" (Argyris et al, 1985), introducing participation as an aspect into shared awareness as necessary for defining variables. Endsley's (1995) stages and Brewer's (2010) Action Theorem suggest the relationship of awareness to the environment and the potential to change as new knowledge is gathered and awareness is formed into understanding through the willingness of two entities to participate in sharing. Closely tied to participation is the need or desire to participate, beyond the willingness, this is best stated by Brewer's (2010) justifiable action in a situation is to assess the comprehensibility of reality, sans the contradiction of the entities own perceptions (p. 86). This asserts a desire must be present before sharing can be affected. Desire in itself is not sufficient for forming the basis for sharing; a process that allows for sharing must be present to overcome disparity in perspectives.

As Plato may have envisaged, the logical stratification of knowledge is linked with social stratification (Friedell, 1954). Maltz (2010) states: "Culture (personal and shared beliefs and values) is the strongest determinant of emergent (indeed, all) behaviors" (p.1). The generative process, as a formal aspect of the CRR, draws on culture in the formation of perspectives. For the purpose of this study culture, worldview, and paradigm are considered synonyms and are referred to only as culture. An aware entity [node] can have more than one perspective, the relationship between one perspective and another can be weak or strong. An individual [entity] has a dominant perspective that they are predisposed to and serves as the default disposition and any other perspective would be considered the recessive predisposition. Predisposition is informed by culture. When faced with an incomprehensible perspective the perspective must adapt or change for a comprehensible perspective, this is reflected in Brewer's Adaptation Theorem (Brewer 2010, p. 86) supporting the notion that the individual can and will shift from a predisposition to another.

"By the term awareness context we mean the total combination of what each interactant in a situation knows about the identity of the other and his own identity in the eyes of the other" (Glaser & Strauss, 1964, p. 670). This emphasis of context in the study of awareness also resonates with Brewer's (2010) Learning Theorem "*Within a CRR, lack of understanding justifies learning*" (p. 85) iterating the practical nature of studying shared awareness within a bounded or bounding construct and should resonate in the variable for shared awareness, that in order to share an entity must understand the situation. Glaser and Strauss (1964) identify four types of awareness context that provides insights into development of shared awareness within a domain.

- An open awareness context obtains when each interactant is aware of the other's true identity and his or her own identity in the eyes of the other.
- A closed awareness context obtains when one interactant does not know either the other's identity or the other's view of his or her identity.
- A suspicion awareness context is a modification of the closed one: one interactant suspects the true identity of the other or the other's view of his or her own identity, or both.
- A pretense awareness context is a modification of the open one: both interactants are fully aware but pretend not to be. (Glaser & Strauss, 1964)

This necessitated the recognition of the constraints for understanding and for sharing to occur, and is reinforced by Grunig's (1992) three variables for communication to affect situational theory:

- problem recognition,
- level of involvement, and
- constraint recognition.

These variables were used to develop Grunig's (1992) theory of communication and aide in predicting how well and effective people communicate establishing the dependency shared awareness has on communication.

Common to all of the readings is the idea of understanding, as well as parameters, and the need for participation. Sharing is predicated on understanding, awareness is predicated on self-aware and the act of shared awareness is predicated on participation of the self-aware entities.

3.2. Conditions for Shared Awareness

Sousa-Poza et al. (2008) provides the methodical and ontological conditions for the development of a SOSE perspective as congruent with situations theory. Conditions of multidisciplinary, multi-faceted domains, complexity, and uncertainty are examples and form the basis for extracting the conditions for shared awareness. Emergence, non-linear, and dynamic are all conditions that challenge shared awareness. Emergence, described as 'the whole is greater than the sum of its parts' suggests that sharing is not an aggregate of the perspectives but rather an integration of parts. Non-linear implies a disparity that resists sharing with anything but that of a common nature and a catalyst for emergence. Dynamic implies change both between individuals as well as within the situation that invokes the participatory/actionable necessity for emergence. The variables extracted from the readings and observations from '*the project*' are meant to obviate these challenges and all for understanding as a condition of shared awareness. The following variables are proposed for shared awareness and for the experiments conducted for this study.

3.2.1. Similarity in Culture – [pre]disposition

Predisposition (for the experiments color is used to distinguish predispositions [red and blue]. Culture imparts understanding and informs perspective. An individual has its own predisposition that is informed by culture and can create a homogeneous or heterogeneous environment. The level of awareness [and sharing] is based on the proximity of one individuals [node] [pre]disposition to another individuals [node] [pre]disposition. A node is predisposed to one perspective: the dominant perspective, making all others perspectives recessive. A predisposition is homogeneous if it is accepting of other predisposition(s) and it is heterogeneous if it is not. A homogeneous predisposition will accept any homogeneous predisposition; however, a heterogeneous predisposition may only share with other predisposition through its recessive perspectives. Hence, a node's predisposition may be heterogeneous but have access to its recessive perspective(s) to accommodate acceptance of another heterogeneous predisposition in regards to sharing. For the purpose of this study a nodes predisposition will be either homogeneous or heterogeneous and each predisposition will have a common recessive perspective. It is assumed that nodes and their perspectives born of the same culture will not, generally, be the same, but will be reconcilable sharing a common axiological foundation. The success of a predisposition for accessing their recessive perspective is determined by its orthodoxy.

3.2.2. Orthodoxy

Orthodoxy involves understanding boundaries. Orthodoxy is the level of accepting recessive perspectives by the effort required to access and draw on the recessive predisposition. Orthodoxy is the level of resistance a dominant perspective has for accessing a recessive perspective. Orthodoxy is influenced by the node's intent.

3.2.3. Participation

Level of intent to participate is demonstrated by the willingness to access the recessive predisposition, or amount of effort that a node is willing to expend to access the recessive predisposition willingness to participate. The key is in the word willingness. A node can be willing to participate and connect with another node however this condition is not conducive to sharing. An assumption of willingness is that it has to be present for shared awareness to occur. Willingness influence is either externally, i.e. mission statement, or internally, i.e. integrity. The model assumes either one is sufficient for shared awareness and are treated equally.

3.2.4. Desire

Level of intent is demonstrated by the desire to form a shared awareness. For this study, a high desire to share is assumed as a condition for the experiment. Desire is the tone [positive or negative] of a node and its desire to share. For the purpose of this study desire is always assumed positive.

3.3. Factors to Consider for Studying Shared Awareness

Disposition (two perspectives are used in this study represented by the color red or blue). Every aware entity [node] may have many perspectives. Disposition is the perspective that is enacted at any given moment in the situation. Disposition indicates which perspective is being informed based on access (a latent variable) and any external treatment.

Access – a latent variable created by the relationship between intent and orthodoxy. The implication of intent is the inverse proportionality of willingness to orthodoxy and is consistent within the definition of the two variables. Access is the conceptual distance between two nodes and represents the quality of the communication between two nodes. Access is a latent variable, and, is calculated by the type of predisposition, orthodoxy, and willingness node1 has towards node2 (determined by primacy).

In addition to the variables for Shared Awareness additional variables are introduced for the purpose of experimenting with the models built for shared awareness to test observations and the rational for shared awareness.

Dependent Variable1 is processing information links. If the conditions of the variables for understanding does not provide the conditions for understanding between two nodes than no connection will be made between nodes. Connection between nodes is not a physical connection rather than a perceptual connection indicating whether sharing will occur or factors are not congruent to sharing.

Dependent Variable2 is sharing information. If the conditions of the variables for sharing does provide the condition for understanding between nodes than a connection will be made between nodes. Understanding is established by the disposition of each node and the willingness to overcome orthodoxy.

Control Variable1 is primacy. Primacy is the directionality of the sharing process, and for the purpose of this study primacy is always with node1 (for the purpose of the experiment primacy is established when a node (node1) is attempting to communicate with another node [node2]). Primacy establishes dominance between the two nodes and imposes change on the second node to adopt its recessive perspective.

Control Variable2 is the event. The situation has a profound effect on shared awareness in terms of how sharing occurs. For the purpose of this study event is a control variable that asserts urgency on orthodoxy, assuming that the higher the urgency the more willing a node will let go of their predisposition and adopt a differing perspective. Understanding is established by the disposition of each node and the willingness to change. Utility theory is used as the model for change.

These variables highlight the criteria for determining and implementing a viable method for measuring shared awareness as well as substantiating the understanding generated from this hypothesis testing. The following section describes the method for hypothesis testing of shared awareness and the canons for understanding in the context of this study.

3.4. A Theory for Explaining Emergence

Statistical mechanics provides the framework for relating the properties of the particulate to the macroscopic phenomena of the whole, where the whole cannot be explained simply by studying its particulates. Statistical mechanics deals with thermodynamics [self-organization] and the resultant macroscopic [emergent] product of the behaviors of the particulates. Percolation Theory is a method employed within statistical mechanics that measures the effect of the medium on the flow's that tells us when a situation is macroscopically open for a given phenomenon.

Percolation methods are a considered as a subset of theories derived from statistical mechanics. Percolation processes have been used in most social network analysis as well as a model representing the emergent characteristics found in self-organization. As a metaphor percolation theory measures the emergent effect of shared awareness within multiple CRR's. Percolation is a simple probabilistic model that exhibits a phase transition (Kersten, 2006). Percolation tells us when a system is macroscopically connected and more importantly the universal scaling laws found near the percolation threshold tell us which aspect of the phenomena is important to determine the relevant macroscopic properties necessary for the emergent condition of shared awareness.

The fundamental postulate in statistical mechanics (also known as the *equal a priori probability postulate*) is the following:

> *Given an isolated system in equilibrium, it is found with equal probability in each of its accessible microstates.*

This postulate is a fundamental assumption in statistical mechanics - it states that a system in equilibrium does not have any preference for any of its available microstates. Given Ω microstates at a particular energy, the probability of finding the system in a particular microstate is $p = 1/\Omega$ (Albert, 2002). This is necessary because it allows one to conclude that for a system at equilibrium, the thermodynamic state (macro state) which could result from the largest number of microstates is also the most probable macro state of the system.

In this section, the relationship from techniques found in statistical mechanics and how they might be applied to study within [complex situations] situations theory are made explicit by analogizing the postulates of percolation and applying them to the CRR as a medium.

Percolation was introduced in a study of the random properties on how a 'medium' influences the percolation of a 'fluid' through it (Broadbent & Hammersley, 1956). The method differs from diffusion theory by focusing on the medium rather than the fluid. Their study introduced the percolation process on a structure that is 'homogeneous in the larger' through which local variations from the particulate 'fluid' may pass. The structure was any multi-dimensional medium where random characteristics can be introduced [by limiting the number or openness of the connections that link the particulates].

The medium they used for their study was an abstract crystal which is described as:

"Thus the structure might be that of an edge-centred cubic atomic lattice, which is homogeneous in the large in the sense that all cells are alike, although it has local variations inasmuch as atoms at the centre of an edge have two nearest neighbours whereas atoms at the corner of a cube have six."

For the crystal Hammersley identified abstract objects called atoms [later to be denoted as sites] and bonds. A bond is a path between two atoms and may either be two ways or in one direction only. From this work they state three postulates that the medium must satisfy, a summation of the percolation process as described by Broadbent and Hammersley (1956) is provided:

P1: Each atom of the crystal belongs to just one of a finite number of outlike classes…an outlike class is a setoff pairwise outline particles.

P2: The number of bonds leading from any atom of the crystal is finite.

P3: if a subset of atoms either (a) contains only finitely many atoms, or (b) does not contain any atoms of at least one outlike class, then this subset contains an atom from which a bond leads to some atom not in the subset (Broadbent & Hammersley, 1956).

Broadbent and Hammersley (1956) expanded on their work by introducing randomness to the medium (called a random maze) and provided corresponding postulates that the medium must satisfy.

P4: The set of bonds from which a maze is derived constitute a reversible crystal…reversible crystals have the property that, when direction of each bond in the crystal is reversed, the resulting set of atoms and bonds is also a crystal.

P5: Each bond of a maze has, independently of all other bonds, a fixed probability of $q = 1 - p$ of being dammed.

Hammersley (1956) revised the original work to deal with a medium consisting of "infinite atoms and bonds." This revision caused him to revisit two of the original postulates P1 and P3 to accommodate use of an infinite medium.

P1 was dispensed entirely.

P3 was revised as P3(a): Any finite subset of atoms contains an atom from which a bond leads to some atom not in the subset.

The significance of this rework to the original theory was to study the lower bounds of the critical probability [defined as the "supremum of all values of p such that when A is the only source atom, A wets only finitely many atoms with probability of one"(Hammersley, 1956, p.3).

The corresponding theorems and proofs, in both papers, provided the basis for validation of the percolation process, however, for this document the focus is on the postulates of the medium and whether they can be met by the medium that consist of CRR and their corresponding sites (to be discussed later).

Since its introduction percolation process has been applied in myriad applications such as petroleum flow in sandstone, spread of blight disease in orchards, conductive transport in rock or alloys, and traffic flow in city street networks (Wierman, 1982). Additional work in fractal patterns, hydrodynamic dispersion, semiconductors, and composite material mediums can be found in Sahimi (1994). However the most significant [to this document] medium is in social network analysis (Pollner et al., 2008) and large networks such as the world wide web (Albert, 2002), which shift the nature of the medium from tangibles objects to the more relevant phenomena of behavior; these are key in this study.

Percolation Theory shows promise for providing methods for dealing with the implications of complexity, particularly in the development of understanding and shared awareness.

3.5. Percolation Theory Applied to Shared Awareness

To determine whether percolation methods are appropriate to studying situations theory, more specifically emergent conditions of shared awareness it is important to first establish whether the medium of [shared] awareness is analogous to the defined medium for which percolation is applied. Generally, the intrinsic and the random characteristics of the medium, together with any external laws which may operate…The intrinsic characteristics of the medium consist in its interconnecting structure. This structure is formulated in the CRR as a site or node and the exchange of knowledge/context that is exchanged between CRR's a bond or link. The structure must be homogenous in the large [all CRR's are alike (a generative process and structure) although local variations, inasmuch in terms of the bond in relationship to where the CRR, exists within the medium [or lattice]. Atoms at the center of an edge have two nearest neighbors whereas atoms at the corner of a cube have six. Within this abstract medium of self-awareness, a CRR is a site and the bond is a LOC (line of communication) between sites the randomness of the medium is introduced by damming some of the communication lines and observing the flow of knowledge through the maze [bond percolation], or changing the state of a site and observing the connections with other sites within the maze [site percolation]. For the purpose of this study the focus of the experiment is site percolation. Within the medium there exists an infinite set of CRRs and LOCs. There is a time dependency to this medium since a suitable choice of the number of LOC between CRRs will always be possible. What remains for this part of the discussion is the analogous relationship of the postulates of percolation theory and that of the CRR. The postulates, as defined by Broadbent and Hammersley (1956), are listed below with the corollary principle of the CSP and accompanying interpretation.

P1[2]: The number of bonds leading from any atom of the crystal is finite

This postulate speaks to the following principles of a CSP.

- Self-Awareness Principle: Self-awareness defines a unique existence within reality.

- Awareness Principle: Awareness of other-than-self defines a unique existence within reality.
- CRR Principle: The result of awareness is a cognitive representation of reality.
- Structure Principle: Cognitive representations of reality are characterized by a structure reflective of its generative processes.

Essentially, the Domain of Awareness is all the portion of reality that can be accessed by the CRR and by definition is a bounded construct (unique existence within reality). As such the CRR can only have a finite number of bonds.

P2[3a]: was revised as: Any finite subset of atoms contains an atom from which a bond leads to some atom not in the subset.

- Incompleteness Principle: Everything cannot be contained within less than everything.
- Spatial and Temporal Characteristics: Awareness incorporates the principal temporal and spatial dimensions.

The CRR contains not only what can be made known and explicit, but also aspects of what cannot be known. This speaks to the aspect of knowledge and not knowledge as well as the descent of form from universals.

P3[4]: The set of bonds from which a maze is derived constitute a reversible crystal…reversible crystals have a property that, when direction of each bond in the crystal is reversed, the resulting set of atoms and bonds is also a crystal.

- Structure Principle: Cognitive representations of reality are characterized by a structure reflective of its generative processes.
- Situations Theorem: Absent additional information, each fundamental situation related to comprehensibility and understanding is equally relevant at any given time.
- Context Corollary: Justifiable operations within a given situation must include all other situations as relevant context.

Structure is inextricably tied to its generative process as such has a causal relationship, lending itself to a coherent reversibility within the CRR. This can be extrapolated out to the domain of awareness and other CRR based on the shared comprehensibility and understanding of all CRR's within a shared of awareness.

P4[5]: Each bond of a maze has, independently of all other bonds, a fixed probability of $q = 1 - p$ of being dammed.

- Reality Principle: Reality is (that which exists).
- Self-Awareness Principle: Self-awareness defines a unique existence within reality.
- Awareness Principle: Awareness of other-than-self defines a unique existence within reality.

These principles speak to the complementary nature of a situation itself and its unique relationship with the CRR. Each aware entity can have many CRRs and each CRR can have many perspectives yet each perspective is unique to its awareness. Important to the discussion is deriving arguments that can be tested to support the development of a General Theory of Shared Awareness.

CHAPTER 4

METHODOLOGY

Our feeling of intellectual security is so deeply anchored in us that we even do not see how it could be shaken. Even if we suppose that we could observe some phenomenon seemingly quite mysterious, we still would remain persuaded that our ignorance is only provisional, that this phenomenon must satisfy the general laws of causality, and that the reasons for which it has appeared will be determined sooner or later. Nature around us is order and reason exactly as is the human mind. Our everyday activity implies a perfect confidence in the universality of the laws of nature (Levy-Bruhl, as cited in Prigogine & Stenzer, 1986, p.282)

4.1. Inductive Rationalism

The use of rational inductive methodology is discussed extensively in Brewer (2010), Padilla (2010) citing Sousa-Poza et al.'s (2008) work on defining a methodology for an effective approach for research where 'empirical approaches may not provide the exploratory and theoretical development capability sought by the researcher' (p.58). The central focus of the methodology is to provide a means to a map inductive based methodology with modeling and simulation techniques. Justification is maintained in the explicit nature of the assumptions, logic, and behaviors built into a coherent structure of the model. Sousa-Poza et al. (2008) posits a method consisting of three components that include exploration, structuration, and conclusion for the maturation of new theory. The method consists of extracting generalizations from the body of knowledge and compiling them in a coherent system of propositions and premises with stated assumptions thus avoiding contradictions.

This methodology has been widely applied in social sciences dealing with aspects related to demography, migration of populations, regional geography and opinion formation (Galam 2004a, 2004b; Hegselmann & Krause 2002; Helbing 1995, 2002; Holyst & Kacperski 2001; Holyst, Kacperski, & Schweitzer 2000; Kacperski & Holyst 1997, 1999, 2000; Kohring 1996; Laguna, Abramson, & Zanette 2003; Lewenstein, Nowak, & Latane 1992; Nowak & Lewenstein 1996; Nowak et al. 1990; Osgood & Tannenbaum 1955; Schweitzer & Bartels 1991; Weidlich 1994, 2000; Weidlich & Haag 1983; Weisbuch 2004; Weisbuch, Deffuant, Amblard, & Nadal 2001).

The results achieved by the authors mentioned above substantiate that this methodology and method are suitable to study shared awareness. This is primarily because this modeling method allows connecting the micro level of individuals' perspectives and understanding of the situation, which are intentionally driven, and the macro level of the influences and motivators the environment may have on the resulting emergent shared awareness. The results obtaining while using this approach are complementary to verbal qualitative analysis from the subject matter experts and the environments for which the decision to share exist. The insights from running the simulations will prove invaluable to understanding for the dynamics of shared awareness. Thus, if the macro variables are chosen in such way that the interpretative transparency is preserved, a qualitative argumentation and interpretation of the results might contribute to enrich the model in such way it turns out to be generic and robust - by augmentation and refinement (Weidlich, 2000). For the purpose of this study Sousa-Poza et al.'s (2008) methodology and method is used.

4.2. Method

This inductive study uses a rational method [modeling] that proposes the following steps for substantiation of a General Theory for Shared Awareness. Inductive reasoning is widely accepted for theory development and is particularly useful when empirical data are either not available or impractical to obtain. When studying social behavior or macro behavior within the enactment of the micro state validity of data between each state is compromised, observation and gathering of insights may provide a more robust understanding of the behaviors in relationship to the particulates.

The inductive process proposes observations from a real-world project gathering insight from participants to guide and focus research through the inductive path. As part of the process literature will be scoured for current theories and techniques that will aide in the development of theory culminating in the development of rationally based models to experiment and test the theories for describing a General Theory of Shared Awareness.

Inductive reasoning is used in the process of deriving the models' logic and behaviors, allowing for the implementation of the research questions into the models and, the definition of the research hypothesis (which, eventually, will constitute a specific set of rules for the simulation). Rationality can be evaluated by comparing the logic sequences and the behaviors of the entities based on the observations within '*the project*'. The inductive process is mainly supported by a qualitative analysis of the results obtained from an Agent Based Model and Simulation.

The central focus of the methodology for this study is a qualitative description of conditional shared awareness, where conditionality is temporal, ergo within the moment, and an effective decision is best generated from a common position, necessitating a change in perspective to affect understanding. The temporal aspect is that the change occurs based on imminent need and will eventually revert back to the original predisposition once the compelling need is no longer present. An example germane to *'the project'* would be Office and Field Operations (OFO) changing to an Office of Border Patrol (OBP) perspective when placed within the OBP environment and tasked to work as a cohesive unit. With that objective in mind, two methods will be implemented and the results compared. The first method is a qualitative description of shared awareness based on literature and theory tempered by observations in a real world project that informs behavior of entities. The second method consists of building and running an Agent Based Model – ABM – to replicate the individuals' behaviors of the entities [nodes] and applying a macro-logic as responses to these particulate behaviors. The results obtained by both methods will be compared using qualitative analysis and subject matter experts against the canons for this study to determine the relevance of the findings. This model does not assume horizontal and/or vertical perspectives. The implication is that at any level of resolution there is a new perspective (both deterministic and stochastic). The assumption is that access is tied to location and that movement up or down or right or left is significant to the perspective (i.e. strategic perspective is different than tactical perspective, or field office perspective is different than border patrol perspective – imparting an observational role to the node). Although this is not incorrect for stochastic or deterministic models it is not relevant in a situations model where understanding and context are both conditions of the node regardless of physical location. This model, assumes a phased space where each perspective is weighed not by its physical location but by the culture (predisposition) and context (proximity) of the nodes implying self-awareness rather than an observational role.

4.2.1. Agent Based Modeling

ABM is well suited for research. It is a method for studying situations exhibiting the following two properties: (1) is composed of interacting agents; and (2) exhibits emergent properties, that is, properties arising from the interactions of the agents that cannot be deduced simply by aggregating the properties of the agents. When the interaction of the agents is contingent on past experience, and especially when the agents continually adapt to that experience, mathematical analysis is typically very limited in its ability to derive the dynamic consequences. In this case, ABM might be the only practical method of analysis (Axelrod & Tesfatsion, 2013).

Agent Based Modeling and Simulation (ABMS, shortened to ABM for this study) can be a natural complement to classical research methods, of significance is the ability to study situations for which traditional analytical methods cannot support. ABM is found in many fields including: complexity science, systems science, systems dynamics, computer science, management science, the social sciences in general and traditional modeling and simulation (Macal & North, 2010). ABM draws on many fields for its theoretical foundation but of interest to this study is that it is a modeling methodology in statistical mechanics (discussed earlier) congruent with the theories put forward, and a valuable tool for the methodology being employed for this study. Moreover, ABM supports Complex Situations Paradigm for which analytical solutions cannot be found anymore extending beyond the heroic assumptions of simple models that explore behaviors that can only be numerically determined and which have little relevance to reality.

Agent Based Modeling arose out of the work on Complex Adaptive Systems (CAS) at Santa Fe Institute. In ABM (Agent Based Modeling), the focus is on global behavior (of a system of individual agents) arising from local rules and interactions of individual agents. In ABM, focus is on individual agents, their rules, their behaviors, and their interactions with each other and the environment. Collectively agents may exhibit emergent behaviors such as self-organization. Since agents do not follow a pre-scripted flow (as in Discrete Event) and their structure is not pre-specified at the global/aggregate level (as in System Dynamics), they can exhibit novel or surprising behaviors that were not anticipated during design. ABM is a great methodology for exploring non-linear, dynamic environments. ABM is also well suited for situations with no precedent or where past data or experience does not exist. When combined with data and data analytics, ABM forms one of the most powerful predictive analytics / forecasting methodology. (Helbing & Balietti, 2011)

Agent Based Model and Simulation begins with assumptions about agents and their interactions and then uses computer simulation to generate "histories" that can reveal the dynamic consequences of these assumptions. Thus, ABMS researchers can investigate how large-scale effects arise from the micro-processes of interactions among many agents. These agents can represent people (say consumers, sellers, or voters), but they can also represent social groupings such as families, firms, communities, government agencies and nations (Axelrod &Tesfatsion, 2013).

Consequently, simulation differs from standard deduction and induction in both its implementation and its goals. Simulation permits increased understanding of systems through controlled computational experiments. As was stated before, the dynamics of collectives is the result of nonlinear interactions between the collective, the individuals, and the environment. (Weidlich & Haag, 1983) explored the possibility of an isomorphism between the natural and the sociological collectives supported by three assertions: 1) individuals (or units of the collective) interact; 2) the transition between states for both collectives (natural and social systems) has one-to-one correspondence; 3) also, there is a one-to-one correspondence for the introduction of broad distinctions in the collectives. If these assertions are right, it is possible to state that the dynamics of both systems (as described by the transitions mentioned above) is formally identical and independent of the nature of the individuals (or units) (Weidlich & Haag, 1983).

In other words, as presented by Mainzer, (2004), the mathematical modeling methods from synergetic and statistical mechanics, when applied in social sciences, suggest a relationship between the individuals' behavior and the dynamics of the collective. Ergo, Agent Based Modeling is an appropriate modeling method for shared awareness.

4.3. Discussion of the Canons

Canons vary across different disciplines and are foundational to the research conducted within them. This remains true for the work within Complex Situations Paradigm (CSP), hence, adopting Brewer's (2010) Canons for research within CSP is a logical step for this study. The following is a summary of these canons and their applicability to this study.

Brewer (2010) identifies canons that:

"In order to develop the CSP using a rational research methodology, the research developed generalized canons based on the JTB(+) definition of knowledge, and instantiated these for the CSP. The instantiation of those canons for the CSP provide sufficient guidance to justify internal consistency. The characteristics of this research require particular attention to the appropriate research methodology. Canons for research are typically based on philosophical foundations of rationalism or empiricism; hence this

research derives a set of generalized canons based on a specific definition of knowledge, which must be instantiated as specific research canons for a given philosophical foundation. The methodology for this research must be consistent with said canons and the associated definition of knowledge" (p. 103)

The set of generalized research canons *(italicized from Brewer, 2010)* for JTB(+) knowledge is defined as, along with the corollary description germane to this study:

- Truth: the research must establish that an individual's belief is reflective of reality (whether through correspondence or coherence) – the method is based on the participatory aspect of the individual based on the interpretation of the CRR through the instantiation of the domain of interest represented by the flow of information through the critical probability to the point of a second order phase transition .
- Justification: the research must provide for establishing truth external to the individual – use of percolation theory as a means for describing shared awareness as represented by the K-threshold [second order phase transition] occurs and is representative of the expected behaviors of the individuals.
- Method: the research must establish reliable ways of justification – the method, ABM, appropriately represents the continua and topologically random networks within the medium of the CRR and its macroscopic connectivity.
- Context: the research must establish reliable means of justification, addressing the resources used in the ways of justification - the archeological, the propositions, and implications to [shared] awareness are consistent to the method employed.

4.4. Experimentation Protocols

The hypothesis for the formulation of a general theory of Shared Awareness through the study of macro level behavior based on the actions of the particulates is provided as arguments for formulating and conducting the ABM experiments

Argument 1: Given random entities (nodes) under the conditions of a homogeneous environment, normal distribution, and desire to exchange information, shared awareness will emerge from the interactions of random entities based on the principles of percolation theory. This experiment is indicative of a single agency (hypothetically identified within the project as CBP to form a [super] cluster based on random interactions. This argument (as the best case scenario) sets the parameters for testing conditional share awareness, the implication being that any behavior in conditional shared awareness will not exceed the behaviors of unconditional shared awareness. It also establishes the comparative metrics necessary for the qualitative analysis of further experimentation.

Argument 2: Given random entities (nodes) under the conditions of a heterogeneous environment, normal distributions, and desire to exchange information, shared awareness will emerge from the interactions of random entities based on the principles of Bohr's (from Wolfe, 1989) Principal of Complementary and the variables of shared awareness governed by CSP. This experiment is indicative of a multiple agencies (hypothetically identified as OFO and OBP within the project) to form a [super] cluster(s) based on random interactions. This argument (as the best case scenario for complementary and disparate perspectives) sets the parameters for testing the extreme limits of conditional share awareness based on the variables of shared awareness. The implication being that any behavior in conditional shared awareness when pushed to the extreme will show behaviors that will not exceeds the behaviors of conditional shared awareness. It also provides metrics for comparison with unconditional shared awareness in the first experiment as well as an additional set of comparative metrics necessary for the qualitative analysis of further experimentation. A latent variable (access) is introduced based on the relationship between orthodoxy and intent

This argument has five parts. The first argument set the condition to a heterogeneous environment, a normal distribution within each heterogeneous cluster and the desire to exchange information is still assumed high, however all variables for shared awareness are set at null. The remaining four arguments follow the test matrix provided below and represent the four extreme limits of shared awareness in an heterogeneous environment.

Test	Variable 1 - Orthodoxy	Variable 2 - Intent
1	Stubborn (0)	Standalone (0)
2	Stubborn (0)	Willing (1)
3	Accommodating (1)	Willing (1)
4	Accommodating (1)	Standalone (0)

Table 1. 2x2 Argument Conditions

Argument 3: Given random entities (nodes) under the conditions of a heterogeneous environment, normal distributions, a desire to exchange information, shared awareness will emerge from the interactions of random entities based on the variables of shared awareness governed by CSP, an inverse relationship between orthodoxy and intent, and a disposition towards one view or another based on utility theory. This experiment is indicative of a multiple agencies (hypothetically identified as OFO and OBP within the project) to form a [super] cluster(s) based on the decision for an entity to switch perspectives from external influences. This argument (as the best case scenario for external influences) sets the parameters for testing the effect of external influences on conditional shared awareness. The implication being that any behavior in conditional shared awareness when pushed to the extreme will show behaviors that will not exceeds the behaviors of conditional shared awareness. It also establishes the metrics for comparison unconditional shared awareness as well as an additional set of comparative metrics necessary for the qualitative analysis of further experimentation.

Establishing heuristics for the development of the ABM model logic was straight forward. An aware entity [node] can have more than one perspective, the relationship between one perspective and another can be weak or strong. A node has a dominant perspective that nodes are predisposed to and serve as the default predisposition, any other perspective would be considered the recessive predisposition. Predisposition is informed by culture and is measured by the type of understanding the node has with its environment, common or individual. A node can either be homogeneous or heterogeneous to its environment. For the purpose of this study there are two predispositions one of which will be dominant [A or B] and each will have a recessive predisposition. It is assumed that perspectives born of the same predisposition will not, generally, be the same, but will be reconcilable sharing a common axiological foundation. Orthodoxy is the nodes cognitive preference or 'attitude' (analytic vs. holistic), and has an influence on predisposition. The level of influence orthodoxy has on the dominant predisposition determines the accessibility to its recessive perspectives and is measured by how much resistance exist that must be overcome to access the recessive perspective. Resistance is measured by the constraints or limitation of the dominant perspective, high orthodoxy high constraints/limitation, and low orthodoxy low constraints/limitations. Desire is the willingness to share, for the purpose of this study it is assumed that all nodes have desire. A line of communication is a virtual link between the perspectives of two separate nodes that are motivated to share

The Shared Awareness simulation is a two-dimensional node automation in which each node represents an aware entity and can either share or not share based on its disposition. Links that form (representing information) between nodes represent a primacy of node 1 querying node 2 to determine how the second node will interact. Nodes can:

- stand apart – no connection is made, or
- cluster based on a behavior and logic, or
- a connection is made representing a second order phase transition. The existence of two clusters represent a bifurcation that indicates two complementary perspectives

Change occurs in the disposition of the node based on an internal decision or external influence using utility theory. The models used in the experiments are extracted from NetLogo's 5.0.3 Model Library (ccl.northwestern.edu/netlogo/). The NetLogo model has been peer reviewed and validated for accuracy and intent. The arguments are used to expand the core model; each derivative model is built from its predecessor culminating in the last model that satisfies the last argument.

4.5 Experimentation Element Coding

The model consists of three elements:

1. Node – represents an entity

2. Link – represents an interaction
3. Environment – represents relationships for interactions between nodes and links.

Each element is described in the following sections. Additionally, specific logic for developing the relationships for all elements is also provided.

4.5.1 Coding Node Attributes

The following attributes are assigned to each node and referred to as turtles-own in NetLogo:

- Color – predefined by the program used to differentiate nodes and assign differing values and randomness
- Explored – trigger uses to indicate whether node was interacted with by another node used in counters and random selections
- Predisposition1 – at setup = node color. Dominant disposition (influenced by generative process)
- Predisiposition2 – at setup = opposite node color. Recessive disposition (influenced by generative process)
- Disposition – represents decision by node based on proximity1 and intent to change predisposition1 to predisposition2 for node2 at each iteration
- Intent – Willingness of node randomly assigned, or selected by a range slider
- Proximity – Level of resistance each node has for changing predisposition. Randomly assigned or selected by a range slider
- Access – Proportionally inverse relationship between orthodoxy and intent
- Proximity1 – orthodoxy of node based on external event

- Event – external variable used to reduce the effect of orthodoxy on the node. Cardinal scale used to represent intensity of the event.

4.5.2 Coding Link Attributes

Attributes of the connection between nodes:

- Links-own predefined by the program used to color the link based on interactions of the node.

4.5.3 Coding Environment Attributes

Environment coding attributes establishes the rules for the space in which the nodes interact and connect.

Environment attribute coding, referred to as global in NetLogo:

- Component-size – captures the number or turtles explored in current component, provides size count and comparison to other nodes to determine whether a supercluster has formed
- Giant component-size – used to distinguish a supercluster from other clusters.
- Giant start node – used to identify starting node in a supercluster so relationships can be assessed and coded based on primacy
- Primacy – determined by the 'ask' command in NetLogo.

4.6 Specific Code per Experiment

4.6.1 Experiment 1 Homogeneous environment

Two node attributes are used in this experiment – color and predispostioin1. Color is used to determine the homogeneous nature of the nodes signified by using one color. After each interaction a different color is assigned to the nodes and links of the supercluster (the largest cluster to form at each iteration) differentiating it from other clusters. Predisposition1 is used to compare one node to another when interacting and because this experiment is homogeneous each compare results in a link. The link attribute is used to maintain a consistent color of the link to the color of the node. Component-size is used to compare clusters and determine which cluster is biggest displaying all clusters individually as well as providing the number of iteration the model runs. Giant-component-size is used to monitor the growth and progress of the largest component at any given iterations, this information is displayed in the environment by a predetermined color. Giant-Start-node is used to keep track of connects in the giant component to determine plot for K-Threshold. Primacy – set primacy to node1 at each iteration.

4.6.2 Experiment 2 Heterogeneous Environment

This experiment builds on experiment 2 with the inclusion of the following attributes and relationships in the elements: intent, proximity, and access. Two colors are used to determine the heterogeneous nature of the nodes signified. Within each interaction a color is randomly assigned to the node. Intent and orthodoxy are assigned either a 1 or a 9 and can be toggled by the operator to observe the affect the variables have in the formation of the clusters. Access is the computation of the inverse proportionality between orthodoxy and intent. This value is used to determine whether a predisposition is willing to connect to another node (if the second nodes predisposition is different). Predisposition1 is used to compare one node to another when interacting, each compare results in a link determined first by predisposition, then by access if predisposition is not the same, to show convergence of similar predisposition. If predisposition is the same or access is greater than 1 a link is formed. The link attribute is used to maintain a consistent color of the link to the color of the node. Primacy – is used to set primacy to node1 as the model iterates through interactions.

4.6.3 Experiment 3 Heterogeneous Environment with External Event

This experiment builds on experiment 2 with the inclusion of the following attributes and relationships in the elements: disposition, predisiposition2, proximity1, and event. Two colors are used to determine the heterogeneous nature of the nodes signified. Within each interaction a color is randomly assigned to the node. Intent and orthodoxy are assigned a random value between 1 and 9s. Access is the computation of the inverse proportionality between orthodoxy and intent. Proximity1 represents the decision of the node to adjust their access to a different predisposition based on a value assigned by event (cardinal scale 1-9) and the level of orthodoxy randomly assigned (orthodoxy – event). This value is used to determine whether a predisposition1 is willing to connect to another node if the second nodes predisposition1 is different. Predisposition1 is used to compare one node to another when interacting, each compare results in a link determined by the first nodes predisposition1. If predisiposition1 for of node 1 is not the same as disposition1 of node 2, node 2 predisposition1 is changed to its predisosition2 (recessive predisposition). A decision is elicited by node1 on whether a recessive predisposition is warranted based on access (>1), a node's predisiposition2 is assigned to disposition which is used for comparison in future iterations and a link is formed. The link attribute is used to maintain a consistent color of the link to the color of the node. Primacy is used to set primacy to node1 at the model iterates through interactions. If predisiposition1 is the same between two nodes a link is formed. If predisposition1 is different than predisposition and the relationship defined in the attributes is greater than 1 that predisposition1 are linked.

CHAPTER 5

RESULTS

5.1. Confidence in the Conclusions Drawn

Justification of the logic for conditional sharing against the canons for this research:

Truth: the research must establish that an individual's belief is reflective of reality (whether through correspondence or coherence) – the method is based on the universality of the CRR to reality through the instantiation of the domain of interest represented by the flow of information through the critical probability to the point of a second order phase transition. This was represented both through utilization of theory [percolation theory and statistical mechanics as accepted and effective for studying Shared Awareness based on Micro Interactions within Situational Theory and demonstrating Micro to Macro Dynamics within Situations Theory. The application of modeling techniques [ABM] conducive to this type of research maintained the coherency of the study to the formation of theory.

Justification: the research must provide for establishing truth external to the individual – shared awareness as represented by the probability threshold [second order phase transition] occurs.

Key to experimentation is addressing bias caused by observation and manipulation. The logic applied to the behaviors and their interactions were consistent with existing models used for decisions [utility theory] as well as measuring change [inverse proportionality]. Bohr's (from Wolfe, 1989) Principle of Complementary is sufficiently grounded with the community. Any bias assimilated via inductive reasoning would be challenged in the experiments that were governed by well-grounded theory and assumptions and referenced throughout this document.

Method: the research must establish reliable ways of justification – The method was well grounded not only within the context of the research but as an acceptable method within the broader community of engineering management.

Context: the research must establish reliable means of justification, addressing the resources used in the ways of justification – The inductive approach (from the archeological journey to the discovery of theories) reinforced from observation towards the formulation of theory is widely accepted (and documented within this document) within the engineering management community for justification of knowledge. The arguments and conclusions were logically consistent with the theories presented as well within the context of engineering management followed by the premises and implications to[shared] awareness are consistent to the to the method employed

5.2. Experiment 1: Homogeneous Population

Experiment 1 provides the justification for percolation as a proposition for shared awareness. It is a controlled experiment to test whether model is complying with behaviors expected by percolation theory. A single color [red] represents homogenous individuals. An example from *'the project'* would be based on different levels of abstraction such as an environment where only Border Patrol agents are sharing common perspective such as detection techniques over a desert terrain. Another level of abstraction would be Law Enforcement, comprised of different agencies, sharing a common perspective such as the 'Miranda Rights'. The expectation from the experiment is to observe the individual node form into a connected network.

In a network, a "component' is a group of nodes that are all connected to each other, directly or indirectly. So if a network has a "giant component", that means almost every node is reachable from almost every other. This model, based on Wilensky (2005, 1999), shows how a giant component arises if you grow a random network. The significance to shared awareness is that every combination of nodes will be linked (homogeneous, desiring population). The giant component represents the best-case K-threshold possible given near perfect conditions [effects of node organization are not considered]. Table 2 lists the variable settings for the model.

Variable	Setting	Comments
Primacy	N/A	Homogeneous population
Predisposition	All A's	Homogeneous population
Orthodoxy	All accommodating	No impact since homogeneous
Intent	All willing	No impact since homogeneous
Desire	Assumed high	
Access	Not used in model	

Table 2. Experiment 1 Parameters

Iterating through the model two nodes are chosen randomly and connected. One tick is equal to an iteration; one iteration is relative to one unit of time. Because the nodes are homogeneous primacy is not applicable, it can be assumed that the outcome of the link would be the same regardless of primacy since both nodes are predisposed to connect with each other. After each tick, numerous small components begin to form where the entities are either directly or indirectly connected to each other. If two small components are connected the two components merge into one component. The model interprets the state of the clusters after an iteration based on the number of connections and colors the largest component red, while the remaining components remain white. The number of connections per node and the percentage of nodes in the largest component are plotted. This model was run with 50, 500, and 1,000 nodes respectively. The model was run 10 times for 50 nodes, three times for 250 and 500 nodes respectively. The resulting data (Table 1) were collected. The K-threshold is qualitatively analyzed and discussed in the interpretation of the experiment.

5.2.1. Results of Experiment 1

The intent of running 50, 250, and 500 nodes test is to establish an expected consistency in the experiment to preclude having to run the same series for every experiment. I.E. it is assumed that the results in the remaining models will stay within the boundaries of the best case scenario established in this model.

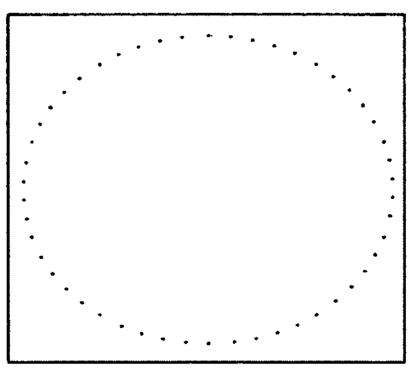


Figure 6. 50 Node Setup

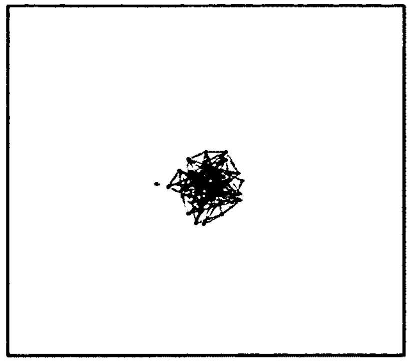


Figure 7. 50 Node Supercluster

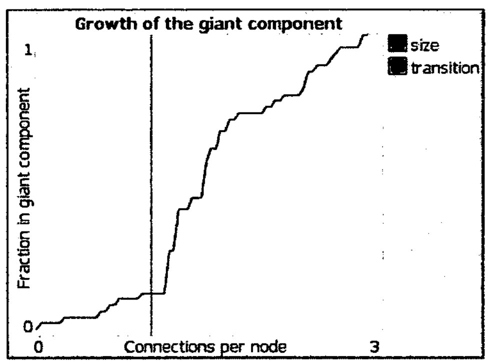


Figure 8. Sim-1 K-threshold

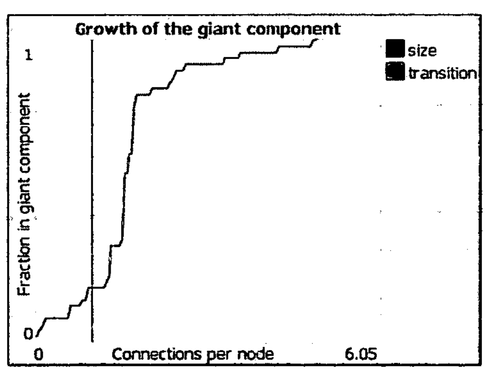


Figure 9. Sim-2 K-threshold

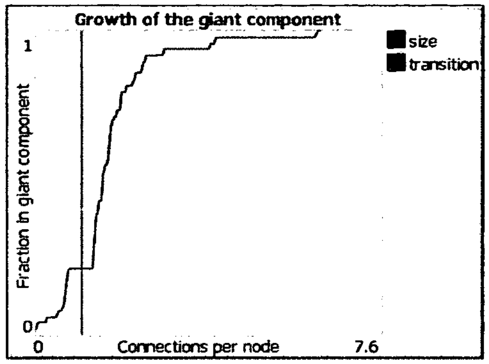


Figure 10. Sim-3 K-threshold

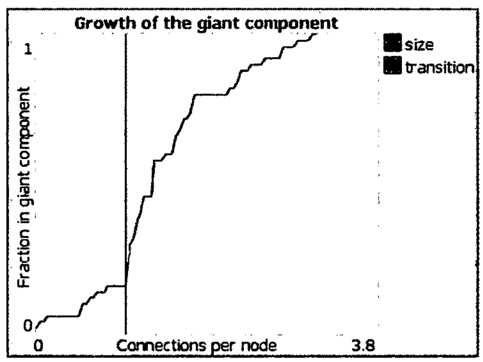


Figure 11. Sim-4 K-threshold

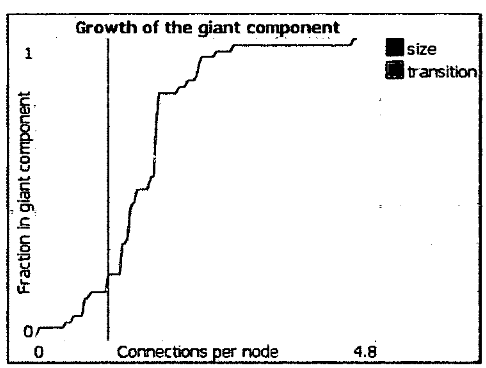


Figure 12. Sim-5 K-threshold

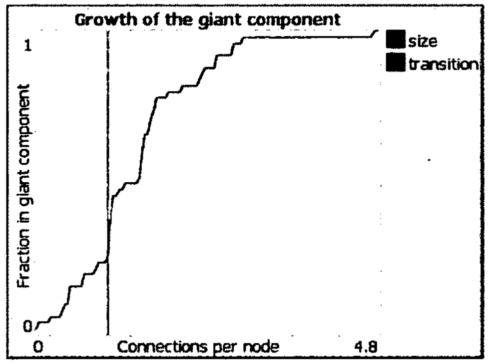


Figure 13. Sim-6 K-threshold

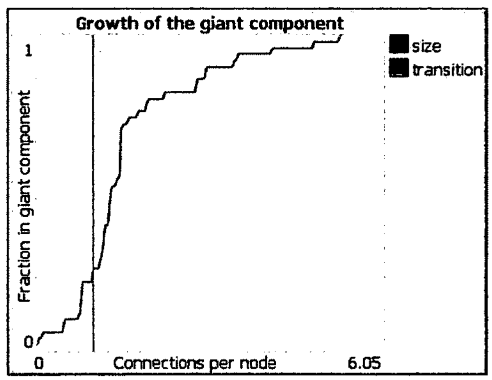


Figure 14. Sim-7 K-threshold

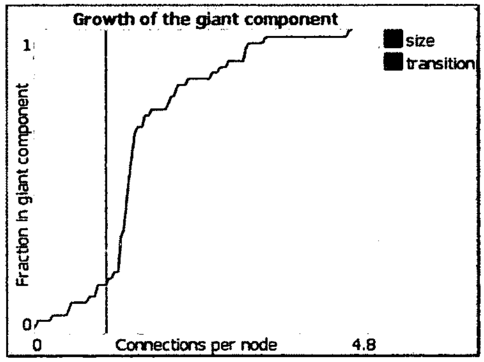


Figure 15. Sim-8 K-threshold

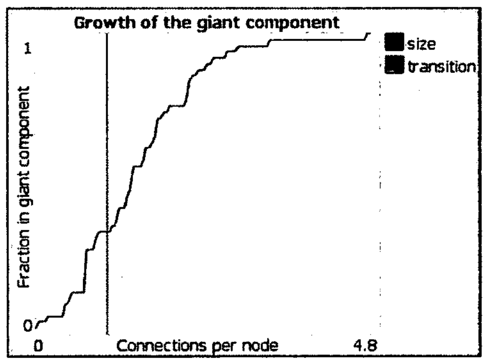


Figure 16. Sim-9 K-threshold

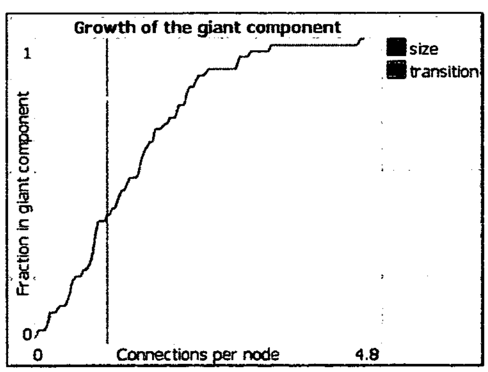


Figure 17. Sim-10 K-threshold

Column1	lower range x	lower range y	upper range x	upper range y	avg range	ticks
plot1	1.12	0.139	2.87	0.78	1.995	72
plot 2	1.27	0.185	1.79	0.815	1.53	123
plot 3	0.66	0.076	2.46	0.92	1.56	157
plot 4	1	0.168	1.75	0.794	1.375	78
plot 5	0.66	0.076	1.72	0.815	1.19	112
plot 6	1.04	0.248	1.7	0.782	1.37	119
Plot 7	0.74	0.101	1.47	0.71	1.105	133
Plot 8	1.15	0.202	1.66	0.739	1.405	111
Plot 9	0.68	0.139	2.14	0.845	1.41	117
Plot 10	0.16	0.034	2.41	0.895	1.285	114
		Totals				
P(c)		1.4225				
Avg Ticks		113.6				
Avg nodes Lower range		0.1368				
Avg nodes Upper range		0.8095				

Table 3. Data Extracted from 10 Simulation Runs for Experiment 1

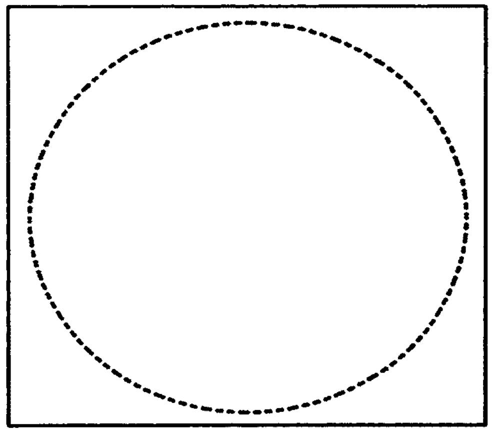


Figure 18. 250 Node Setup

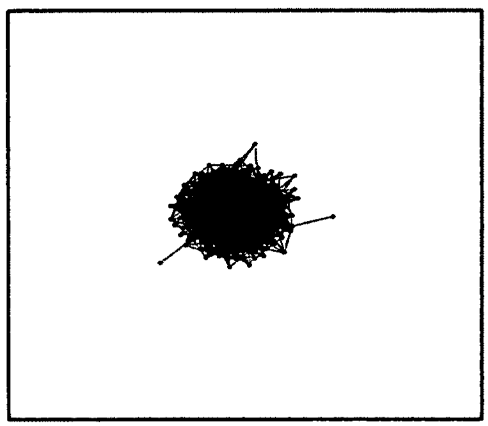


Figure 19. 250 Supercluster

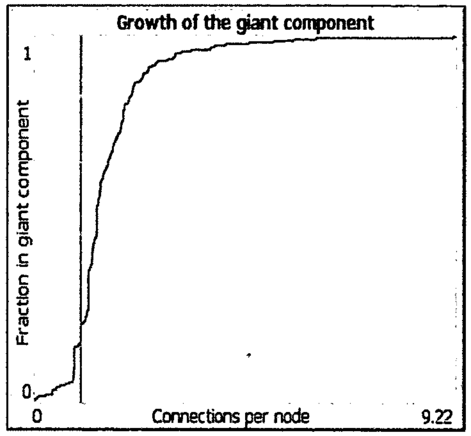


Figure 20. Sim-11 K-Threshold

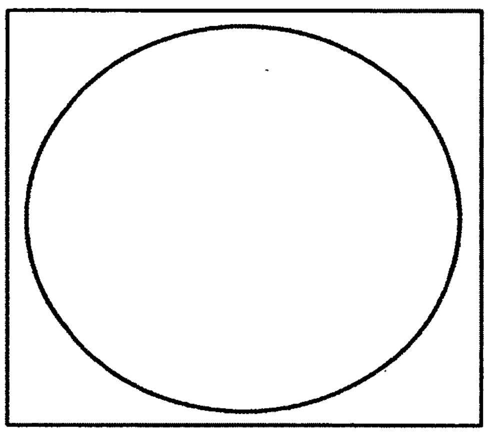


Figure 21. 500 Node Setup

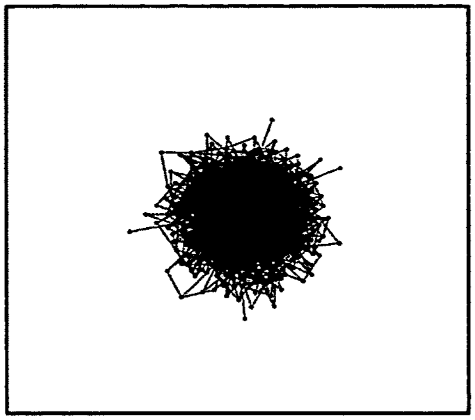


Figure 22. 500 Supercluster

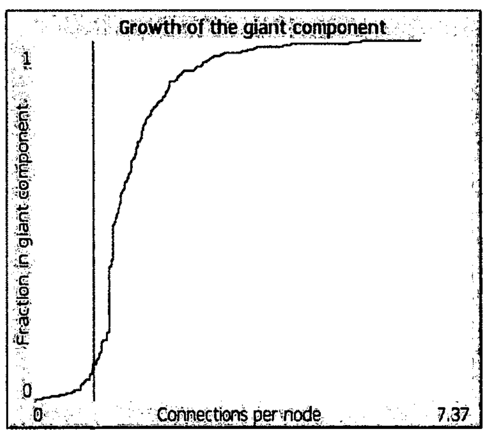


Figure 23. Sim-12 K-threshold

5.2.2. Interpretation of Experiment 1

A qualitative analysis of the plots and subsequent data from the 10 runs of 50 nodes indicates that a K-threshold occur beginning when the nodes have an average of 80% connection, it is reasonable to round up to one connection per node as a quantifiable result for K-threshold. The upper range of the phase transition was plotted and recorded giving an average K-threshold of 1.42 connections for 50 nodes with a total of 49 possible connections per node. A vertical line in the plot indicated where the average number of connects per node equals one; this was used as a reference point for assessing when a phase transition occurred. As expected, the 250 and 500 runs resulted in similar plots. The model demonstrates that the largest connected component of randomly connecting two random nodes rapidly grows after the average number of connections equals approximately one connection per node indicating a critical point in the network where a phase transition occurs from smaller unconnected clusters to an emergent super cluster where all nodes belong to the same connected component. There was no significant deviation when increasing the number of nodes to 250 or 500 with the obvious exception to the number of ticks. A refresh of argument [hypothesis] 1:

Given random entities (nodes) under the conditions of a homogeneous environment, normal distribution, and desire to exchange information, shared awareness will emerge from the interactions of random entities based on the principles of percolation theory.

The significance of this experiment was to establish the proposition that percolation theory and statistical mechanics as a valid proposition for the study of Shared Awareness. The implication being that any behavior in conditional shared awareness will not exceed the behaviors of unconditional shared awareness. It also establishes the comparative metrics necessary for the qualitative analysis of further experimentation.

5.3. Experiment 2[a-e] Heterogeneous Population

This series of experiment simulates a heterogeneous population and the effect of the variables of shared awareness at their extremes. Multiple colors imply a heterogeneous environment, in regards to *'the project'* Secure Border Initiative (SBI) is a heterogeneous environment, as well as the Operational Integrated Center (OIC).

This experiment is in five parts:

- Experiment 2a – establishes heterogeneous conditions of the nodes and the behavior when variables are set at random
- Experiment 2b – node variables are stubborn and standalone
- Experiment 2c – node variables are stubborn and willing
- Experiment 2d – node variables are stubborn and standalone
- Experiment 2e – node variables are accommodating and standalone

The purpose of experiments 2[a-e] is to further test the formation of shares awareness by testing the behavior of the construct under well-defined extreme positions based on predisposition, orthodoxy, and intent.

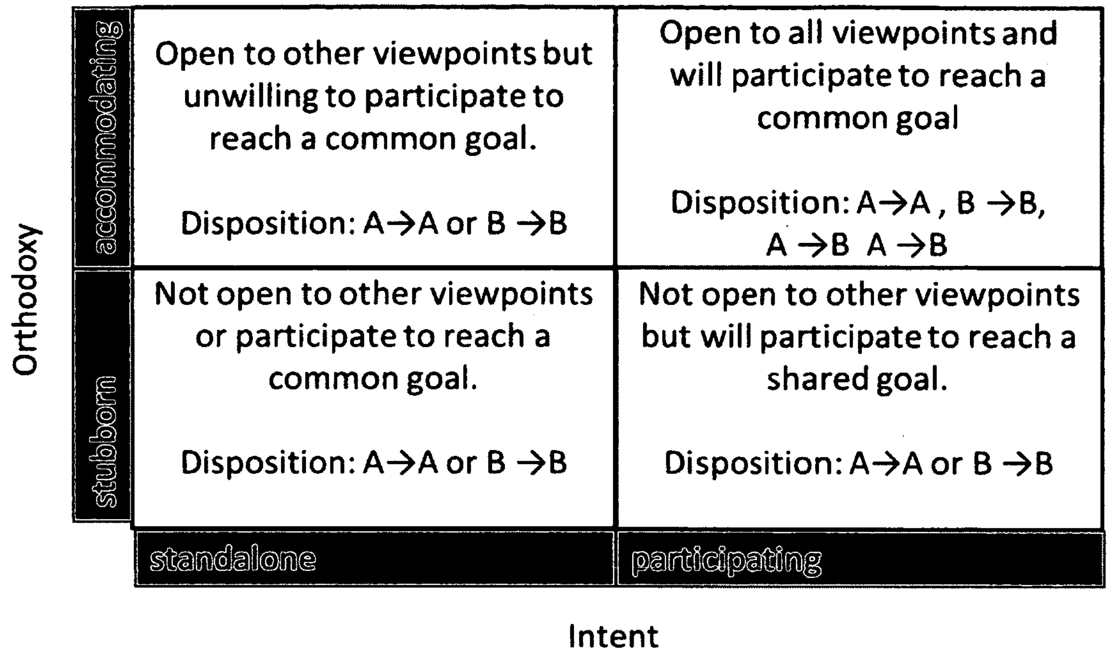


Figure 24. Description of Experiments 2[a-e]

Each node is assigned a color that represents their predisposition, either blue or red. Blue will connect with blue and red will connect with red. Iterating through the model (tick) two nodes are chosen randomly and asked to connect. Primacy is assigned as a means to determine a starting point for each cluster, and the asking node. After each tick either a red or blue component begins to form where the entities are either directly or indirectly connected to each other. If two small components of the same color are connected the two components merge into one component. After a tick the model interprets the state of the clusters based on the number of connections and displays the networks based on the color of the node determined initially by the node 1. A qualitative analysis of the observations from the runs will provide a baseline for interpretations for experiments 2a – 2d. An analysis of the data from the 10 runs of 50 nodes establishes an average number of interactions necessary for heterogeneous nodes [red and blue] to form as well as confirm that two homogeneous clusters formed. The average will be used as a comparison for experiments 2a-2d. Three runs of 250 and 500 are provided to show similar patterns regardless of number of nodes and will not be repeated for experiments 2a–2d.

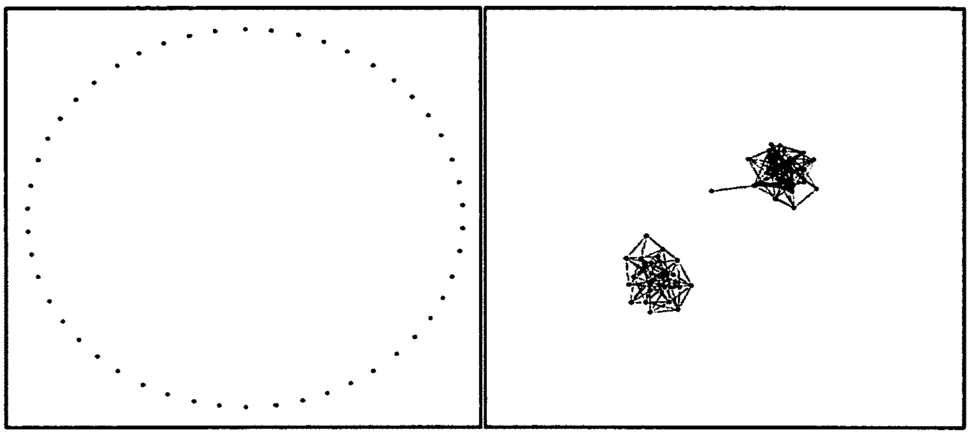
5.3.1. Experiment 2a results

Entities with disparate dispositions, and no other variables considered, will hinder shared awareness. The heuristic is based on indeterminacy; a node will only connect with another node of the same disposition. A node is either A or B with a predisposition of either blue or red. A link will form based on predisposition, A to A and B to B. Because each node can reject a connection due to dissimilarities in predispositions the time for complete clusters to form should be longer than in a homogeneous condition, however expect as many clusters as there are predisposition. For the purpose of this study the number of predispositions was limited to two. The variable settings for the model are below.

Predisposition	**A & B**	**Randomly assigned**
Primacy	Node1	let node1 one-of turtles let node2 one-of turtles ask node1
Orthodoxy	Not used	
Intent	Not used	
Desire	Assumed high	
Access	Not used	

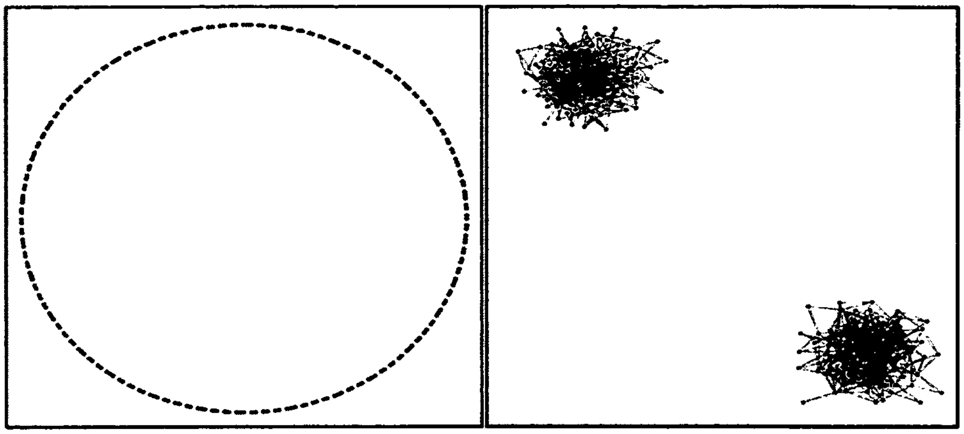
Table 4. Parameters for Experiment 2a

This model was run with 50, 250, and 500 nodes respectively. The model was run 10 times for 50 nodes and three times for 250 and 500 nodes respectively. The resulting data (Table 5) were collected.



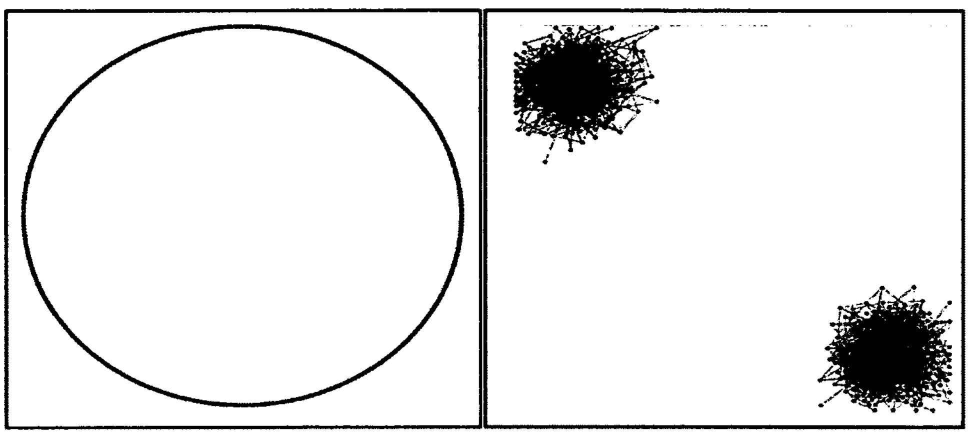
(a) (b)

Figure 25. Exp-2a 50 Nodes (a) Setup (b) Results



(a) (b)

Figure 26. Exp-2a 250 Nodes (a) Setup (b) Results



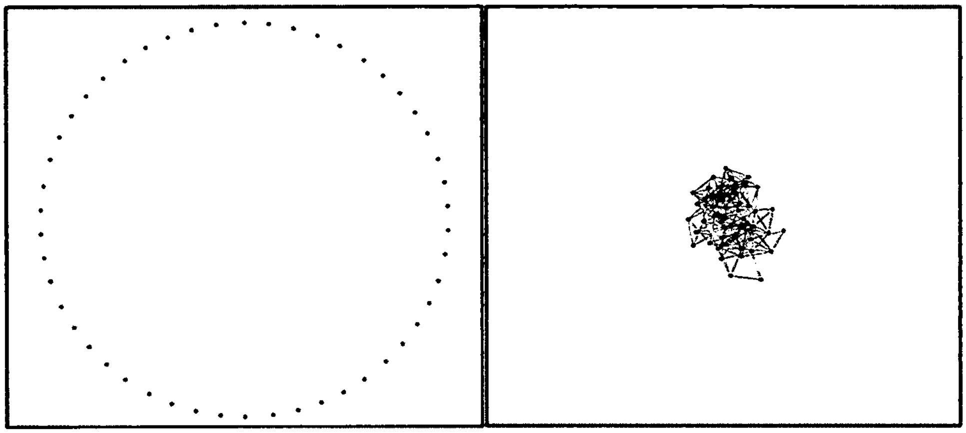
(a) (b)

Figure 27. Exp-2a 500 Node (a) Setup (b) Results

Data extracted from experiments (bold indicates which run is used for figures provided).

exp 2	Column1	Column2	Column3	Column4
run	# nodes	ticks	# red nodes	# yellow nodes
1	50	259	25	25
2	50	215	25	25
3	50	200	26	24
4	50	183	27	23
5	50	389	33	17
6	50	176	29	21
7	50	217	23	27
8	50	228	26	24
9	50	240	32	18
10	50	222	21	29
avg ticks		233		
11	250	1523	122	128
12	250	1288	129	121
13	250	1860	128	122
avg ticks		1557		
14	500	3429	260	240
15	500	3435	248	252
16	500	2506	253	247
avg ticks		3123		

Table 5. Data Extracted from Experiment 2a



(a) (b)

Figure 28. Exp-2a Random Variables (a) Setup, (b) Results

5.3.1. Experiment 2b Results

The purpose is to further test the formation of shares awareness by testing behavior under well-defined extreme positions. This experiment introduces a latent variable; access that is effected by the relationship between the two variables orthodoxy and intent. Primacy is an enabler for shared awareness, where willingness is inversely proportional to orthodoxy. Node1 will only connect if node2 is disposed to its predisposition. In the model this is represented by node1 with predisposition of blue/red connecting with a node2 with a red/blue. A node is either A or B with a predisposition of either blue or red and an alternate disposition of red or blue, respectively. With both variables [orthodoxy/intent] set to low, two separate clusters form based on the dominant perspective. Each cluster is homogeneous, indicating a willingness to communicate with similar predisposition only [same colored clusters], but no willingness to share [two different colored clusters formed red and blue]. The clusters formed following patterns common to percolation.

The clusters formed following patterns common to percolation. Table 6 lists the variable settings for the model.

Predisposition	A & B	Randomly assigned
Primacy	Node1	let node1 one-of turtles let node2 one-of turtles ask node1
Orthodoxy	stubborn	Set at 1 for all nodes
Intent	standalone	Set at 1 for all nodes
Desire	Assumed high	
Access	Intent is inversely proportional to orthodoxy	if intent > orthodoxy [set access 9] if intent = orthodoxy [set access 1] if intent < orthodoxy [set access .11] Connect if access > 1

Table 6. Parameters for Experiment 2b

This model was run with 50, 250, and 500 nodes respectively. The model was run 10 times for 50 nodes and three times for 250 and 500 nodes respectively. The resulting data (Table 7) were collected.

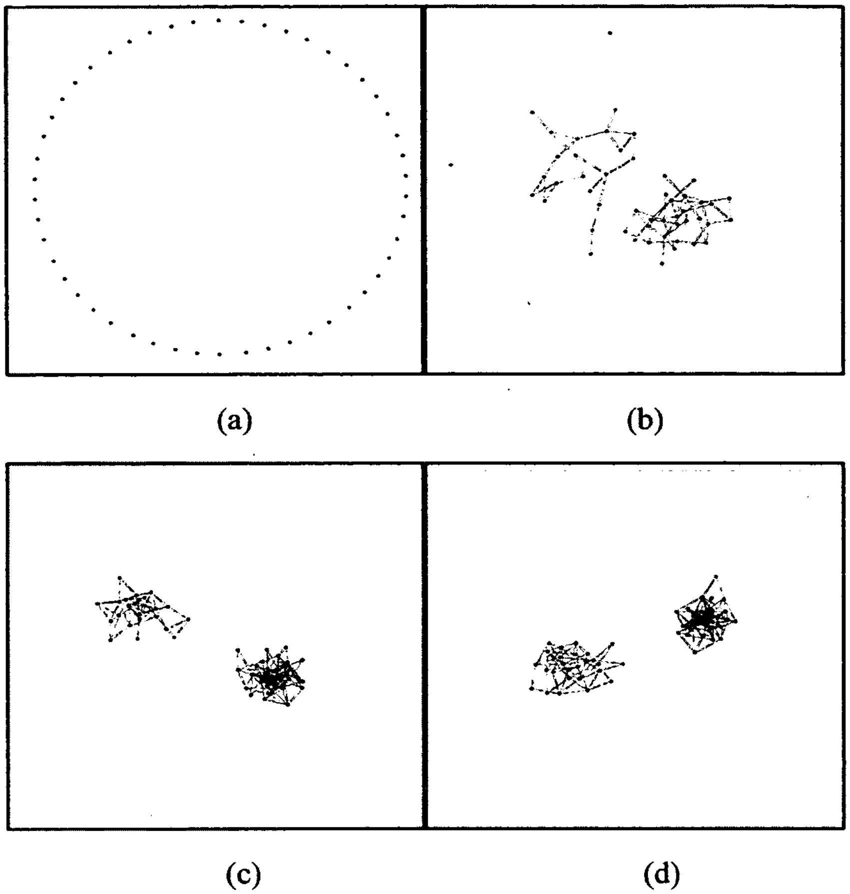


Figure 29. (a) Exp-2b 50 Node Setup, (b) Exp-2b Node Sequence-1, (c) Exp-2b Node Sequence 2, (d) Exp-2b 50 Node Sequence 3

Data extracted from experiments (bold highlight indicates which run is used for figures provided).

exp 2a	# nodes	# ticks	# red nodes	# yellow nodes
1	50	177	26	24
2	50	231	24	26
3	50	320	30	20
4	50	175	24	26
5	50	329	23	27
6	50	298	31	19
7	50	263	30	20
8	50	223	22	28
9	50	180	30	20
10	50	350	27	23
avg ticks	50	254.6	20	30

Table 7. Data Extracted from Simulation Runs for Experiment 2b

5.3.1. Experiment 2c Results

The purpose of Experiment 2c is to further test the formation of shares awareness by testing behavior under well-defined extreme positions. This experiment introduces a latent variable; access that is effected by the relationship between the two variables orthodoxy and intent. Primacy is an enabler for shared awareness, where willingness is inversely proportional to orthodoxy. Node1 will only connect if node2 is disposed to its predisposition. In the model this is represented by node1 with predisposition of blue/red connecting with a node2 with a red/blue. A node is either A or B with a predisposition of either blue or red and an alternate disposition of red or blue respectively. With both the orthodoxy variable set to low and the intent variable set to low one clusters form based on the dominant perspective, however, the cluster is not homogeneous indicating a willingness to communicate [indicated by the link] but not necessarily to change perspectives for sharing [indicated by red and blue nodes]. The clusters formed following patterns common to percolation. Table 9 lists the variable settings for the model.

Predisposition	**A & B**	**Randomly assigned. 50:50?**
Orthodoxy	accommodating	Set at 1 for all nodes
intent	willing	Set at 9 for all nodes
Desire	Assumed high	
Access	Intent is inversely proportional to orthodoxy	if intent > orthodoxy [set access 9] if intent = orthodoxy [set access 1] if intent < orthodoxy [set access .11] Connect if access > 1

Table 8. Parameters for Experiment 2c

This model was run with 50, 250, and 500 nodes respectively. The model was run 10 times for 50 nodes and three times for 250 and 500 nodes, respectively. The resulting data (Table 10) were collected.

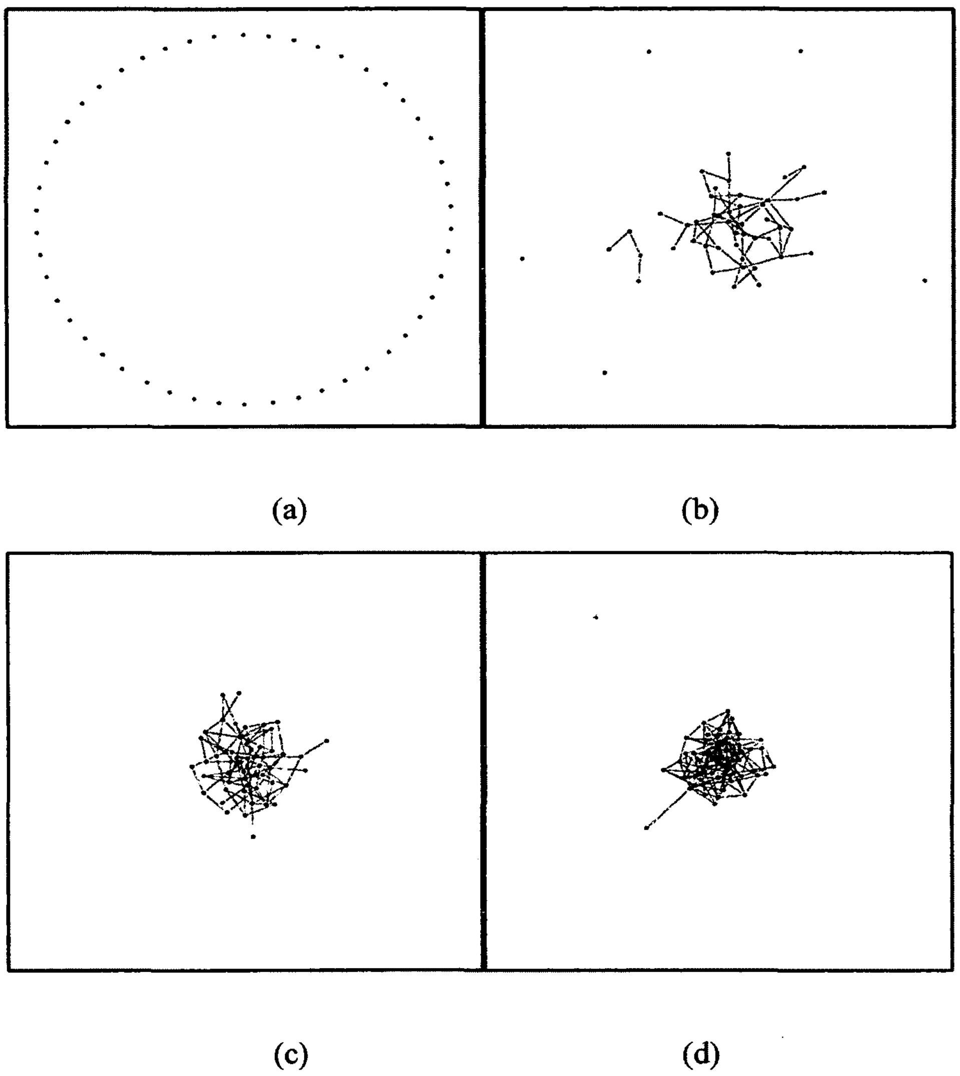


Figure 30. Exp-2c: (a) 50 Node Setup, (b) Sequence-1 (c) Sequence-2, (d) Sequence-3

Data extracted from experiments (bold indicates which run is used for figures provided).

exp 2b	# nodes	# ticks	# red nodes	# yellow nodes
1	50	100	33	17
2	50	93	24	26
3	50	105	17	33
4	50	134	18	32
5	50	85	23	27
6	50	117	29	21
7	50	81	24	26
8	50	121	25	25
9	50	123	20	30
10	50	133	19	31
avg ticks		109.2	31	19

Table 9. Data Extracted from Simulation Runs of Experiment 2c

5.3.4. Experiment 2d Results

The purpose of this experiment was to further test the formation of shares awareness by testing behavior under well-defined extreme positions. This experiment introduces a latent variable; access that is effected by the relationship between the two variables orthodoxy and intent. Primacy is an enabler for shared awareness, where willingness is inversely proportional to orthodoxy. Node1 will only connect if node2 is disposed to its predisposition. In the model this is represented by node1 with predisposition of blue/red connecting with a node2 with a red/blue. A node is either A or B with a predisposition of either blue or red and an alternate disposition of red or blue respectively. With both variables [orthodoxy/intent] set to high two separate clusters form based on the dominant perspective. Each cluster is homogeneous, indicating a willingness to communicate with similar predisposition only [same colored clusters], but, no willingness to share [two different colored clusters formed red and blue]. The clusters formed following patterns common to percolation. Table 10 lists the variable settings for the model.

Predisposition	**A & B**	**Randomly assigned. 50:50?**
Orthodoxy	stubborn	Set at 9 for all nodes
Intent	willing	Set at 9 for all nodes
Desire	Assumed high	
Access	Intent is inversely proportional to orthodoxy	if intent > orthodoxy [set access 9] if intent = orthodoxy [set access 1] if intent < orthodoxy [set access .11] Connect if access > 1

Table 10. Parameter Setting for Experiment 2d

This model was run with 50, 250, and 500 nodes, respectively. The model was run 10 times for 50 nodes and three times for 250 and 500 nodes, respectively. The resulting data (Table 12) were collected.

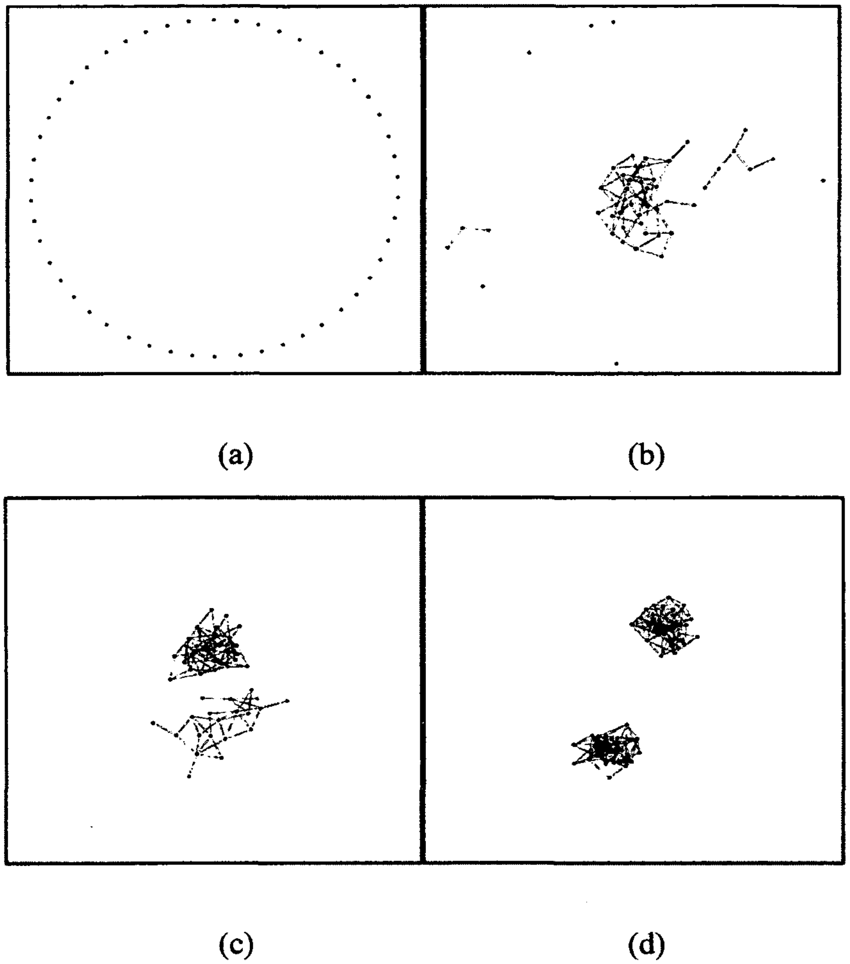


Figure 31. Exp-2d: (a) 50 Node Setup, (b) Sequence-1, (c) Sequence-2, (d) Sequence-3

Data extracted from experiments (bold indicates which run is used for figures provided).

exp 2c	# nodes	# ticks	# red nodes	# yellow nodes
1	50	227	30	20
2	50	384	28	22
3	50	204	28	22
4	50	267	23	27
5	50	209	24	26
6	50	200	21	29
7	50	171	27	23
8	50	265	34	16
9	50	218	25	25
10	50	184	28	22
avg ticks	50	232	27	23

Table 11. Data Extracted from Simulation Runs for Experiment 2d

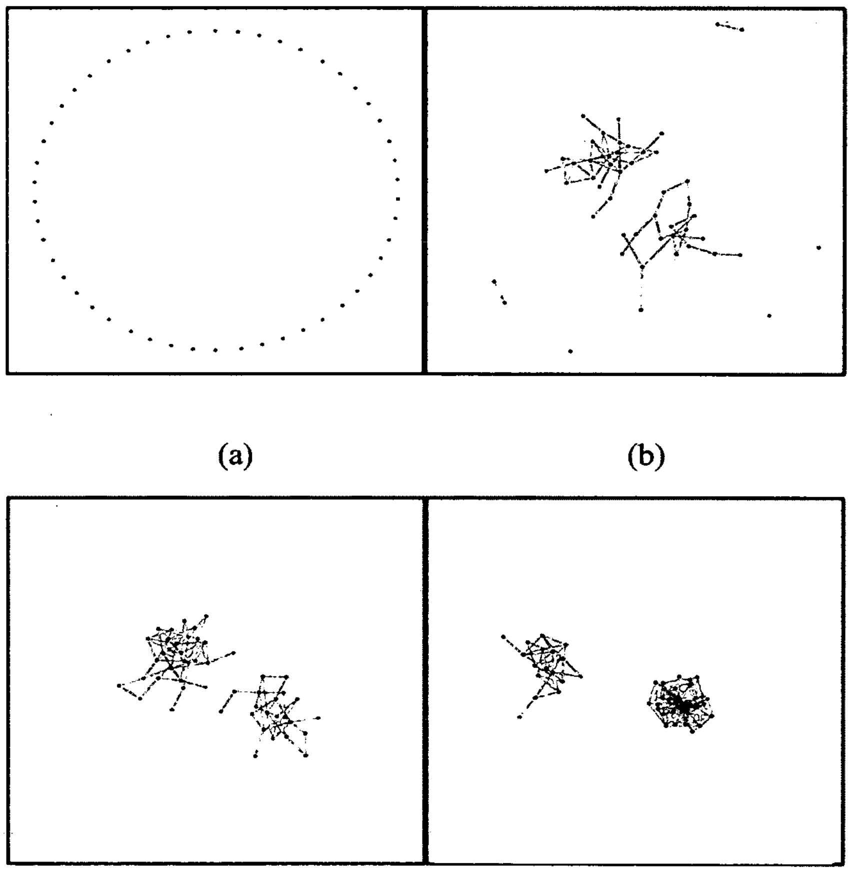
Experiment 2e Results

Purpose is to further test the formation of shares awareness by testing behavior under well-defined extreme positions. This experiment introduces a latent variable; access that is effected by the relationship between the two variables orthodoxy and intent. Primacy is an enabler for shared awareness, where willingness is inversely proportional to orthodoxy. Node1 will only connect if node2 is disposed to its predisposition. In the model this is represented by node1 with predisposition of blue/red connecting with a node2 with a red/blue. A node is either A or B with a predisposition of either blue or red and an alternate disposition of red or blue respectively. With both variables [orthodoxy/intent] set to low two separate clusters form based on the dominant perspective. Each cluster is homogeneous, indicating a willingness to communicate with similar predisposition only [same colored clusters], but, no willingness to share [two different colored clusters formed red and blue]. The clusters formed following patterns common to percolation. The clusters formed following patterns common to percolation. Table 13 lists the variable settings for the model.

Predisposition	**A & B**	**Randomly assigned. 50:50?**
Orthodoxy	accommodating	Set at 9 for all nodes
Intent	standalone	Set at 1 for all nodes
Desire	Assumed high	
Access	Intent is inversely proportional to orthodoxy	if intent > orthodoxy [set access 9] if intent = orthodoxy [set access 1] if intent < orthodoxy [set access .11] Connect if access > 1

Table 12. Parameter Settings for Experiment 2e

This model was run with 50, 250, and 500 nodes, respectively. The model was run 10 times for 50 nodes and three times for 250 and 500 nodes, respectively. The resulting data (Table 12) were collected.



(a) (b)

(c) (d)

Figure 32. Exp-2e 50 Nodes (a) Setup, (b) Sequence-1, (c) Sequence-2, (d) Sequence-3

Data extracted from experiments are in the table below.

exp 2d	# nodes	# ticks	# red nodes	# yellow nodes
1	50	228	29	21
2	50	154	27	23
3	50	319	26	24
4	50	238	26	24
5	50	252	25	25
6	50	229	25	25
7	50	180	21	29
8	50	151	22	28
9	50	145	23	27
10	50	260	24	26
avg ticks		215.6	19	31

Table 13. Data Extracted from Simulation Runs of Experiment 2e

5.3. Interpretation of Experiment 2[a-e]

As stated earlier two perspectives (red and blue) were represented it this series of experiments. The results of the four extreme states of sharing reflected what was expected. Experiment 2a set the initial condition for the behaviors of two disparate predispositions, although the results were anticipated it provided substantiation for the effect of the variables on shared awareness. Additionally, the run with randomly assigned variables indicates that a variable has a stronger influence on the formation of the clusters than the rest. Experiment runs 2b, 2d, and 2e maintained two separate perspectives each forming their own perspectives. Duration, as indicated by number of ticks, had very little variation with each other however, time to form a cluster between heterogeneous environments versus homogeneous environments were understandably greater. This would indicate that entities in a heterogeneous environment do not necessarily infer sufficient motivation for change when forced to work with each other, ergo shared awareness did not occur. In the case of 'the project' even though techniques were employed to affect sharing, as long as each entity maintained their perspective sharing across disparate perspectives (e.g. SBI vs. OBP) did not occur. It was significant to observe that although shared awareness did occur in the moment, the different perspectives acted as if they had understanding of the situation based on the tasking and action items that were captured and polls conducted during the workshops, it was obvious that each time the groups reconvened any shared awareness was no longer present. In contrast experiment 2b formed a single cluster and the duration for the cluster to form was nearly the same as a homogeneous environment. Of note in this experiment was willing and accommodating entities formed a single supercluster yet both perspectives were maintained within the cluster forming a bifurcation that is apparent in the model. The most significant of the experiment is the dominant effect intent has on predisposition and its willingness to access other predisposition. However, although links were established between the cluster remained heterogeneous. This suggests that even in the extreme where the variables were considered conducive to sharing, shared awareness did not necessarily emerge. In observations of 'the project' it was often assumed that OFO and OBP shared a common understanding based on their Law Enforcement culture, yet rarely was there any commonality between the two agencies when discussions between the two agencies revolved around solving a problem such as security. Ironically, even though agreement was rare it was again assumed sharing occurred, so much so that during one of the workshops when each individual was asked to define their mission, no two mission statements were identical and yet the expectation was that they had a common understanding of the mission. Although the super cluster formed there was a distinct bifurcation present in the cluster. The assumption that a heterogeneous environment when abstracted to a homogeneous environment will overcome disparity in perspectives is indicative of a false positive. A refresher of argument [hypothesis] 2:

Given random entities (nodes) under the conditions of a heterogeneous environment, normal distributions, and desire to exchange information, shared awareness will emerge from the interactions of random entities based on the principles of Bohr's (as cited in Wolfe, 1949) Principal of Complementary and the variables of shared awareness governed by CSP.

The significance of these experiments is the effect of the variables [at random and in the extreme] has on the formation of a supercluster. Setting the boundaries for the expected behaviors of the node is based on the extremity. Of particular note was the indication of a dominant variable indicated in the random experiment and identified in the subsequent experiments.

5.4. Experiment 3 [a-b]

This series of experiment simulates a heterogeneous population and the effect of the variables of shared awareness at their extremes. Multiple colors imply a heterogeneous environment, in regards to *'the project'* Secure Border Initiative (SBI) is a heterogeneous environment, as well as the Operational Integrated Center (OIC).

This experiment is in two parts:

- Experiment 3a – sets the external event to high
- Experiment 3b – sets the external event to low

The purpose of experiments 3[a-b] is to further test the formation of shares awareness by testing the behavior of the nodes influenced by an external factor. The effect of the external factor will test the formation of a cluster based at its effect on predisposition, intent, and orthodoxy. For the purpose of these experiments the number of predispositions was limited to two.

Each node is assigned a color that represents their predisposition, either blue or red. Blue will connect with blue and red will connect with red. If two nodes are not similar dispositions node 1 will attempt to access node 2 based on node 2's willingness to change perspective based on the urgency of the external influence. The external factor represents the increase in motivation due to the increase in urgency of the environment for sharing. An example is first responders arriving at an incident where jurisdictional policies conflict as the incident increases in urgency the jurisdictional disparate responders overcome their predisposition to form a common perspective conducive to meeting the incident. Iterating through the model (tick) two nodes are chosen randomly and are asked to connect. Primacy is assigned as a means to determine a starting point for each cluster, and the asking node. After each tick either a red and blue components begin to form where the entities are either directly or indirectly connected to each other. After a tick the model interprets the state of the clusters based on the number of connections and displays the network with both predisposition linked based on the color of the node determined initially by the node 1. A qualitative analysis of the observations from the runs will provide a baseline for interpretations for experiments 3[a-b]. An analysis of the data from the 10 runs of 50 nodes establishes an average number of interactions necessary for heterogeneous nodes [red and blue] to form. Three runs of 250 and 500 are provided to show similar patterns regardless of number of nodes and will not be repeated for experiments 3[a-b].

The purpose is to introduce an external factor onto the experiments to observe its effect on the behavior of the nodes and the formulation of a shared awareness.

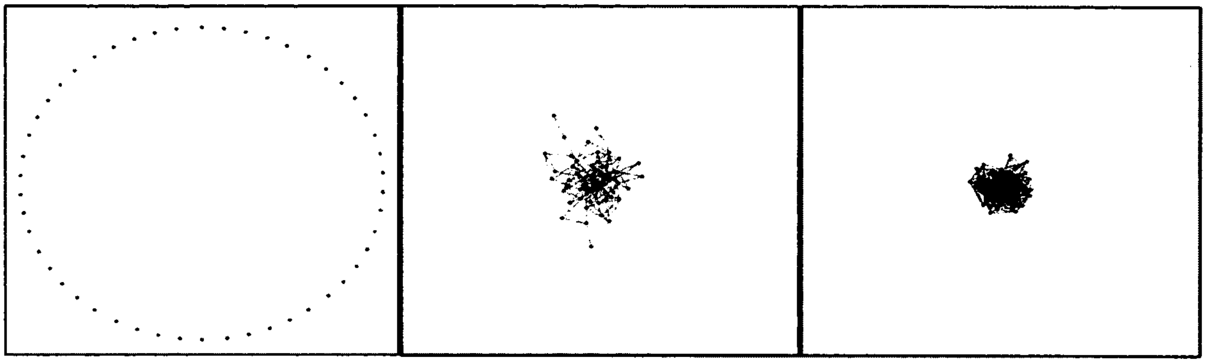
5.4.1. Experiment 3a results

A high setting (9) for the event indicated an immediate crisis, (e.g. terrorist attack, fire, loss of life) and which would suggest that individual participants would reduce the effect of orthodoxy on the nodes ability to both connect [based on the relationship between orthodoxy and intent] and share [based on the relationship between orthodoxy and the event]. As the experiment ticked, connections were made regardless of predisposition, however, apparent changes were occurring within the nodes. A node could change color based on the interaction with another node. Each tick indicated a different interaction so the node could possible change color again based on new interactions and the predisposition of the other node and primacy. Ultimately a homogeneous supercluster formed based on the interactions. The disposition of the supercluster was sporadic and indeterminate until the last node changed color. Table 14 lists the variable settings for the model.

Predisposition1	A & B	Randomly assigned red or yellow
Predisposition	a & b	Opposite of predisposition2
Orthodoxy	0-9	Randomly assigned
Intent	0-9	Randomly assigned
Desire	Assumed high	
Access	Intent is inversely proportional to orthodoxy	[ifelse proximity1? <= 0 [set access? 1] [set access? (intent? / proximity1?)]]
Disposition	Utility theory: yellow or red	if [predisposition1?] of node1 = disposition? [set color [color] of node1 create-link-with node1]
Primacy	Node1	
Event	Set 9 (high)	ask turtles [set proximity1? proximity? - event]

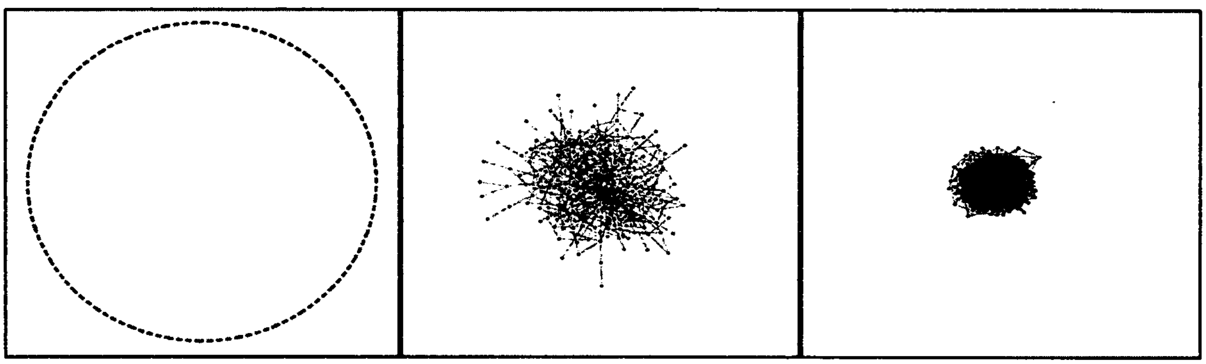
Table 14. Settings for Experiment 3a

This model was run with 50, 500, and 1,000 nodes respectively. The model was run 10 times for 50 nodes, three times for 250 and 500 nodes respectively. The resulting data (Table 15) were collected.



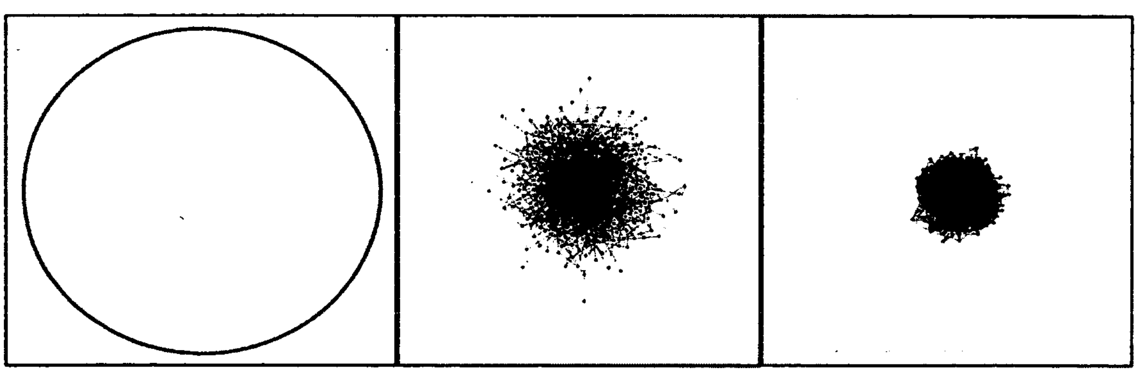
(a) (b) (c)

Figure 33. Exp-3a 50 Nodes: (a) Setup, (b) Connected, (c) 50 Disposition



(a) (b) (c)

Figure 34. Exp-3a 250 Nodes (a) Setup, (b) Connected, (c) Disposition



(a) (b) (c)

Figure 35. Exp-3a 500 Nodes (a) Setup, (b) Connected, (c) Disposition

Data extracted from experiments are provided below (bold indicates which run is used for figures provided).

exp 3	event set 9	Column1	Column 2	Column 3	Column4	Column5
run	# nodes	ticks	# red	# yellow	disposition	tick node 100% connected/red
1	50	335	27	23	red	88/16
2	50	329	24	26	yellow	120/29
3	50	323	22	28	red	150/46
4	50	468	25	25	yellow	150/31
5	50	381	24	26	yellow	73/37
6	50	324	25	25	red	179/44
7	50	214	29	21	red	138/31
8	50	203	28	22	red	161/46
9	50	190	29	21	red	134/49
10	50	260	18	32	yellow	133/12
11	250	2696	115	135	yellow	1378/130
12	250	2264	124	126	yellow	1034/127
13	250	1423	128	122	red	723/168
14	500	2395	126	374	yellow	824/137
15	500	4500	247	243	307 red	2269/216
16	500	4600	242	258	130 red	2464/184

Table 15. Data Extracted from Simulation Runs of Experiment 3a

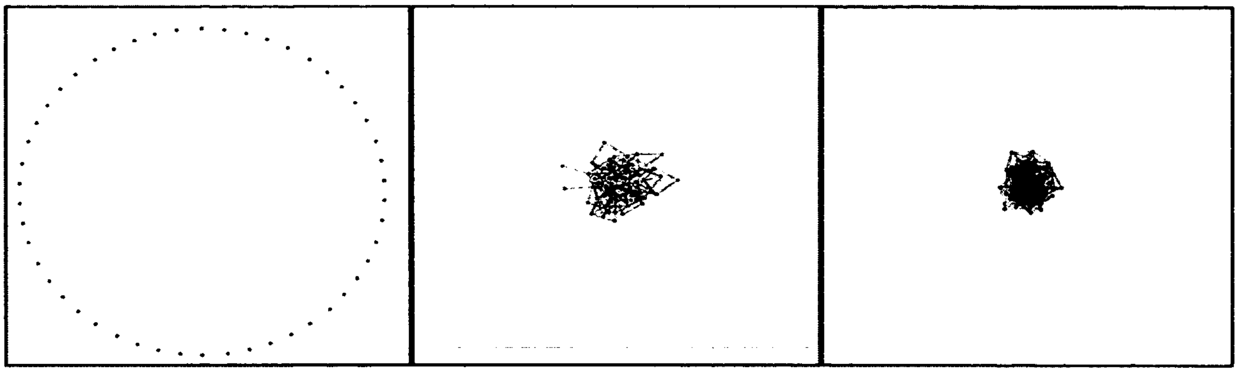
5.5. Experiment 3b Results

A low setting (1) for the event indicated a mild crisis, (e.g. short suspense, conflict resolution, sports event) and suggests that individual participants would reduce the effect of orthodoxy on the nodes ability to both connect [based on the relationship between orthodoxy and intent] and share [based on the relationship between orthodoxy and the event]. As the experiment ticked, connections were made regardless of predisposition, however, apparent changes were occurring within the nodes. A node could change color based on the interaction with another node. Each tick indicated a different interaction so the node could possible change color again based on new interactions and the predisposition of the other node and primacy. Ultimately a homogeneous supercluster formed based on the interactions. The significance of this experiment was even with a low crisis nodes were willing to change disposition, however the amount of time [number of ticks] required for the cluster to become homogenous was significantly longer. The disposition of the supercluster was sporadic and indeterminate until the last node changed color. Table 16 lists the variable settings for the model.

Predisposition1	A & B	Randomly assigned red or yellow
Predisposition	a & b	Opposite of predisposition2
Orthodoxy	0-9	Randomly assigned
Intent	0-9	Randomly assigned
Desire	Assumed high	
Access	Intent is inversely proportional to orthodoxy	[ifelse proximity1? <= 0 [set access? 1] [set access? (intent? / proximity1?)]]
Disposition	Utility theory: yellow or red	if [predisposition1?] of node1 = disposition? [set color [color] of node1 create-link-with node1]
Primacy	Node1	
Event	Set 1 (low)	ask turtles [set proximity1? proximity? - event]

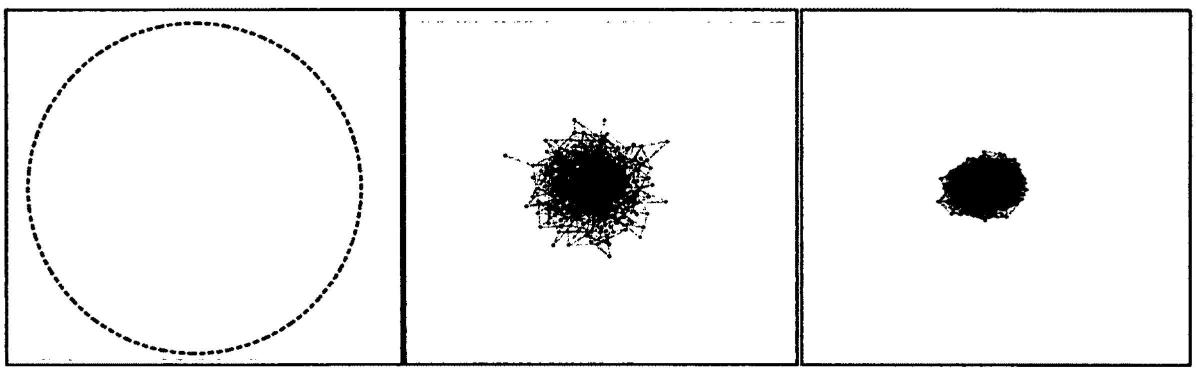
Table 16. Settings for Experiment 3b

The model was run with 50, 500, and 1,000 nodes respectively. The model was run 10 times for 50 nodes, three times for 250 and 500 nodes respectively. The resulting data (Table 17) were collected.



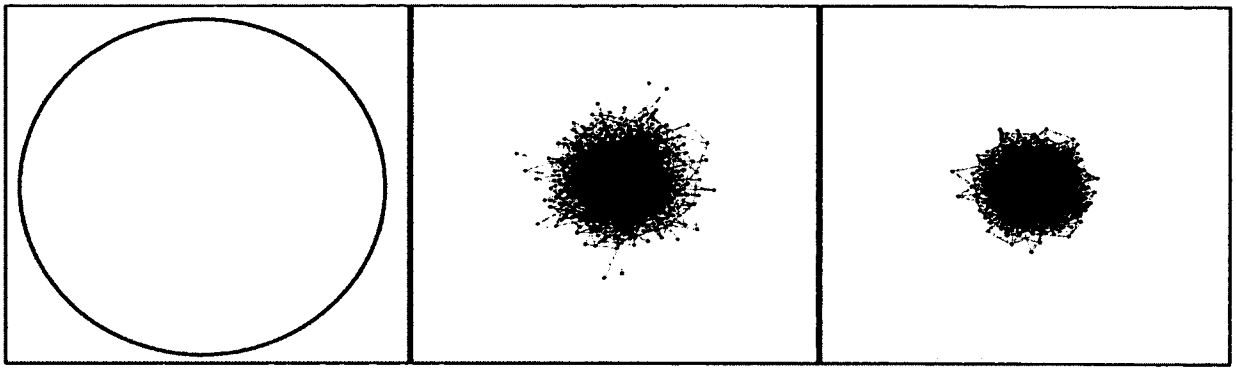
(a) (b) (c)

Figure 36. Exp-3b 50 Nodes (a) Setup, (b) Connected, (c), Disposition



(a) (b) (c)

Figure 37. Exp-3b 250 Nodes (a) Setup, (b) Connected, (c) Disposition



(a) (b) (c)

Figure 38. Exp-3b 500 Nodes (a) Setup, (b) Connected, (c) Disposition

Data extracted from experiments are provided below(bold indicates which run is used for figures provided).

exp 4	event set 1	500 max ticks allowed	Column 1	Column 2	Column3	Column4
run	# nodes	ticks	# red	# yellow	disposition	tick/nodes 100% connected(red)
1	50	390	20	30	yellow	188/15
2	50	500/15	25	25	735/yellow	273/18
3	50	500/48	24	26	519/red	188/27
4	50	500/4	24	26	669/yellow	206/27
5	50	500/48	24	26	625/red	109/29
6	50	500/16	23	27	750/yellow	203/16
7	50	500/48	25	25	548/red	187/12
8	50	500 4	21	29	566/yellow	136/17
9	50	399	25	25	red	109/29
10	50	500/47	29	21	927/red	221/29
11	250		131	119		2222/155
12	250		114	136		1682/120
13	250		123	127		1311/115
14	500		271	223		3140/314
15	500		247	253		2519/264
16	500		248	252		2885/207

Table 17. Data Extracted from Simulation Runs of Experiment 4

5.5.1. Interpretation of Experiment 3 [a-b]

This set of experiments understandingly provided the most significant insights into conditional sharing. Indicated in the previous set of experiments, willingness was not sufficient to overcome extreme orthodoxy, yet, as Klein (1993) would suggest, crisis is indicative of a common purpose within a specific timeframe. Utility theory was used by each node to decide on which perspective to adopt, yet without a focal point for primacy it took an extended amount of time at a low crisis for the supercluster to form. To extend on the scenario described in the second experiment 2B with regard to 'the project', shared awareness did form [a single super cluster with one perspective] when a significant event was introduced into the scenario. In regards to 'the project' while OFO and CBP were not able to coalesce into a singular perceptive within one cluster in 2c it can be inferred that under crisis one perspective is foregone for another and either OFO or CBP would change their perspective as long as the crisis was. Of interest is the evolution of the cluster, it was not apparent which perspective would emerge with primacy set solely on the node rather than the culturally generated perspective even when the crisis was significantly low however as the event significance increased it became apparent which perspective was dominant by the time 100% of the nodes were connected. A refresher of argument [hypothesis] 3 is:

Given random entities (nodes) under the conditions of a heterogeneous environment, normal distributions, a desire to exchange information, shared awareness will emerge from the interactions of random entities based on the variables of shared awareness governed by CSP, an inverse relationship between orthodoxy and intent, and a disposition towards one view or another based on utility theory.

Throughout the experiment, one of two nodes resisted change, even having a short term effect on the cluster swaying it to the opposite color This is significant in the sense that not all nodes must shift perspective for effective shared awareness, this would suggest, as describe by Klein's (1993) and natural decision making, that effective conditional shared awareness can be expected to form sufficiently for a collective act with sufficient external motivation, such as a crisis. As event setting increases a homogeneous supercluster will form over time from two disparate groups of perspectives. The amount of time is significantly reduced as the event setting [external factor] is increased, representing a greater crisis. This experiment is indicative of a multiple agencies (hypothetically identified as OFO and OBP within the project) to form a [super] cluster(s) based on the decision for an entity to switch perspectives from external influences. This argument (as the best case scenario for external influences) sets the parameters for testing the effect of external influences on conditional shared awareness. The implication being that any behavior in conditional shared awareness when pushed to the extreme will show behaviors that will not exceeds the behaviors of conditional shared awareness. It also establishes the metrics for comparison unconditional shared awareness as well as an additional set of comparative metrics necessary for the qualitative analysis of further experimentation.

CHAPTER 6

DISCUSSION

Based on the outcome of the experiments a follow-up conversation was conducted with a senior executive familiar with '*the project*' that could lend credence to the efficacy of the experiments. The discussion revolved around the outcome of the models and the effect of the variables on shared awareness. Experiment 2 [a-e] were presented and discussed.

6.1. Follow-up Interviews

Additionally, an informal question was posited and forwarded to eleven senior leaders in numerous positions in academia, industry, government, and consulting to explore the significance of willingness towards shared awareness as observed in experiment 2[c] and 3 [a-b].

Question:

Q1: shared awareness is when an individual, who can have a similar or unique perspective with another individual, can have a productive dialog to move forward on a shared premise. Assume willingness to participate is based on a shared premise, in your experience have you ever seen a successful integration with a perspective that did not have a willingness to participate.

Responses were gathered from Industry CEO's, Executive and Senior Leadership in Government agencies and Military organizations, Senior Consultants, and Academia

Responses were varied:

A1: I can think of many but one would be our discussions the DHS tasks since it seemed futile to develop a system that had its automated data sources restricted and required manual input (copied) from those systems vs. direct access for formulation. We still did it despite the illogic of it all.

A2: I am not sure how anyone can have a successful integration with a perspective that did not have at the core, a willingness to participate. Maybe I am being too literal but seems very difficult, if not impossible, to do.

A3: This can be looked at from sociological, psychological and engineering perspectives. I also tried to think of examples where this was NOT the case.

From a sociological perspective, willingness to participate is the first step towards successful integration with a common or new perspective. Willingness to participate has to be approached from "what's in it for me?" I'm thinking this is the approach you would use for applying to getting communities, state/local governments involved. Tailor approach from a local perspective in order to convince people to participate in a larger, more global problem/perspective.

From a psychological perspective, it's less about a willingness to participate because you are working with consciousness and unconsciousness – and you can consciously participate but not really be truly engaged. Where a shared premise will be successful in this instance, is by developing trust and collaboration.

From a systems engineering perspective, yes there has to be a willingness to participate in order to have successful integration of systems. Must understand the systems perspective and the sensitivity analysis of all the different factors involved.

A4: Willingness trumps everything when trying to build cohesion in a team from different backgrounds and experiences

A5: The example is for two organizations (vs. individuals), but I guess you could make the argument that the guidance and differing opinions came from the two organizational leaders. When I was a captain at AF Space Command, a decision was made that all operational/weapon system software maintenance should be transitioned to AF Material Command. Space didn't want to give up control. AFMC wanted the control (and prestige) and argued they could do things better and cheaper. I was responsible for transitioning the Cheyenne Mountain software to AFMC. Each side dug-in hard with their opinions (the operational vs. logistical side). We had to work through a lot of cultural differences, funding issues, and build an incredible amount of trust. Would should have taken 6 months probably took about 4 years of total effort.

A6: One example. I can think of, I guess dozens of scenarios where I've worked with people of differing opinions and managed to succeed. Most from the USAF. Most of those cases though worked through a motivation of sense of service, improving operations, or trying to draw down costs.

A7: yes, every day ... it's called marriage.

A8: From my experience, two entities can have shared awareness, without a willingness to participate (although it is less likely it is possible). But they cannot coordinate, synchronize, and integrate their actions without a willingness to participate. So the answer is NO, I have never seen a successful integration without a willingness to participate....even if the two entities did by chance have a common awareness (I have seen that).

A9: If I understand the question, I think it is possible. The question becomes how do measure success. Have you opened another's mind or eyes? Has anyone benefited no matter what the motivation from either side? Has the world taken a step forward because of the interaction? Have you gained a new perspective even if your mind has not changed? Will either party work harder to improve a situation after the fact? Many positive results have come about from hearts that were not completely in the game. One of my favorite quotes (or paraphrasing of a quote) is, "It may not be the party we had hoped for but while we are here we may as well dance." I feel the same way when working with people I don't exactly agree with. Sometimes it is tough but it is worth looking deeper to see if something has improved because of the collaboration.

A10: I have been witness to many people who help us build Habitat homes for what people might say are the wrong reasons.... guilt, pier pressure, job pressure, or court ordered are just a few. Many start out for the wrong reasons and end up "getting it" or as I like to say, "feel the feeling." Those who never get it have still helped a good family build and buy their home. So the end result is good.

The other thing that I witness on are regular basis is the people who come out thinking they are giving so much to help someone else. The experience ends up showing them that they receive much more than they have given. It is a rush for me when I witness that phenomenon.

A11: "We" currently promote the notion of "common understanding," which does NOT require agreement but does indeed require acceptance of and/or organizing under a commonly agreed to purpose. As I suspect you already know, your invocation of the term "successful" becomes highly problematic because "success" is so frequently "determined by the elites with power. From their point of view "successful integration" can be achieved (only EVER in the too short term but nonetheless) through coercion/force/power difference. If, alternatively, you intend "successful integration" to be essentially self (uncoerced)-sustaining integration over the long term by everyone organized voluntarily (willingly) under the common purpose my answer to your last question would be no. I must caution (as I again suspect you know) that you would be tackling a tough tangle of confounding variables before you could be satisfied of your premise validity.

6.2. Understanding and Comprehensibilty

Sousa-Poza (2013) describes the guiding principle of situation theory is to: "maintain within the developed constructs [that which is comprehended] the natural tie to reality…" this in turns determines "…the degree that which the construct can be understood" (p. 21). The CRR is the means by which understanding can occur from the condition created through the observation of that which is bounded and the participant whom must act within the bounding. The incompleteness of the situation is the impetus for the method proposed by Brewer (2010, 2013), adopted by Sousa-Poza (2013) and informs the CRR in any given situation.

Foundational to this study is that aspect of situations theory that allows for shared awareness through understanding. Brewer (2010, 2013) addresses the relationship of understanding and comprehension within a CRR as well as within reality, germane to this study is a comprehension within a CRR. It should be noted that without a feedback loop to 'reality' comprehension can only be attained within the CRR. This is reflected not only in the interviews but the experiments as well since responses can only be within their own perspectives and not that of a the whole or 'reality'. That which can be understood in reality can be comprehensible, however because an entity can only understood that which is perceived it is hampered in understanding fully and as such is limited in comprehension. In this instance changing perspective is seated in the entities ability to understand to attain comprehensibility beyond their perspective. This bounds the discussion to those aspects of shared awareness where there is either a complete understanding within the entities, defined by Sousa-Poza (2013) as a simple situation, or where understanding is the impetus for action to obtain comprehension of the situation, described as a complex situation. Given the first experiment, it asserts a completeness that is indicative of a simple situation. This is reflected in both the homogeneity at large in the supercluster and the relative quick transition of the K-threshold and formation of the supercluster. In regards to the second series of experiment comprehension was present only within the understanding of like perspectives creating incomprehensibility between disparate perspectives and clusters. In the case of high intent and low orthodoxy the nodes were actionable, however they were unable to form a consistent understanding for adapting. It required and external event to imbibe learning and adaptation for complete understanding in lieu of the consistency established by the link. These responses provide strong indications that willingness has a significant influence on shared awareness and substantiates the research and experiments in this dissertation.

Providing the justification for the rational for the formation of the clusters, specifically in situations that are not considered simple and where comprehension is the means for understanding, thus providing the basis for how the Theory of General Shared Awareness is being used.

CHAPTER 7

A GENERAL THEORY OF SHARED AWARENESS

7.1. Definition of Awareness

Awareness (*CSP*):

1. A condition of having or showing realization *[a self-generative process and structure]*, perception *[that forms a picture of reality]*, or knowledge *[for which understanding can be established]*

2. The situation of which an individual becomes cognizant, for which the comprehension is bounded by the reciprocal effect of the individual's disposition and the state within which the individual perceives to be immersed.

2a. A necessary condition for a situation to exist.

The reciprocal relationship between self and other-than-self, means that the disposition of an individual will be reflected in the beliefs held about themselves and their environment. Awareness is consequently situationally specific, and individually unique.

7.2. Definition of Shared Awareness

1. Shared Awareness (*CSP*): A state of shared comprehension established through adaptation resulting in a common context.

1a. A state in which, conditional to the existence of a common disposition and the desire to share, a common comprehension is established.

1b. A condition in which two entities with common disposition and desire to share can attain a common comprehension of a situation.

For populations, shared awareness must been seen as the condition in which a common comprehension of a situation is established across a population. The establishment of such a shared awareness is non-linear, and the dynamics of forming a shared awareness is best described as an emergent attribute, reflective of the phenomena described in percolation theory. The ability to share will be contingent on the desire to share (by definition), the orthodoxy and willingness to establish a common disposition among entities (from situations theory, CRR) that cannot be assumed to share the same predispositions (heterogeneous population).

7.3. General Theory of Shared Awareness

Shared awareness is a state of comprehension generally shared by the population that is functionally dependent on the establishment of shared awareness between a critical number of entity pairs. Shared awareness is proportional to the desire to share and the willingness by entities to adapt from predispositions to establish a common disposition, and inversely proportional to the orthodoxy of the entities.

7.4. Categories of Shared Awareness

The scope of this study was focused on conditional shared awareness based on observations from a real world operational integration project, however, as the study progressed it became clear that conditional shared awareness is but one of four types of shared awareness. Although the remaining three types are not within the scope of this paper they are within scope of the research and are topics for future research and necessary for a final articulation of the general theory of shared awareness.

The factors for studying shared awareness proposed by this research are:

- understanding the situation
- understanding the constraints of the situation
- intent to participate, and
- desire to share.

As noted this study was to focus on a shared awareness in a specific situation, however through discovery and observations four types of shared awareness emerged.

The types of shared awareness are:

- Conditional
- Contextual
- Synthetic
- Synoptic

7.4.1. Conditional Sharing

Natural decision making is described as a method for disparate entities to come to a common perspective for reaching a goal. It is focused on crisis decisions that are temporal in nature (i.e. first responders for multiple jurisdictions that may have conflicting authorities responding to an event). A premise of natural decision making is within the situation a shared awareness emerges to respond to the event (Klein, 1993). Conditional sharing - the focus of this study - explored how heterogeneous perspectives, presumably under the conditions describe for natural decision making, can share. It assumes Bohr's (as cited in Wolfe, 1989) principle of complementary as a condition of the situation and an external factor as the impetus for disparate perspective's to change to generate a shared awareness. This type of sharing is temporal in the sense that as the motivation within the event disappears the each entity will resume their predisposition; it implies no memory or shift in culture.

7.4.2. Contextual Sharing

Maltz (2010) describes shared situational awareness as common awareness precipitated by culture for the purpose of satisfying a mission. Maltz provides the example of the military culture informing and guiding the actions of the participants within the culture. Endsley (1995) speaks to the commonality of information as a means of affecting situational awareness as in a common operating picture or a singularly focused agency such as border patrol. Key to each situation is the context within the situation as well as the spatial change rather than change over time [temporal].

7.4.3. Synthetic Sharing

Joint Forces Command was charter with the mission to create purple or integration of disparate cultures into an emergent 'joint culture' (Kovacic, 2006). In the context of synthetic sharing, integration is to form, coordinate, or blend into a functioning or unified whole. The implicit goal for Joint Forces Command was to integrate the four services into a joint service. The type of sharing necessary for this assumes incremental shifts within the perspective to allow the integration of other perspectives, a blending of all the characteristics of all the components.

7.4.4. Synoptic Sharing

Plato provided the relationships that gave context to Zeno paradoxes in his dialog on universals – we understand in spite of the knowledge. Plato's philosophic method implied the descent of knowledge of universal forms (or ideas) to a contemplation of particular imitations of these ideas (Jowett, 2009). The universals formed from the observations existing within both the observer and reality created the conditions for Zeno's thought experiments. These universals play an important role in understanding and knowledge that is discussed later in this study; however, the significance is that common variables that exist at both the macro and micro levels can be identified as a means to affect shared awareness. Plato finds that the universal exists apart from particular things, and is related to them as their prototype or exemplar. The idea of knowledge as a descendent of universals resonates with Wittgenstein's (1995) tractatus , Sousa-Poza's (2005) pragmatic idealism (2005), and Brewer's (2011) Complex Situations Paradigm. All this would lead to the insight put forth from Aristotle and Plato in regards to the concept of universality within a CRR and form the foundation for synoptic sharing.

CHAPTER 8

CONCLUSION

8.1. Summary

This study presented an anthropological journey into the disparity of perspectives along with the implications this rift has on shared awareness. The journey was an extrapolation intended to show the breadth and depth of the bifurcating nature of observation has on reality and the limitations it creates on understanding. Key to this study was the introduction of Complex Situations Paradigm (CSP) and Situations Theory as a way to obviate the implications of disparate perspectives. Foundational to the theoretical underpinnings were the musings of Pragmatic Idealism, a philosophic litany of how understanding is formed within situations. A systematic description of [shared] awareness and the proposition that percolation theory and CSP as descriptive of how to define and study shared awareness lay the foundation for experimentation. The method for experimenting and analysis, conducive to this type of subject matter, provided both substantiation and context to how what shared awareness is and the influencing factors, ultimately leading to the articulation of the General Theory of Shared Awareness GTSA). Defined at a high level, continued research into the depth of this theory and its implications to the study of macro behavior based on micro dynamics is warranted.

8.2. Assumptions

Assumptions for this study of shared awareness:

- Awareness can be shared between individuals.
- Information flows between individuals.

- An entity can have infinite number of CRRs.
- The result of the flow of information amongst individuals is the potential for shared awareness.
- Shared awareness establishes shared context and subsequently understanding.
- Spatial and temporal interpretations form the basis of understanding.
- The existence and the acceptance of CSP and Situations Theory to the extent necessary for this study are accepted as valid.
- The study is limited to comprehensibility within the CRR and makes no concessions to a feedback loop to 'reality'.

8.3. Future Research

The insights provided by this study both in the articulation of a General Theory of Shared Awareness as well as situations theory highlight the necessity for continued study. Future research can be described in terms of studies for how shared awareness can be explored or studies on how shared awareness would benefit a practical venue.

8.3.1 Extending on the Research

The experiments raise implications to understanding that suggest that willingness is necessary to 'change' predispositions coupled with an empathy that allows for a path for that change. Exploring this facet of willingness on the relationship between orthodoxy and intent would provide a finer granularity to how willingness can affect shared awareness. Additionally, as the study indicates, individuals tend to stay in their 'comfort zone' subscribed to orthodoxy. Along with study of the relationship of an entities willingness to leave this 'comfort zone' exploration into the 'conceptual distance' between disposition would be another facet to add for a robust variable for further experimentation, e.g. what is the effect of similarity in terms of willingness and the ability to overcome orthodoxy?

The K-threshold was explored as the critical probability before a second order phase transition that is described as shared awareness. In the experiment the generative process labeled as culture was defined simply as a difference that may or may not exist between nodes. Experimenting with the ontology of the interplay with culture, the generative process, and interpretive framework as well as adding granularity to each of the elements would provide insights into what aspects of the generative process and/or interpretive framework could be manipulated to produce a predicted behavior toward share awareness. The makeup of how orthodoxy is formed and how intent influences orthodoxy beyond an inverse proportionality would provide incredible inferences for the dynamics that form shared awareness. Notionally, a strong case could be made that participation is the key to overcome orthodoxy, intent, and a possible avenue for reaching the K-Threshold with fewer interactions. Experimenting with structures to affect these efficiencies would prove useful in organizational dynamics. Implementing structure, such as hierarchy, as a rule would become more akin to implementing hierarchy as a means for providing a type of sharing to facilitate understanding within an organization.

8.3.2 Extending the Research to Practice

The current work described conditional awareness as on category of awareness, this view was supported by the necessity of intent or a willingness to change, which was reinforced by external subject matter experts. Also supported in the research was the notion that individuals tend towards orthodoxy and that any extreme positions make sharing impossible. An external event (conditional) was required to move these individuals away from the extreme into the realm of change. Views not supported by the experiments and suggestive of further study to completely formalize a general theory of shared awareness are the categories that were identified during the study. These views provide the necessary direction for studying each type of shared awareness in its contextual domain. Explaining 'together but separate' during the study did not completely explain all the forms of together that were possible. During the course of the study three other categories emerged that provided more explanation for this. Continued experimentation into contextual, synthetic, and synoptic sharing is required to fill out the complete theory. Engineering Management is predicated on constructing a bridge between the paradoxes that are created. Fundamental to the study was the flaw imposed on knowledge that causes anxiety in disciplinary from paradox. Continued research into how a disposition is maintained would shed light into how a bridge might be maintained or more probable what change is necessary for adopting one side of the paradox over the other to affect sharing. Another significant view that needs exploring is the idea of learning and memory and the implications for sharing beyond one iteration. Experimentation with common goals, visions, premises under the premise of memory or learning would provide insights into the tangible value of 'commanders intent' 'art of war', or other intuitive processes that up to this point were merely intangible.

This research, unsophisticated yet powerful, opens the door to reinterpretation and exploration in theory and practice of nearly every aspect or method employed within engineering management; from quantifying ambiguous boundaries, team building, social dynamics, context, and environments. Quantifying shared awareness opens the door for dealing with the macro to micro dynamics for emergence in any dynamic, non-linear, complex, and uncertain situation and provides a means for study in Engineering Management that was not possible before.

REFERENCES

Adams, K., & Keating, C. (2011). Overview of the systems of sytems engineering methodology, *International Journal of Systems of Systems Engineering*, Vol 2, Issue 2/3, pp. 112,119).

Adams, M. J., Tenney, Y. J., & Pew, R.W. (1995). Situation awareness and the cognitive management of complex systems, *Human Factors*, Vol 37, Issue 1.

Albert, R. & Barabasi, A., (2002). Statistical mechanics of complex networks, Reviews of Modern Physics, Vol 74, p. 59.

Argyris, C, Putnam, R., & Smith, D. M. (1985). *Action Science: Concepts, Methods, and Skills for Research and Intervention.* San Francisco: Jossey-Bass.

Aristotle (1994). Metaphysics. (W. D. Ross, Translator). Original work circa 350 BCE. Retrieved from http://classics.mit.edu/Aristotle/metaphysics.html. Aristotle, Oxford companion.

Aronson, D. (1996). Using systems thinking to increase the benefits of increased innovations, *R&D Innovator*, Vol. 6, Issue 2.

Axelrod, R. & Tesfatsion, L. (2013). On-line guide for newcomers to agent-based modeling in the social sciences. Retrieved from http://www2.econ.iastate.edu/tesfatsi/abmread.htm.

Bayes Theorum. (2013). Scholarpedia. Retrieved from http://www.scholarpedia.org/article/Bayesian_statistics.

BarYam, Y., (2010). New England Complex Systems Institute. Retrieved from http://necsi.edu/.

Bergson, H. (1912). *An introduction to metaphysics.* New York: G.P. Putnam's Sons.

Biggiero, L., (2001). Sources of Complexity in Human Systems, *Nonlinear Dynamics, Psychology, and Life Sciences* , Vol. 5, Issue 1.

Bohrs, N. (1949). *Discussions with Albert Einstein on Epistemological Problems in Atomic Physics, Albert Einstein: Philosopher-Scientist.* Cambridge, MA: Cambridge University Press, 1949

Brewer, V. (2008). *Anatomy of systems: A debate on complexity.* Candidacy Exam, Old Dominion University, Norfolk, VA.

Brewer, V. (2010). *A Decision Making Construct for Complex Situations*, Dissertation, Old Dominion University, Norfolk, VA.

Brewer, V. (2013*). PRISM, A Philosophical Foundation for Complex Situations, Managing and Engineering in Complex Situations*, Chap 3 (45-79) New York: Springer.

Broadbent S., & Hammersley, J. (1956). Percolation Process I. Crystals and Mazes, *Camb. Philos.* Vol. 53, Issue 3, p. 632.

Center for the Study of Complex Systems (CSCS). (2013). About us/mission. University of Michigan. Retrieved July 12, 2013 from http://www.lsa.umich.edu/cscs/.

Derényi, I., Palla, G., & Vicsek, T. (2005). Clique percolation in random networks. *Phys. Rev. Lett.* Vol. 94, Issue 160202.

Endsley, M. R. (1995). Toward a theory of situation awareness. *Human Factors*, Vol. 37, Issue 1, pp. 32-64.

Everett, M. G. & Borgatti, S. P. (1998). Analyzing clique overlap. *Connections*, Vol. 21, p. 49-61.

Friedell, M. (1960). On the structure of shared awareness, *Behavioral Science*, Vol 14, p. 66.

Galam, S. (2004a). Contrarian deterministic effects on opinion dynamics: "The hung elections scenario". *Physica A*, Vol. 333, pp. 453-460.

Galam, S. (2004b). The dynamics of minority opinions in democratic debate. *Physica A*, Vol. 336, pp. 56-62.

Grimmett G. (1999). *Percolation*. Cambridge: Cambridge University Press.

Gutwin, C., & Greenberg. S. (1999). A framework of awareness for small groups in shared workspace groupware. Technical Report 99-1 Department of Computer Science, University of Saskatchewan, Canada

Hair, J., Black, W., Babin, B., Anderson, R., & Tatham, R. (2006). *Mutlivariate Data Analysis*, 6th Ed. Upper Saddle River, NJ: Pearson Prentice Hall.

Hamilton P. (1992). Grunig's Situational Theory: A Replication, Application, and Extension, *Journal of Public Relations Research*, Vol. 4, Issue 3, pp. 123-149.

Hammersley, J. (1956). Percolation processes: Lower bounds for the critical probability. *The Annals of Mathematical Statistics*.

Hegselmann, R., & Krause, U. (2002). Opinion dynamics and counded confidence models, analysis, and simulation. *Journal of Artificial Societies and Social Simulation*, Vol. 5, Issue 3.

Heilbing, D. & Bailetti, S. (2011). How to do agent-based simulations in the future: From modeling social mechanisms to emergent phenomena and interactive systems design. Santa Fe Institute, SFI Working Paper, 2011-06-024.

Heinsenburg, W. (2001). Uncertainty principle, The Stanford Encyclopedia of Philosophy. Retrieved from http://plato.stanford.edu/entries/qt-uncertainty/

Heisenberg, W. (1972). *Physics and beyond.* New York: Harper & Row.

Helbing, D.,(1995). Quantitative sociodynamics: Stochastic methods and models of social interaction processes. Dordrecht: Kluwer Academic Publishers.

Holyst, J., & Kacperski, K. (2001). Social impact models of opinion dynamics. *Annual Reviews of Computational Physics IX*, pp. 253-273.

Holyst, J., Kacperski, K., & Schweitzer, F. (2000). Phase transitions in social impact models of opinion formation. *Physica A*, Vol. 285, pp. 199-210.

Honderich, T. (1995). *The Oxford Companion to philosophy.* Oxford: Oxford University Press.

International Conference on Systems, Man and Cybernetics. (2005). Vol 3, pp. 2744-2750.

Jowett, B. (1994-2000). *Parmenides.* Translated by Benjamin Jowett, Massachusetts Institute of Technology, Retrieved August 10 2009 from http://classics.mit.edu/Plato/parmenides.html.

Kacperski, K., & Holyst, J. (1997). Leaders and clusters in a social impact model of opinion formation. In F. Schweitzer (Ed.), *Self-Organization of Complex Structures: From Individual to Collective Dynamics* (pp. 367-378). London: Gordon and Breach.

Kacperski, K., & Holyst, J. (1999). opinion formation model with strong leader and external impact: A mean field approach. *Physica A*, Vol. 269, pp. 511-526.

Kacperski, K., & Holyst, J. (2000). Phase transitions as a persistent feature of groups with leaders in models of opinion formation. *Physica A*, Vol. 287, pp. 631-643.

Kersten, H. (2006). What is percolation? *Notices of the AMS*, Vol 53, Issue 5, p. 572.

Klein, G. (1993). A recognition-primed decision (RPD) model of rapid decision making. In G. Klein, J. Orasanu, R. Calderwood, & C. Zsambod (Eds.), *Decision making in action: Models and methods*, pp. 138-147. Norwood, NJ: Ablex.

Kohring, G. A. (1996). Rising models of social impact: The role of cumulative advantage. *Journal de Physique I*, Vol. 6, pp. 301-308.

Kollman, T.E. (2010). *Survey and framework for transdiciplinary research activities.* Texas Tech University, Dissertation.

Kovacic, S. (2005). General taxonomy of system[ic] approaches for analysis and design, IEEE SMC Proceedings, #824.

Kovacic, S., Sousa-Poza, A., Keating, C. (2006). Complex situations: An alternative approach for viewing a system of systems, systems of systems engineering. 2006 IEEE International Conference.

Kovacic, S. (2010). Complex adaptive situations environment-learning management framework. Technical Report, Accenture.

Kovacic, S., & Sousa-Poza A. (2010). Customs and Border Protect, Final Report.

Kuhn, T. (1996). *The structure of scientific revolutions*. 3rd Ed. Chicago: Univ. of Chicago Press.

Laguna, M. F., Abramson, G., & Zanette, D. H. (2003). Vector opinion dynamics in a model for social influence. *Physica A*, Vol. 329, pp. 459-472.

Lewenstein, M., Nowak, A., & Latane, B. (1992). Statistical mechanics of social impact. *Physical Review A*, Vol. 45, Issue 2, pp. 763-776.

Macal C., & North M.J. (2010). Tutorial on agent-based modeling and simulation part 2: How to model with agents. Center for Complex Adaptive Agent Systems Simulation (CAS2) Decision & Information Sciences Division Argonne National Laboratory Argonne, IL 60439, *U.S.A Journal of Simulation*, Vol. 4, pp. 151–162

Mainzer, K. (2004). Thinking in complexity: The Computational dynamics of matter, mind, and mankind. Berlin: Springer.

Maltz, R. (2010). Shared situational understanding: Fundamental principles and iconoclastic observations. *Military Review.*

Massachusetts Institute of Technology. (2007). Engineering Systems Division. Retrieved Sept 10, 2007 from http://esd.mit.edu/academics/sm.html

Nassim, T. (2007). *The black swan: The impact of the highly improbable.* New York, NY: Random House.

National Centers for System of Systems Engineering. (2007). Mission Statement. Old Dominion University. Retrieved Sept 10 ,2007 from http://www.ncsose.org/.

New England Complex Systems Institute (2010). About NESCI, retrieved from http://necsi.edu//

Nowak, A., & Lewenstein, M. (1996). Modeling social change with cellular automata. *Modeling and Simulation in the Social Sciences from a Philosophical Point of View* (pp. 249-285). Boston: Kluwer.

Nowak, A., Szamrej, J., & Latane, B. (1990). From private attitude to public opinion: A dynamic theory of social impact. *Psychological Review*, Vol. 97, Issue 3, pp. 362-376.

Department of Engineering Management. (2007). Old Dominion University. Retrieved Sept 10 2007 from http://web.odu.edu/engr/enma/.

Osgood, C., & Tannenbaum, P. (1955). The principle of congruity in the prediction of attitude change. *Psychological Review*, Vol. 62, Issue 1, pp. 42-55.

Owen, G.E.L. (1958). Zeno and the Mathematicians, Proceedings of the Aristotelian Society.

Oxford English Dictionary. (2010). Online.

Palla, G., Derenyi, I., Farkas, I., & Vicsek, T. (2005). Uncovering the overlapping community structure of complex networks in nature and society. *Nature Publishing Group*, Vol. 435, pp. 814-815

Palla G., Barabasi, A., & Vicsek. T. (2007). Quantifying social group evolution. *Nature Publishing Group*, Vol, 446, pp. 664-667

Padilla, J. (2010). *A theory of understanding within problem situations*. Dissertation. Norfolk: Old Dominion University

Padilla, J., Sousa-Poza, A., Tejada, A., & Kovacic, S. (2007). Towards a diagnostic framework for understanding complex situations. 7th International Conference on Complex Systems and 7th International Conference on Complex Situations, Quincy, MA.

Polanyi, M. (1966). *The tacit dimension*. New York: Double Day & Company, Inc.

Pollner P., Palla G., Abel, D., Vicsek, A., Farkas, I., Derenyi, I., & Vicsek, T. (2008). Centrality properties of directed module members in social networks, *Physica A*, Vol. 387, pp. 4959-4966

Prigogine, I. (1997). *The end of uncertainty*. New York City, NY: The Free Press.

Prigogine, I., & Stengers, I. (1984). *Order Out of Chaos, Man's New Dialogue with Nature*. New York, NY: Bantam New Age Books. 1984. Includes works from:

Bergson, H.-L.,1859-1941, p. 92
Diderot, D., 1713-1784, pp. 80, 83
Hegel, G., 1770-1831, p. 90
Kant, I., 1724-1804, p. 86, 87
Levy-Bruhl, 1857-1939, p. 292
Merleau-Ponty, 1908-1961, p. 299
Pascal, B., 1623-1662, p. 3
WhiteHead, A., 1861-1947, p. 94

Rescher, N. (1996). *Instructive Journey: An Autobiographical Essay*. Lanham, MD: University Press of America.

Rescher, N. (2000). *Process philosophy: A survey of basic issues*. Pittsburgh: University of Pittsburgh Press.

Rittell, H., & Webber M. (1973). Dilemmas in a general theory of planning, *Policy Science*, Vol. 4, Issue 2, pp. 155-169.

Rosenfeld, L. (1961). Foundations of quantum theory and complementarity. *Nature Volume*, Vol. 190.

Russell B. (2009). *The problems of philosophy*. Stillwell, KS: Digireads.com Publishing.

Sahimi, M. (1996). Scaling properties of a percolation model with long-range correlations. *The American Physical Society, Phys. Rev.* Vol. E 54, pp. 3870–3880.

Santa Fe Institute. (2007). Complexity Research, Retrieved Sept 10 2007 from http://www.santafe.edu/about/mission-and-vision/.

Schweitzer, F., & Bartels, J. P. (1991). Simulation of opinion structures in social systems. In W. Ebeling, M. Peschel & W. Weidlich (Eds.), *Models of Self-Organization in Complex Systems* (pp. 236-243). Berlin: Akademie-Verlag.

Sedley, D. (2003). *Plato's Cratylus*, Cambridge: University of Cambridge Publishing.

Shepard, L.A. (1993). Evaluating test validity. *Review of Research in Education*, Vol. 19, pp. 405-450

Sousa-Poza, A. (2013). A narrative of [complex] situations and situations theory. *Managing and Engineering in Complex Situations* (pp. 13-45). New York: Springer.

Sousa-Poza, A. (2007). Class lecture notes. ENMA 821: Research Methods. January – May, 2007. Old Dominion University.

Sousa-Poza A., & Correa-Martinez, Y. (2005). Pragmatic idealism as the basis for understanding complex domains: The trinity and SOSE. 2005 IEEE Proceedings.

Sousa-Poza, A., Kovacic, S., Keating, C. (2007). CASM, the environment and strategic decision making, Technical Report to DHS S&T.

Sousa-Poza, A., & Kovacic, S. (2009). Dealing with complex situations. Training course presented to LE agents in CBP.

Sousa-Poza, A., Padilla, J., & Bozkurt, I. (2008), Implications of a rationalist inductive approach in system of systems engineering research. Proceedings of the Third International Conference on System of Systems Engineering, Monterey, CA.

Sousa-Poza, A. (2008). Research Methods, Engineering Management graduate course, ENMA 821. Old Dominion University

Sousa-Poza, A, Kovacic, S., & Keating, C. (2008). Systems of systems engineering: An emerging multidiscipline. *International Journal of Systems of Systems Engineering*, Vol. 1, Issue 1/2.

Stacey, R., Griffin, D., & Shaw, P. (2004). Complexity and management, fad or radical challenge to systems thinking. London: Routledge.

Standard Encyclopedia of Philosophy. (2009). Analysis. Retrieved from http://plato.stanford.edu/entries/analysis/

Stanford University (2007). Management Science and Engineering. Retrieved Sept 10, 2007 from http://www.stanford.edu/dept/MSandE/cgi-bin/index.php

Stevens Institute of Technology. (2007). Department of Systems Engineering and Engineering Management. Retrieved Sept 10 2007 from http://www.soe.stevens-tech.edu/seem/About_SEEM/management.html.

Systems of Systems Center of Excellence. (2007). Systems of Systems Engineering. Retrieved Sept 10, 2007 from http://www.sosece.org/index.cfm?fuseaction=4F68D291-802C-E84F-68643FD05F21FFB4

Yeh, R.T. (1991). System development as a wicked problem. *International Journal of Software Engineering and Knowledge*. Vol. 1, Issue 2, pp. 117-130.

Umpelby, S. (2011). Cybernetics, systems, informatics. Retrieved 14 Aug 2011, from http://www.iiis2011.org/wmsci/Website/AboutConfer.asp?vc=1

United States Air Force Scientific Advisory Board. (2005). Report on system-of-systems engineering for air force capability development, SAB-TR-05-04.

University of Missouri, Rolla. (2007). Engineering Management and Systems Engineering Department. Retrieved Sept 10, 2007 from http://emse.mst.edu/

Wierman, J. (1982). Percolation Theory. Special invited paper, *The Analysis of Probability*, Vol. 10, Issue 3, pp. 509-524.

Weidlich, W. (1994). Synergetic modeling concepts for sociodynamics with application to collective political opinion formation. *Journal of Mathematical Sociology*, Vol. 18, pp. 267-291.

Weidlich, W. (2000). *Sociodynamics: A systematic approach to mathematical modeling in the social sciences.* Singapore: Hardwood Academic.

Weidlich, W., & Haag, G. (1983). *Concepts and models of a quantitative sociology: the dynamics of interacting populations*. Berlin: Springer-Verlag.

Weisbuch, G. (2004). Bounded confidence and social networks. *The European Physical Journal B*, Vol. 38, pp. 339-343.

Weisbuch, G., Deffuant, G., Amblard, F., & Nadal, J. P. (2001). Interacting agents and continuous opinions dynamics. Unpublished manuscript.

Wilensky, U. (2005) NetLogo giant component model. Retrieved from http://ccl.norhtwestern.edu/netlogo/models/GiantComponent. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

Wilensky, U. (1999). NetLogo. Retrieved from http://ccl.northwestern.edu/netlogo/. Center for connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

Wolfe, F. (1989). Taking the quantum leap: The new physics for the non-Scientist. New York, NY: Harper and Row Publisher.

VITA

Samuel Kovacic has dedicated more than a decade to advancing knowledge of Complex Situations. He has undertaken this work as part of an ongoing research program conducted through the Engineering Management and Systems Engineering Department at Old Dominion University. His particular focus has been on operational integration. His research builds on, and contributes to, several different fields, including: systems engineering, decision making, organizational theory, management, project management, risk management, and system of systems engineering.

Mr. Kovacic has worked on numerous funded research projects. His main sponsors include the office of the Under Secretary of Defense for Acquisitions, Technology and Logistics (OUSD AT&L), the Department of Homeland Security Science and Technology (DHS S&T), the Department of Homeland Security Customs and Border Protection (DHS CBP), the Joint Forces Command, the U.S. Coast Guard, MITRE, Lockheed Martin, and SPAWAR San Diego. He has been awarded $600,000 as the Principal Investigator (PI), $4.9 million as a co-PI, and nearly $2.5 million as a research scientist.

To establish the research being undertaken and to leverage capabilities, Mr. Kovacic collaborated closely with numerous academic institutions, small businesses, and corporations. He is the co-founder of the Managing and Engineering in Complex Situations Forum (MECS Forum) a community of interest and network. The MECS Forum focuses on increasing the understanding of wicked problems, and developing pragmatically sensible, robust methods to manage and engineering in conditions of high uncertainty and transience.

Mr. Kovacic has published more than 10 refereed conference proceeding papers and journal articles. His research projects have resulted in 12 technical reports. His research, networking, and collaborative efforts have culminated in an edited book titled Managing and Engineering in Complex Situations published in 2013 by Springer of which he is the co-editor, and to which he has contributed several chapters.

Mr. Kovacic served 21 years in the U.S. Air Force retiring as a Major. He started his scholarly activities and research on retiring from the Air Force, first as a Principle Systems Engineer for the Concurrent Technologies Corporation, and then as a Research Scientist at the Old Dominion University. He is presently working as a Chief Systems Engineer for the Space and Warfare Command, United States Navy.

Mr. Kovacic holds a B.Sc. in Computer Science from the University of Maryland University College, and an M.B.A. in Business Administration from Embry Riddle Aeronautical University. He is presently a Ph.D. Candidate in the Engineering Management and Systems Engineering department at Old Dominion University.