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Interpreting Commander's Intent: Do we really know what we know and what we don't know?

Jeffrey A Thomas
Linda G Pierce
Melissa W Dixon
U.S. Army Research Laboratory
Human Research and Engineering Directorate
Aberdeen Proving Ground, MD 21005
Jeffrey.alexander.thomas@us.army.mil
Linda.pierce@us.army.mil
Melissa.dixon@us.army.mil

Gwenda Fong
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[To be completed]

Abstract

The 21st Century Military is shifting its focus from traditional combat operations to stability, security, transition, and reconstruction (SSTR) operations (Department of Defense Directive, 2005). US policy on SSTR operations requires full interoperability among representatives across US Departments and Agencies, foreign governments and security forces, international organizations, US and foreign non-governmental organizations, and members of the private sector. This shift in focus has drawn attention to the idea that one of the most salient dimensions of 21st Century warfighting is the ability to operate effectively with others despite the fact that there are likely substantial differences in capabilities and cultural backgrounds. However, knowing the degree to which a team is completely interoperable can be elusive and hard to quantify. One approach is to evaluate how effective teams are able to interpret commander's intent and develop situational awareness in various conditions. This paper describes a technique for evaluating interoperability through a quantitative evaluation of commander's intent and how intent was promulgated through a simulated, distributed and collocated Coalition Task Force (CTF) during an October 2006 Defense Advanced Projects Agency (DARPA) sponsored joint experiment between the Singapore (SN) Armed Forces and the U.S. Army Research Laboratory, Human Research and Engineering Directorate (ARL-HRED).

Background

The intent of this paper is to leave the reader with an appreciation of a SA (or CI) technique using true/false probes that can be used in real-time to quantify and improve the degree of interoperability within the context of the challenges faced by Soldiers in the 21st Century.

Introduction

Two characteristics define 21st Century warfighting; teamwork and the proliferation of command, control, communication, computers and intelligence (C4i) systems. Their interaction form what Warne et al (2004) consider to be one of the most salient dimension of 21st Century warfighting: the ability to operate effectively with others in a network of C4i systems. Salmon et al (2006) state that C4i systems comprise both human and technological agents and are designed to gather information and facilitate the accurate communication of this information between multiple agents. The expectation of C4i systems is to allow a much greater dissemination and clearer exposition of information. It is the ability of the Commander to articulate his intent and for the command to decide on the best way of carrying that out. Alberts and Hayes (2003) postulate that the degree to which these processes, procedures, and C4i systems are interoperable will determine how well collocated and distributed individuals interpret commander's intent and arrive at a common situational awareness.

The processes supporting an *accurate* awareness and interpretation of commander's intent have never been more complex and necessary than today. The activities of September 11, 2001 and beyond marked a changing geopolitical landscape where the U.S. Military recognized that the Cold War modus of operandi is no longer relevant. A decade ago America could readily identify its adversary as the Soviet Union, whose stated intent was to destroy the United States. However, the 21st Century environment is much more complex. For example, the enemy is less transparent (i.e. Disguised gunmen infiltrates secure Iraqi site, killing five Americans in Baghdad), technologically savvy (roadside bombs), and surprisingly agile. Evolving intelligence shows that the 21st Century enemy is made of complex and robust socio-political networks with national and international reach-back capabilities. With these constantly changing threats to national security, the requirements for U.S. Commander's and the military missions they lead must adapt. To this end, senior leadership within the U.S. Department of Defense (DoD) has embarked on a period of transformation. As part of this transformation, the U.S. Department of Defense now recognizes Stability, Security, Transition, and Reconstruction (SSTR) operations as "core" military missions, giving SSTR operations the same priority as traditional combat operations (National Security Presidential Directive-44, 2005 and Department of Defense Directive 3000.25, 2006).

The expansion of military missions to include SSTR operations has presented several obstacles to the U.S. military. While SSTR operations may involve force, these missions are deeply connected to establishing and maintaining peace. Therefore, they are not warfighting operations. SSTR operations require senior DoD leadership, military strategists, and ultimately U.S. Commander's to consider the effects of their actions when developing plans; a new concept of operations titled Effects Based Approach to Operations (EBAO). This new mindset for conducting military warfare also implies that operational and tactical levels of military planning consider the full spectrum of power; political, economic, military, social, information, and intelligence (PEMSII). Militaristic thinking and supporting information databases must expand to include gathering and interpreting information from a much wider perspective.

SSTR operations also require an unprecedented amount of collaboration and cooperation across non-traditional stakeholders. At the helm of these operations are coalition force structures consisting of U.S. military, Departments and Agencies, foreign governments and security forces, global and regional international organizations, U.S. and foreign non-governmental organizations (NGOs), and private sector individuals and for-profit companies, each intimately linked to the other (Alberts and Hayes, 1995). Paramount to mission effectiveness is the ability to achieve a unified command team. Pierce and Bowman (2002) noted that the effects of cultural and organizational barriers on the cognitive fundamentals of teamwork, such as coordination and decision-making, must be understood to ensure the effectiveness of CTF. Findlay writes that participants were well aware that peacekeeping, stability, and reconstruction operations (PS&RO) required unity of action from across the intergovernmental and international communities. For example, the provincial reconstruction teams (PRTs) that have proven highly successful in Afghanistan are prime examples of this approach to address these complex contingencies (Agoglia, 2005).

Commander's intent (or situational awareness)

Although there has been much progress in understanding teamwork and identifying characteristics of an effective team (see Paris, Salas, & Cannon-Bowers, 2002 for a review), developing quantitative measures for assessing the interaction of teamwork and C4i (hereafter referred to as "interoperability") remains a challenge (Salmon et al., 2006 and Thomson & Adams, 2005). Recent methodologies for assessing interoperability have included discussions about situated cognition (Miller and Shattuck, 2006), situational awareness (SA; Gorman et al., 2006 and Stanton et al., 2006) and Commander's Intent (Farrell, 2004; Leggatt, 2004; and Edgar et al., 2000).

Situated cognition, SA, and CI all base their approach on a belief that a team can only be *fully* interoperable when each member understands the purpose of the activity and have applied themselves with a unity of effort. While an in-depth discussion about each approach is well beyond the scope of this paper, the concepts and measures of SA are discussed in further detail as they were directly applied in real-time to the conduct of a recent experiment for which ideas described in this article are based. A conceptualization to bear in mind when reading this paper is that the "driver" of SA is commander's intent (CI). Military operations are never started without some level of understanding of the situation and the initial goals and actions to be taken. Leggatt (2004) writes that:

> From the beginning of the written history of warfare, Sun Tzu circa 500BC or Alexander defeating Darius in 333BC, warfighting has been characterized as the Commander imposing his will upon both his own and enemy troops to achieve his desired outcome (Keegan, 1999). p 2.

It is the careful consideration of CI *applied to* developing and dynamic events in the environment about which the Commander and his staff make decisions and take action (Figure 1). To this end, SA and CI may be used interchangeably throughout this paper.

[Need to Insert Figure 1]

A universally accepted definition and model of SA does not exist even after two decades of research and the emergence of three dominate definitions and their accompanying theoretical perspectives (Salmon et al., 2006). As cited in Salmon et al. (2006), the three dominate theories of SA which Stanton et al. (2001) recognize are the three-level model (Endsley, 1995), the perceptual cycle model (Smith and Hancock, 1995), and the activity theory model (Bedny and Meister, 1999). The major difference among the three perspectives depends on whether SA refers to the processes employed in achieving and maintaining it or to the end product derived as a result of these processes. Therefore, in the context of this paper, situational awareness is defined as and refers to the situation-specific information and inferences in a person's mind, not withstanding those initially shaped by the commander's intent, which he or she uses to make decisions. Additionally, SA is also believed to be the combination of true *and* false information, and the premise that good SA is represented by the ability to tell true and false information apart (Edgar et al., 2003).

Perhaps more discouraging is that after their literature review of standard ergonomics textbooks, scientific journals, and existing human factors method reviews, Salmon et al (2006) identified only 17, out of 30 SA measurement techniques that were considered appropriate and applicable to the study of C4i environments. Considering the collaborative and dispersed nature of C4i environments, Salmon et al. (2006) suggest that measures of SA in C4i environments should possess three capabilities. C4i measures should be able to measure SA simultaneously at different geographical locations, measure both individual and team or shared SA, and measure SA in real-time.

The experimental environment

The experimental environment where the measurement of SA was exercised was the October 2006 Defense Advanced Projects Agency (DARPA) sponsored joint experiment between the Singapore (SN) Armed Forces and the U.S. Army Research Laboratory, Human Research and Engineering Directorate (ARL-HRED). This was an Operational and Tactical Level Command peace enforcement experiment which required participants to role-play a Coalition Task Force Headquarters (CTFHQ) and the Brigade Tactical Command Posts as shown (Fig 2).

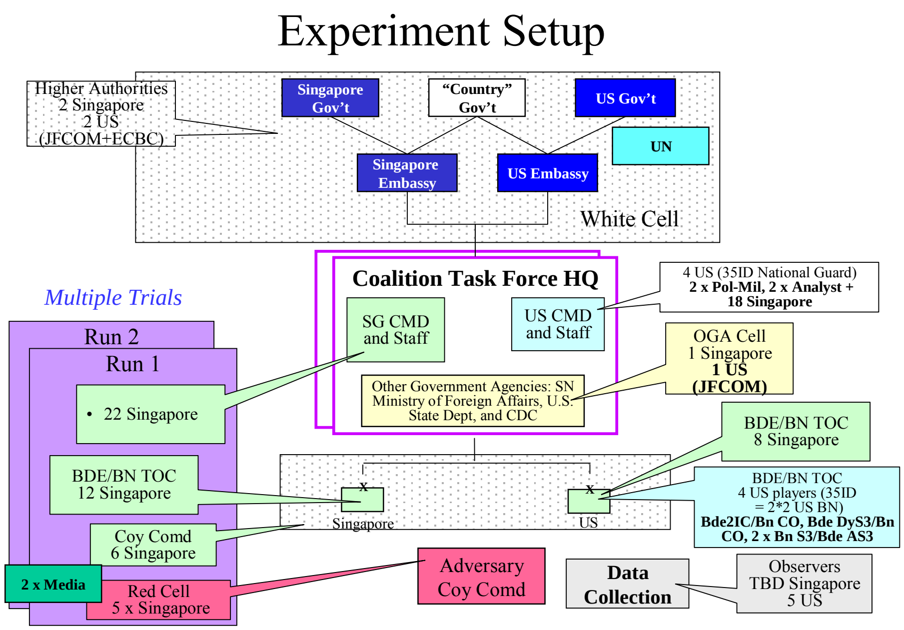

Figure 2. Schematic Drawing of Participant Distribution during Experiment

The participants from SN included students from the Singapore Command and Staff College (SCSC), operational officers from the National Security Coordinating Center (NSCC), CBRE and G3-Army. The participants from the U.S. included DARPA personnel, the Kansas State 35th Infantry Division (35ID), the Joint Forces Command (JFCOM), and the Edgewood Chemical Biological Center (ECBC). In total, there were approximately 140 participants and data collectors. The objective of this experiment was to investigate how future C4i systems may alleviate the real-world challenges faced by a multinational, multi-agency team in order to facilitate interoperability.

The method chosen to evaluate SA was a development of the QUASA^{TM} method (QUantitative Analysis of Situation Awareness; Edgar et al., 2000, 2003; McGuiness, 2004 and Leggatt, 2004). This method uses probe statements about the situation and requires participants to judge whether they are true or false. Their responses can be interpreted using the Signal Detection Theory (SDT) paradigm which allows hits, misses, false alarms, and correct rejections to be calculated (Figure 3: Interpretation of Responses within the Signal Detection Theory Paradigm below). This provides a performance measure but also gives an insight into the bias of the participants. For example, it is possible to ascertain whether groups or individuals are more likely to agree with false information or reject true information.

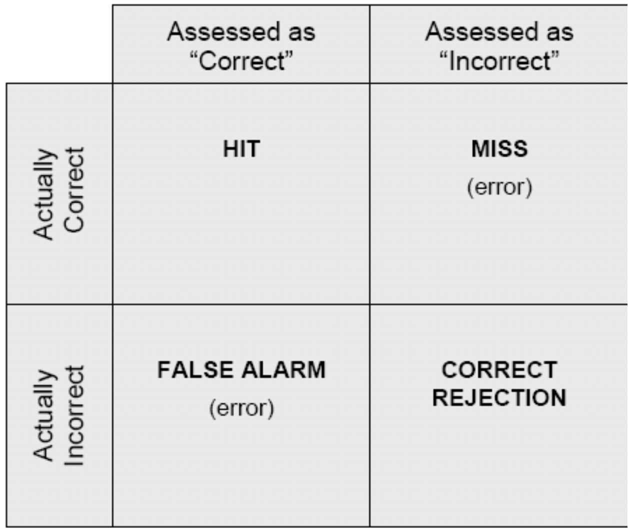

Figure 3: Interpretation of Responses within the Signal Detection Theory Paradigm

Method

Design

There were two experimental conditions, 1 independent variable (interoperability) with 2 levels: non-interoperable (current system) and interoperable (future system). Within the non-interoperable condition (Run 1), participants forming the SN and US Brigades and the Coalition Task Force Headquarters (CTFHQ) each used the same SCME-developed Command and Control (C2) software. For purposes of this experiment, C2 software capabilities were degraded so that Run 1 participants were not supported by collaboration tools such as video conferencing, collaborative document editing, whiteboards, or maps. Participants in Run 1 were expected to communicate in face-to-face meetings (only applicable for collocated teammates) and use basic text-chat and email systems commonly found on today's operating systems. Run 1 participants also shared documents through use of a shared hard drive. Within the interoperable condition, Run 2 participants used a fully interoperable mode of the C2 software provided in Run 1. This allowed participants in Run 2 to communicate via voice-over internet protocol (VOIP), video conferencing, text chat rooms; as well as use collaborative document editing, whiteboards, and maps.

The dependent variables reported in this paper are task performance to the probes (hit, misses, false alarms and correct rejections) which are converted into d', β and confidence ratings.

The hypothesis developed was:

1. H_n: The participants in the fully interoperable condition in Run 2 would have a greater level of SA sensitivity than participants using a degraded version of the C2 software in provided in Run 1.

Participants

There were a total of 136 participant roles to be fulfilled in the DARPA MNDEF SN-US Coalition C2 experiment. These roles were divided into a total of 68 positions for each run. 25 roles were assigned to the Coalition Task Force Headquarters (CTFHQ), a set of 12 roles were assigned to each of the two Brigades, and the remaining 19 roles were considered experimental control (or white cell). Probe data was only collected on participant roles within the CTFHQ and both brigades. The data reported in this report include only those participants who completed all 3 sets of SA probes, 21 and 23 from runs 1 and 2 respectively.

Procedure

The procedure for measuring SA involved two parts, the construction and the administration of the probes. The first set of probes was developed directly from written experimental documentation describing the experiment scenario and rules of engagement. The base probe statements were later refined prior to the start of each experimental run, when the white cell provided a detailed briefing about the experimental scenario, rules of engagement, and the overall mission. During this period, the Commander of the CTFHQ and his Deputy were allowed to ask questions and clarify any concerns they had regarding the experiment.

In addition to the experiment control documents and pre-experiment discussions between the CTFHQ Commander and the white cell, probes also were developed in close association to a set of guidelines identified during the Multi-national Experiments 3 and 4. Amended from the original list of guidelines provided by Leggatt (2004, p. 8) in Table 1, probe statements for this experiment were: a direct reflection of commander's intent, used simple language, a mixture of implicit and explicit issues to include roles and responsibilities, and operationally relevant.

1	Reflect the commander's intent
2	Use simple language (probes should not be a language test for non-native English Speakers
3	Not be a verbatim copy of the published guidance
4	Be a mixture of implicit and explicit issues
5	Be operationally relevant
6	Be equal in number true and false

Table 1: Guidelines for writing probes

This process for developing true/false probe statements was continued two more times throughout each experiment run. A total of 24 probe statements were generated; 3 sets of 8 probes. Each probe was administered at the start, midpoint, and end of each experimental run. The midpoint and ending of each run conveniently occurred around naturally occurring experimental breaks (lunch and dinner) and therefore did not disrupt the flow of the experiment. Before each break, experiment observers and analyst monitored the flow of information and key activities occurring throughout each brigade and the CTFHQ. Such activities included Commander's side-bar meetings with his Deputy or Brigade Commanders. Data was also collected during face-to-face and VOIP meetings, and text-chat. In some cases, content for probes were influenced by the direct observation of the CTFHQ Commander's text chat and e-mail. These correspondences served as rich opportunities for the experiment team to continually update probe statements between probe administrations to players. This was one method to ensure operational relevance of the 2nd and 3rd iterations of probes.

An example of two probe statements is shown in figure 4.

> Sharing information with NGOs is in line with the Commander's intent to avoid civilian casualties. [T]
> If the CTF receives media credit for the recapture of the naval facility, this would be in line with Commander's intent. [F]

Figure 4: An example of two probe statements

Each probe statement was also accompanied by a question asking participants to provide a confidence rating about their decision on a scale from 1 (extremely unconfident) to 7 (extremely confident).

Analysis

The analysis of the probe data was based on the Signal Detection Theory (SDT). SDT originated as a model of perceptual judgment, describing and analyzing how people perform in tasks in which they must detect a certain type of stimulus, a signal and noise. The task is to detect specific signals but not confuse them with non-signals and other irrelevant stimuli (noise). This task is consistent with many real-world military decisions, especially SSTR operations where the Commander and his staff must make sense of incredible amounts of intelligence from a variety of sources. Likewise was the case in this experiment. Therefore, the probe data was grouped into four categories (Figure 5):

> "Hit" - a true statement which the participant agreed was true
> "Miss" - a true statement which the participant thought was false
> "False Alarm" - a false statement which the participant thought was true
> "Correct Rejection" - a false statement which the participant correctly rejected

Figure 5: SDT Categories

After the data were categorized SDT statistics were applied – sensitivity (d') and bias (β). Sensitivity is defined by the SDT as an individual's actual ability to discriminate true signals from non-signals. In the case of true/false SA probes, SA sensitivity can be interpreted as an individual's ability to correctly discriminate between valid and invalid descriptions of the situation. The measure suggests that the greater the sensitivity, the better the individual is at making fewer misses and false alarms when responding to true/false SA probes.

Bias or response criterion specifies the setting of an individual's accept/reject criterion. This can be interpreted as an individual's leaning towards either more readily accepting or more readily rejecting information when he or she is uncertain as to its validity. A low β score suggests a "liberal or risk taking" strategy whereas a high β may represent a "conservative" approach. As McGuinness (2004) notes, it remains to be seen through future research whether a conservative bias reflects a stable disposition of the individual or a more dynamic situation-specific strategy, or is in fact peculiar to the probe technique and is unrelated to SA itself. For this reason and due to experiment limitations and insufficient data (multiple repetitions), individual bias will not be discussed further. Therefore, the remaining paragraphs of the analysis section, results, discussions, and conclusions are strictly based on the sensitivity statistic d' and confidence ratings.

The data collected during the experiment were aggregated and mean d' created for each player, invoking the central limit theorem allowing the data to be treated as interval data and analyzed with parametric statistical tests. Consistent with the approach taken by Leggatt (2004), on those occasions when a participant failed to make a false alarm and thus making it impossible to calculate d', the data were modified in line with Wickens (2002). Wikens suggests arbitrarily modifying the FA rate from 0 to 0.01 and likewise reducing the hit rate to 0.99 to allow d' to be calculated.

A One-way Analysis of Variance (ANOVA) design was applied to test the hypothesis that participants in Run 2 would achieve a greater level of SA sensitivity than those participating in Run 1 as a function of increased interoperability.

Confidence data was analyzed separately to the probe data. These data were of an ordinal nature but a mean confidence rating was calculated. These data were also analyzed using a One-way ANOVA.

Results: Confidence Ratings

Run differences

There were no significant differences between runs. This suggests that within each run, participants found the probe statements to be approximately equal in difficulty to the other. However, this inference is not supported by performance on SA probes which suggests a significant difference between runs.

Results: Sensitivity (d')

<u>Run differences</u>

The ANOVA identified a significant effect of run $F(1,43) = 14.858$; $P < 0.01$. This finding may suggest that the degree of interoperability as measured by the *sheer* amount of available collaborative capabilities does not directly improve the likelihood of an individual's ability to discriminate between valid and invalid descriptions of the situation. Therefore, this finding fails to reject the null hypothesis.

[Need to Insert Graph]

Discussion

The analysis of d' or sensitivity identified that there was a significant difference in performance between runs. The data suggested that participants in Run 1 outperformed those participating in Run 2 in their ability to correctly discriminate between valid and invalid descriptions of the situation. This result was contrary to the hypothesized performance differences being in favor of Run 2 because of their use of a non-degraded, fully interoperable C2 system.

There are a number of possible explanations for this finding. The high sensitivity of Run 1 participants could suggest that the level of interoperability augmented through the "degraded" C2 system was sufficient for supporting their work processes. Although Run 1 participants did not have access to the enhanced collaborative technologies assigned to participants in Run 2, they were observed making extreme use of current collaborative technologies such as text-chat and e-mail. In addition, Run 1 participants were observed spending a significant amount of time in face-to-face small group meetings.

The CTFHQ Commander and his staff in Run 1 also spent a great deal of time discussing strategies for monitoring and integrating new and evolving events into the Commander's purview. Observers noted that one participant developed a method for "flashing" important events unfolding about the scenario on a large information screen for all the collocated CTFHQ staff to view. Additional strategies for monitoring, integrating, and disseminating information throughout the CTFHQ and Brigades emerged when the political, information, diplomatic, and media analyst agreed on a strategy for using 8 LCD flat panel displays to view relevant news reports and other media. This information became critical as the CTFHQ Commander of Run 1 re-tasked a member of his staff to perform the duties of Crisis Manager. The Crisis Manager became solely responsible for ensuring commander's intent was understood throughout the CTFHQ including the Brigades. This was done through face-to-face meetings with different elements of the command staff and e-mail correspondence directly to Brigade Commanders. The creation of the Crisis Manager also proved to alleviate certain tasks from the Deputy Commander of the CTFHQ, freeing him to coordinate directly with the CTFHQ Commander and serve as a liaison to the white cell.

Differences in leadership style between the commanders from each run were noted. Run 1 Commander was perceived as having a stronger presence within the CTFHQ. He was also noted as providing direct tasking to his Brigades. The run 2 Commander on the other hand was much more inclusive and involving of with his staff. He pushed the complete use of the C2 software and attempted to maximize its complete utility. Because of this, Run 2 may have become overwhelmed or lost in the C2 tools capabilities, allowing the technologies to manage them versus them managing it. However, although their sensitivity scores were lower than those of Run 1, several SME observing experimental play were very impressed with the staff within the CTFHQ and Brigades use of the technologies. It must be noted that the signal officers in Run 2 were repeatedly observed monitoring as many as 8 different chats on one display. These officers also alerted the Commander in Run 2 of emerging activities or changing initiatives from the white cell.

Conclusion

This paper describes a method and results used by ARL-HRED to quantitatively measure SA in a simulated CTFHQ and two Brigades during the DARPA MNDEF SN-US Coalition C2 experiment across two different degrees of interoperable conditions. The experimental context was presented and its related nature to the current challenges regarding teamwork and the use of C4i systems was discussed. The use of true/false probes to measure situational awareness was chosen because of its ease of administration, ability to be administered simultaneously and in real-time, and its minimally intrusive nature. Previous research (Leggatt, 2004) also demonstrated its applicability to assessing military missions other than war (MOOTW) such as SSTR operations, and its ability to capture or suggests differences in teamwork and the usage of C4i systems for information gathering and synthesis.

The continual challenge of research using probe statements is the actual probes themselves. The language and composition of each probe may always be reworded for improved understanding. More time can always be spent examining the salient aspects of commander's intent before developing each probe statement. For simplicity sake, the probes in this experiment were developed using four questions we believed summarized the essence of situational awareness and its interaction with commander's intent: *What is happening? Why is it happening? What does it mean in terms of my objectives defined by the Commander? What actions have I been directed to take as a result of the developing situation and the information I have gathered.*

Although we are continually adapting to both the inclusion of non-traditional military missions such as peacekeeping and peace enforcement and the use of C4i technologies, the findings from this report cautiously highlight the importance that additional technological capabilities are not solutions in and of themselves. Future research must continue to replicate real-world environments, and the measurement techniques to follow must be reliable, applicable, simple, and robust enough to capture any differences in performance that may exists. Regardless of the amount of technology that is being provided in the field, and whether researchers agree on definitions of situational awareness or commander's intent, the Commander and his staff will always need to be able to answer the questions: do we know what we really know and what we do not know. Answers to these questions can only be explored through careful experimental designs and applicable measurement techniques.

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About the authors

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