Trust and Situation Awareness in a 3-Player Diner's Dilemma Game

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***Abstract*—This paper studies the relationship between trust and Situation Awareness (SA) in a 3-Player Iterated Diner's Dilemma game. We ran an experiment in which 24 participants each played against two computer opponents for six blocks of gameplay, with different opponent strategies in each block. Based on SA theory and design principles, we developed three different user interfaces, each supporting a specific SA Level. We assess several trust-related metrics during the study, including percentage of cooperation over time and subjective level of self-reported trust towards the opponents, and analyze the interdependencies of trust, SA, and opponent strategy. Results from the experiment reveal highest levels of cooperation at SA Level 1 overall, and a higher level of cooperation for the group of cooperation-encouraging opponent strategies at SA Level 1 and 2 compared to cooperation-discouraging strategies. There is also a positive relationship between self-reported trust in the opponents and cooperation behavior for these strategies, but this relationship was not present in the cooperation-discouraging group. These results show that participants do respond to strategy type in terms of behavior, and that cooperation level is an indicator of the trust that participants place in the opponent players when cooperation emerges.**

***Index Terms*—Diner's Dilemma, Multi-Player Trust Game, Trust, SA, User Interfaces**

I. Introduction

Research on the relationship between trust in a social context and Situation Awareness (SA) has garnered interest in recent years, but the exact extent to which these two concepts interact and relate has not been fully explored. Since trust has been shown to play an important role in social dynamics of a network (Golbeck 2005, O'Donovan 2005), understanding the relationship of trust with SA can provide insight on effective ways to support trust management that will influence social behavior.

In this paper, we report results from an experiment that was designed to clarify the impact of different levels of SA on the cooperative behavior of participants (a measure of trust) in a 3-player Diner's Dilemma game. This dilemma is an n-player version of the well-known Prisoner's Dilemma that has been extensively studied over the years (Glance & Huberman, 1994, Gneezy, Haruvy & Yafe, 2004). In our experiment, each human participant was provided with a visualization designed to convey information at a specific SA Level.

The remainder of this paper is organized as follows: Section 2 describes Situation Awareness and how trust and SA are related to the Diner's Dilemma; Section 3 illustrates the design of our experiment; Section 4 presents the major findings from the experiment; Section 5 further discusses the results and gives an outline of future work.

II. Related Work

A. Situation Awareness

Situation Awareness (SA) can be thought of as an internalized mental model of the current state of an operator's environment – the many streams of incoming data, the external surroundings, and other concerns must be brought together into an integrated whole. This unified picture forms the central organizing feature from which all decision-making and action takes place. Formally, SA is defined as "the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1995). More simply stated, SA involves being aware of what is happening around you to understand how information, events, and your own actions will affect your goals and objectives, both now and in the near future. Research indicates that SA is a fundamental construct driving human decision-making in complex, dynamic environments (Endsley, 1988; 1993; 1995; Strater, Jones, & Endsley, 2001; Endsley, Bolte & Jones, 2003). Endsley (1995) details how effective decision-making requires developing and maintaining SA at three levels, which are described below.

- Level 1 SA (Perception) utilizes the processes of monitoring, cue detection, and simple recognition, leading to an awareness of multiple situational elements (objects, events, people, systems, environmental factors) and their current states (locations, conditions, modes, actions),
- Level 2 SA (Comprehension) involves the processes of pattern recognition, interpretation, and evaluation to integrate Level 1 SA elements to understand how this information will impact goals and objectives, and
- Level 3 SA (Projection) is achieved through integrating Level 1 and 2 SA information and extrapolating this

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Figure 1: Three levels of SA leading to decisions and actions

information to project future actions and states of the elements in the operational environment (See Figure 1).

B. Trust and Situation Awareness in the Diner's Dilemma

Decision-makers in social interactions are often unaware of the way their own actions influence other people, and vice versa. For example, in the intensifying environmental crisis, individuals may not realize that their own conservation or pollution can inspire others to behave similarly by activating norms of reciprocity and punishment, respectively. Researchers often use simplified representations of real world social interactions, presenting explicit actions of two players and the corresponding outcomes obtained when players select that action. Probably the most well-known representation of social interactions is the Iterated Prisoner's Dilemma. This is a common and simplified representation of a dilemma between two players, who decide to take actions without communication. They must decide whether to cooperate or defect, with defection leading to higher outcomes for each, regardless of the other's action, but mutual cooperation leading to higher joint outcomes than mutual or unilateral defection (Rapoport & Chammah, 1965). The main dilemma then is one of avoiding the temptation of short-term defection and instead cooperating, which leads to good mutual long-term outcomes. The proportion of mutual cooperation in this game is often considered a measure of "trust" between the two individuals, a notion that we also explore here.

The Diner's Dilemma is an n-player Prisoner's Dilemma. The scenario is that several individuals go out to eat with the prior agreement to share the bill equally. Each individual will make the decision of whether to order the expensive dish (e.g., lobster) or inexpensive dish (e.g., hot dog). It is presupposed that the expensive dish is better than the cheaper one, but not worth paying the difference when dining alone. The overall best dining experience (food enjoyment divided by price) is achieved when everyone chooses the inexpensive dish. However, for a single round of the Diner's Dilemma, each individual is better off choosing the expensive dish no matter what the others order, and thus Nash equilibrium is achieved when everyone chooses the expensive dish. When the same group of diners meets repeatedly under the same bill-sharing agreement, tacit cooperation may develop, leading to a better overall group dining experience in this simplified scenario.

To our knowledge, no investigations exist regarding SA in games of strategic interaction like the Diner's Dilemma. Intuitively, SA and the different levels of SA should play an important role in the levels of cooperation in this game, and as a consequence, in the levels of trust. Related investigations regarding the effects of interdependency information and the availability of such information to players of the Iterated Prisoner's Dilemma seem to suggest that the information provided would highly influence the level of cooperation (Rapoport and Chammah, 1965; Gonzalez & Martin, 2011; Gonzalez, Ben-Asher, Dutt, & Martin, 2012).

Information about each other's outcomes and actions becomes especially important for decision-makers to infer one another's intentions and to predict one another's actions. For example, Rapoport and Chammah (1965) demonstrated that participants who viewed a payoff matrix in the Prisoner's Dilemma cooperated more than those who learned payoffs through experience alone (46% versus 22% of actions). Unlike individual decision-making, these uniquely social factors make it possible for individuals to alter each other's behavior (Gonzalez & Martin, 2011; Halevy, Bornstein, & Sagiv, 2008).

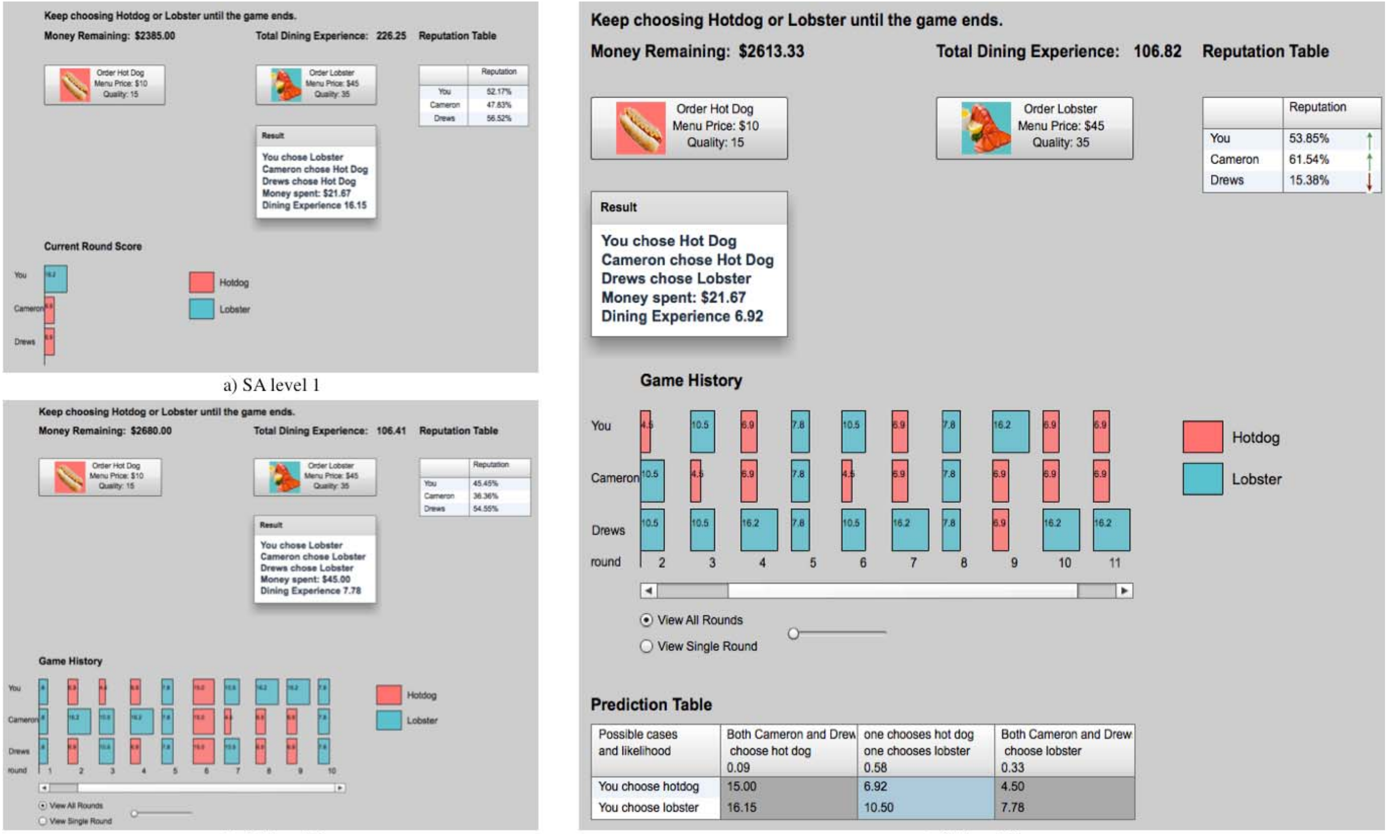
Gonzalez and colleagues (2012, see also: Martin, Gonzalez, Juvina, Lebiere, 2012) have tested the effect of different levels of information in the proportion of cooperation in the Prisoner's Dilemma. In a laboratory experiment, pairs of participants were given differing levels of interdependence information across four conditions: No-Info players saw only their own actions and outcomes, and were not told that they interacted with another person; Min-Info players knew they interacted with another person, but still without seeing the other's actions or outcomes; Mid-Info players discovered the other's actions and outcomes as they were revealed over time; and Max-Info players were also shown a complete payoff matrix mapping actions to outcomes throughout the game. Except for similar behavior in the No-Info and Min-Info conditions, additional interdependence information increased individual cooperation and mutual cooperation, driven by increased reciprocated cooperation (in response to a counterpart's cooperation). Furthermore, joint performance and satisfaction were generally higher for pairs with more information.

The findings reviewed above clearly indicate that awareness of interdependence may encourage pro-social behavior and trust in many real-world interactions. Research on interactive user interfaces for collaborative decision-making highlights the importance of revealing trust-influencing information at different levels of granularity (Swearingen and Sinha, 2001; Bostandjiev et al., 2012). We investigate the effect of three levels of awareness as guided by the information presented at the interface: SA Levels 1, 2, and 3 in the Diner's Dilemma. Intuitively, we expect that interfaces that provide information of higher SA Levels will encourage pro-social behavior when SA reveals that opponents are potentially cooperative and will encourage defection when opponents are consistently exploitive with no chance of conversion to cooperation.

III. EXPERIMENT

A. Overview

In this section, we detail the design and implementation of our experiment that examines the impact of different levels of SA on the cooperative behavior of participants in the Diner's Dilemma. We ran a mixed-design 3x6 (SA Levels x opponent strategies) human subject experiment, with SA Level as a between-subjects independent variable and opponent strategy as a within-subjects independent variable.



a) SA level 1

b) SA level 2

c) SA level 3

Figure 2: Screenshots of the user interface at the 3 different SA Levels

Participants first completed an online demographic survey, and then competed against two computer agents in six rounds of the Diner's Dilemma game. Each participant was assigned one of the three SA visualizations, which remained constant across all six blocks of game play. Each block consisted of 50 rounds and corresponded to each of six opponent strategies (opponent behavior *and names* varied between blocks, indicating a new pair of people to dine with), and the presentation order of the six strategies was randomly assigned for each participant.

In each round of the game, participants chose hot dog or lobster and received immediate feedback on the outcome of their decisions. After each round (i.e., decision), a results box was displayed listing each player's decision, the money that the participant spent and the experience points gained (see Figure 2). After each block of 50 rounds, the participants were required to complete a questionnaire, which was used to assess their understanding of the game, trust in their opponents for this block and their self-assessment of their performance.

B. Participants

24 college students (with age range from 18 to 25, 9 males and 15 females) participated in our study. They all signed up voluntarily through the subject pool in the Psychology Department of the University of California, Santa Barbara.

C. Visualizations for SA

In this subsection, we describe and reason the design of the visual components in each SA Level. Figure 2 shows screenshots of the user interface at different SA Levels.

1) Level 1 SA Visualization: (Figure 2a) For this visualization, we included a display to indicate the human player's money remaining and their total dining experience points gained, which is updated after each decision. Additionally, we provided a horizontal bar graph "Current Round Score" to represent the players' decisions from the previous round. The segments were color-coded to distinguish between the menu items. Each segment displayed a numerical value that represents the points that were awarded for their decision. Additionally, the human player was provided with a "Reputation Table" that displays the percentages of each player's reputation that reflects the number of times the player decided to cooperate (i.e., choose hot dog).

2) Level 2 SA Visualization (Figure 2b): For this visualization, we augmented the "Current Round Score" with "Game History". It is a segmented bar graphical display that illustrates all past decisions of each player and the relative score of those decisions (only for the current block). Viewing all past rounds facilitates the human player to understand the impact of their decisions with the current block's two opponents and it allows the human player to see trends of their opponents' decisions.

3) Level 3 SA Visualization (Figure 2c): For this visualization, we added a "Prediction Table" that displays the likelihood of each outcome occurring for the current decision. The likelihood is computed by treating each opponent's cooperation probability as an independent variable whose value is the same as the opponent's reputation so far. Additionally, we updated the "Reputation Table" that includes the directionality of all players' reputation. This is displayed in the form of a color-coded arrow, a green up-arrow to denote that their opponents think they are more trustworthy than in the previous decision and a red down-arrow to denote that their opponents think they are less trustworthy than in the previous decision. Since some opponent strategies are sensitive to previous human decisions and other opponent strategies are dependent to previous computer agents' decisions, the human player can use the directionality to try and predict the decisions for their opponent in the current block.

D. *Computer Opponent Agent Strategies*

Participants completed six blocks of the Diner's Dilemma game, corresponding to each of six opponent strategies. These strategies determined the "behavior" of the two players with whom the human participant interacted and are described below.

1) Negative 30: In this strategy, the combined cooperation of the two opponents is always 70%. Initially, Opponent 1 will play Tit-for-Tat against the participant and Opponent 2 will always make the decision which makes the combined cooperation of the two opponents closest to 70%. Each of the two opponents makes 50 decisions in the course of a block, for a combined total of 100 decisions. If the two opponents reach a combined total of 70 cooperate (hot dog) decisions (70% of 100 decisions) before the end of the block, both opponents will choose to defect for the remaining rounds.

2) Negative 70: Same as Negative 30, except that the combined cooperation is 30%.

3) Random: The two opponents randomly choose between the two meals with equal probability in each round.

4) Stimulate: case a): if the participant's cooperation percentage so far in the current block of the game is above 66% and the participant chose hotdog in the last round, both computer agents will choose hotdog in the next round; case b): if it's below 33% and the participant chose lobster in the last round, both computer agents will choose lobster; case c): otherwise one agent will choose hotdog and the other will choose lobster.

5) Stimulate Noise: Similar to Stimulate, with the addition of noise. In cases a) and b), the computer agents' decisions are reversed from what they would have been in Stimulate for 10% of the rounds.

6) Tricky: For every other round (0,2,4,6...), both opponents will play "Stimulate" (and only consider the player's every other round's decision as well). For the rest (1, 3, 5, 7...), they will play "Random".

Notice that Negative 70, Negative 30 and Random can be grouped into "Cooperation-discouraging" strategies, as the total-sum result of the opponents' decisions is not affected by the participant's choices, and thus no long-time cooperation inducement can happen by cooperating. Stimulate, Stimulate Noise and Tricky can be grouped into "Cooperation-encouraging" strategies, as the opponents are rewarding cooperation (choosing hotdog) and punishing defection (choosing lobster) to different degrees.

E. *Hypotheses*

For the "Cooperation-discouraging" opponent strategies, the best strategy for the participant is to always choose lobster as his/her decision won't affect the opponents' "willingness" to cooperate. For Stimulate and Stimulate Noise, it is better for the participant to cooperate all the time. This is because the marginal gain of defecting against cooperating when the other two are cooperating is quite small compared to the loss in the next round caused by the others' punishment. For Tricky, the best strategy would be cooperating and defecting alternatively all the time. Our initial hypothesis was that providing more SA information would help the participant better perceive the opponents' strategies and thus make more appropriate decisions.

Table 1: Game Understanding Q & A

Game Understanding Questions	**Answer**
I get more points when everyone chooses Hotdog than when everyone chooses Lobster.	True
I get more points when everyone chooses Hotdog than when I choose Lobster and my co-diners choose Hotdog and Lobster respectively.	True
I get fewer points when everyone chooses lobster than when I choose hotdog and my co-diners choose Hotdog and Lobster respectively.	False
I get most points when I choose Lobster and both my co-diners choose Hotdog.	True
I get the least amount of points when all three of us choose lobster.	False
In sum, the three diners get the least number of points when all of us choose Lobster.	True
Over multiple rounds I will always gather more points by consistently choosing Lobster than by consistently choosing Hotdog, no matter what my co-diners do.	False
In a one-round Diner's Dilemma (only one restaurant visit), I always get more points if I choose Lobster.	True
If my co-diners do not react to my behavior, I am always better off choosing Lobster.	True
My optimal strategy depends on the strategies that my co-diners pursue.	True

F. *In-between Questionnaires*

We use the decisions participants made after each round as "observed trust". In order to better understand why the participants behaved in certain ways, we designed in-between questionnaires that are tailored to each SA Level. There are three parts of the questionnaires: 1) evaluating the opponents' behavior, by giving Likert scale ratings of their cooperativeness and the user's trust in them, as well as text comments. This part collects the participants' self-reported trust in their opponents;

2) evaluating the usefulness of the SA components provided in the game, this is the only varying part of the questionnaire among the three SA Levels; 3) answering true or false questions on what is the best thing to do under 10 different scenarios (Table 1 lists all the 10 questions and the correct answers). Part 2 reflects on how much the participants' thought they caught the game, while part 3 reveals to what extent they truly understood the game.

Each participant was asked to fill in the in-between questionnaire corresponding to the SA Level he/she got after every block. However, in our pilot study most participants felt it was redundant to answer the questions in part 3 after every block. So in our actual experiment we only required the participants to answer part 3 in the first three blocks, but participants could still choose to provide answers after the following blocks in case they wanted to change their previous answers.

IV. Results

In this section, we present the major findings in the data collected from the 24 participants in our experiment. More discussion is given in the next section. All participants played against each of the six opponent strategies of the Diner's Dilemma game. SA Level varied between subjects, with an average of 8 participants in each of the three SA conditions.

Our major findings of the experiment are shown in Figure 3 and Figure 5. Figure 3 is the average cooperation proportion across three SA Levels and two loosely grouped opponent strategies (cooperation-encouraging vs. cooperation-discouraging). This is evaluated as observed trust from the participants. ANOVA test showed a small but significant difference (p=0.0124) of SA on observed participant's trust (i.e. cooperation proportion). And from the plot we can see a clear drop of observed trust from SA Level 1 to Level 2. A post-hoc Tukey-Kramer test showed that there was a higher rate of cooperation in SA Level 1 than in SA Level 2 (p = 0.025) or SA Level 3 (p = 0.042). SA Levels 2 and 3 were not significantly different.

Figure 5 shows scatter-plot graphs of self-reported trust (participant's rated trust against the pair of opponents) against observed trust for each of the 6 strategies. Again we loosely grouped these into columns representing cooperation-discouraging and cooperation-encouraging strategies. No relationship appears between self-reported trust and observed trust for the cooperation-discouraging strategies. However, there is a strong positive relationship in all 3 of the cooperation-encouraging strategies.

A. *Observed Trust across SAs and Strategies*

Figure 3 shows the proportion of cooperation averaged for each of the SA Levels and the two types of strategies, for a loose categorization of opponent strategies into cooperation-discouraging and cooperation-encouraging groups. We note that cumulative proportion of cooperation of the opponent players in the cooperation-encouraging strategies is dependent on (responsive to) participant decisions while the opponent players in the cooperation-discouraging strategies have a fixed overall or random degree of cooperation.

In terms of strategy groups, for both SA Level 1 and 2, there are higher levels of cooperation in the cooperation-encouraging strategies than in the cooperation-discouraging strategies. This is a good indication that the participants did realize the difference among the strategies and were more willing to cooperate when their opponents were "playing nice".

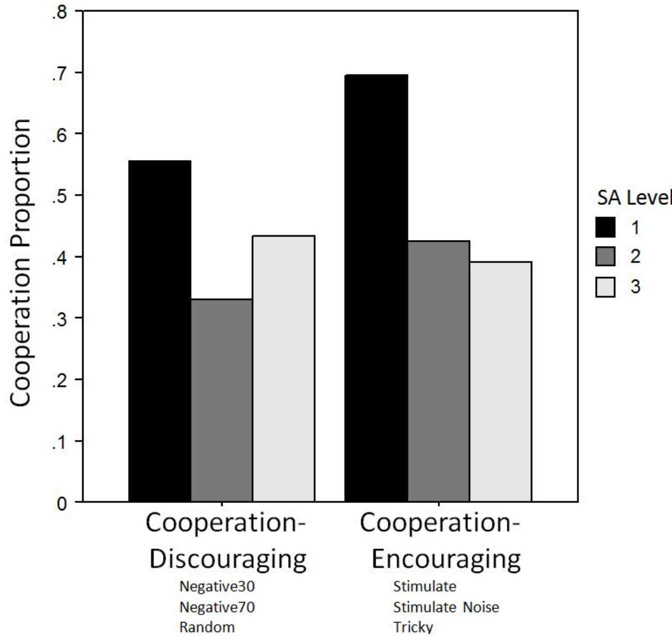


Figure 3: Analysis of Cooperation-encouraging strategy groupings and Cooperation-discouraging strategy groupings.

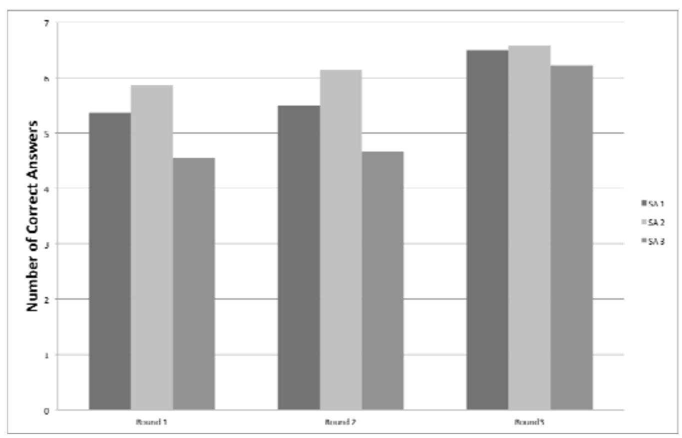


Figure 4: Average number of correct answers for the 10 game understanding questions (most users just answered those questions in the first three blocks)

The participants' comments on their opponents' behavior also confirm this point.

The above observation doesn't hold for SA Level 3. This might be explained by looking at the correct answer rate of the 10 game understanding questions (Figure 4). Results indicate that participants in the SA Level 3 condition actually had a poorer understanding of the game than those in the other two conditions. This suggests that the visualization manipulations did not increase SA in the way they were intended to, which may explain why we did not see an interaction between strategy type and SA Level in Figure 3.

However, it is surprising that cooperation is highest at the lowest SA Level for both groups of strategies, as we might expect this for cooperation- discouraging strategies, but not for cooperation-encouraging strategies. We leave the discussion of this finding to the next section.

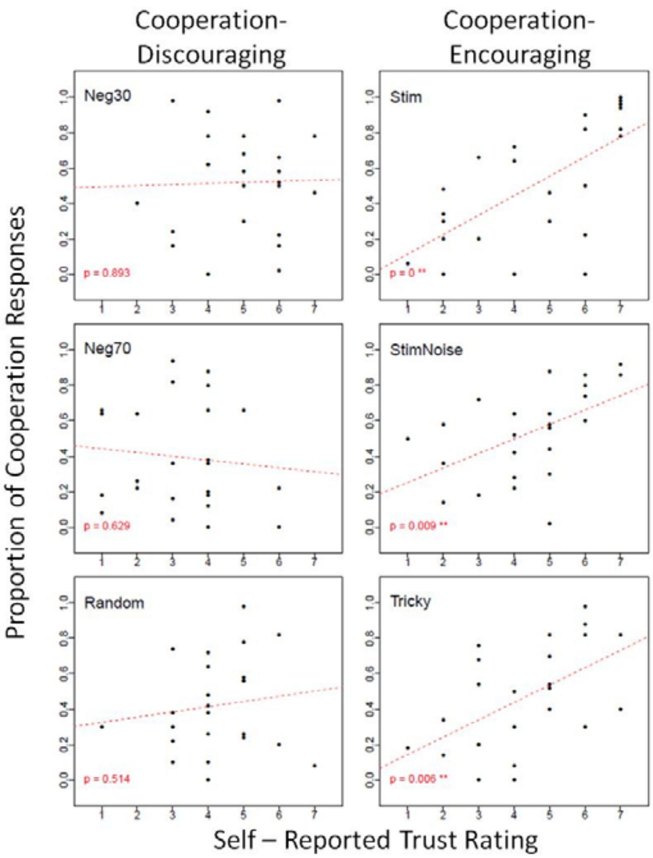


Figure 5: Correlation Analysis of Perceived Trust and Observed Cooperation for 6 Strategies, grouped into Defection-oriented and Collaboration-rewarding columns.

B. Self-reported and Observed Trust

Our next analysis focuses on the relation between observed trust (degree of cooperation) and self-reported trust in the opponent pairs for each strategy. Our goal is to determine whether perception of trust is correlated with behavior in the context of the trust game. For this analysis, results are averaged over all SA Levels. Figure 5 shows scatter-plot graphs for each of the 6 strategies, again loosely grouped into columns representing cooperation-discouraging and cooperation-encouraging strategies.

There is no significant correlation between reported Trust and cooperation behavior in any of the cooperation-discouraging strategies. For the cooperation-encouraging group, significantly positive correlations were observed between perceived trust and cooperation. Our most cooperation-rewarding strategy (Stimulate) exhibited the largest correlation with self-reported trust.

Overall, our findings indicate that the participants did respond to the type of strategy in terms of their cooperation behavior, and that cooperation level is a good indicator of feelings of trust in cooperation-inducing strategies.

V. Discussion & Future Work

We presented results from an experiment on the interactions between trust and Situation Awareness in a repeated Diner's Dilemma decision-making task. 24 participants completed 6 rounds of 50 rounds each of the decision making task, with 6 opponent strategies as a within-subjects independent variable, and visualization interfaces affording varying awareness about the course and mechanisms of the simulation.

The study was aimed at understanding the complex relation that exists between trust behavior and situational awareness in the context of the Diner's dilemma game. Interestingly, the results from the data analysis tend to partially contradict our initial hypothesis. Here we discuss salient results and analyze several possible underlying reasons for the unexpected behavior observed in the study.

1) From SA Level 1 to SA Level 2, decreasing levels of cooperation were observed for all six strategies, irrespective of the behavior of particular strategies. This may be due to the variance in trust propensities across the groups of participants that were exposed to different SA Levels. To investigate this possibility, we analyzed the decision data after a calibration step that represented each user's actions as a deviation from their mean. As a result, the differences between SA Levels disappeared, but the differences across the cooperation-encouraging and -discouraging opponent strategy groups remained significant. These results indicate that more experimentation on the effects of carefully crafted SA interfaces is needed and that follow-up studies could benefit from an increased number of participants.

2) The prediction table in SA Level 3 may have led to SA Level ambiguity in participant's understanding of the opponent strategies based on their subjective interpretation. In this table we showed the participant's score under different player choices for a single round of the game. The scores indicate that the participant is always better off choosing lobster rather than hotdog for a single round, but fail to convey the potential benefits of cooperation for repeated game-play. So if the participant's goal were to earn the highest possible score on a round-by-round basis, he/she would always choose lobster regardless of the opponents' behaviors. In effect, our SA 3 visualizations may actually have decreased awareness of an important element of the gameplay. It is noteworthy that introducing this apparent bias happened inadvertently in spite of our best efforts to portray objective information about the unfolding of the game. This illustrates the manipulative potential of projective forecast visualizations and highlights the importance of carefully representing all aspects of the situation for improved decision making.

3) The opponent strategies may have been too complicated for the participants to figure out. For the Negative 30 and Negative 70 strategies, opponent 1 is playing Tit-for-Tat most of the time, so it is natural for the participant to think that his/her behavior would affect the opponents' choices and thus the outcome, while in reality it does not. It is also difficult to distinguish between a random behavior and a carefully plotted

complex strategy, especially given a limited number of rounds. For the Stimulate and Stimulate Noise strategies, it is possible that participants did not receive enough information to realize that cooperative behavior was rewarding. Furthermore, the 'Tricky' strategy was specifically designed to be too complex for participants to figure out completely in the limited number of rounds allowed. It turns out that in terms of observed participant behavior, it exhibits characteristics similar to the other cooperation-encouraging strategies, so the fact that it was a "responsive" strategy likely came across.

The authors plan to perform a larger-scale experiment with the following modifications that incorporate insights about SA visualization and trust from our initial study:

1) Redesign the SA 3 visualizations to convey the influence of different choices in a repeated game;

2) Cut down the number of potentially confounding strategies and simplify the opponents' behavior, while at the same time increasing the number of rounds in each block of the game. We believe that this will facilitate better observation of different learning effects in the Diner's Dilemma game.

As a control measure, take steps to ensure that participants have the "required" level of understanding that each SA Level is supposed to provide, thereby making it easier to reason about the relation between SA Level and observed trust behavior in the game.

From our analysis so far, it becomes clear that multiple factors influence the relation between trust and situational awareness in the context of the 3-Player Diner's Dilemma game. An analysis of selected correlations between both subjective and objective variables has been presented in this paper. A subsequent evaluation is planned that will examine multiple influence factors in parallel from a model-based learning perspective.

VI. Conclusion

This paper has described a supervised study of the three person Diner's Dilemma problem in which the relation between situational awareness and trust was explored using six different automated opponent strategies. The experiments show increased cooperation (trust) for cooperation-encouraging strategies in SA Levels 1 and 2, but this relationship was not present in the cooperation-discouraging group. A positive relationship was also revealed between self-reported trust in the opponent players and degree of cooperation in the game, leading us to the conclusion that participants do respond to strategy type in terms of trust behavior and that cooperation level is a good indicator of the trust that participants place in their opponents.

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