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Trust in Common Ground: The Association of Coordination Performance and Interpersonal Trust within Asymmetrical Cooperative Pairs

By

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THESIS

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Abstract

Coordination among teams or pairs is vital to completing cooperative problem-solving tasks. Moreover, trust among team members enhances performance in cooperative settings, but how coordination and trust relate to each other among partners who have no past history together is uncertain. Therefore, this study tested the relationship between coordination performance (accuracy and completion time) and levels of trust (cognitive and affective) in an augmented reality tangram matching task. Pairs of young adult participants (*N* = 104) entered a laboratory to play a game wherein "directors" described target shapes to "matchers" who attempted to match targets in a smartphone-displayed grid. Participants answered trust surveys after each of three game rounds. The effects of task-role on self and partners' trust perceptions were explored using an actor-partner interaction model. Cognitive trust was positively associated with accuracy but not completion time, implying the relevance of cognitive trust on coordination task performance among zero-history dyads. Furthermore, directors' cognitive trust towards partners influenced matchers' change in cognitive trust toward directors, but not vice versa. This suggests that differences between task-roles may lead to reciprocated trust from one, but not both, partners in a dyad. The study discussed communication behaviors related to different levels of trust, the grounding process, and incongruencies between task-roles, as to propose future research avenues.

Keywords: coordination, trust, augmented reality, tangram, APIM

Trust in Common Ground: The Association of Coordination Performance and Interpersonal Trust within Asymmetrical Cooperative Pairs

Across professional contexts, individuals frequently coordinate together in small teams. Such teams include two or more individuals (i.e., a dyad), responding to each other's communicative actions as well as acting according to their own thoughts and previous behaviors. Small teams are especially useful for completing tasks involving creativity, innovation, and problem-solving (Donnellon, 1996; Larson et al., 1989). For example, scientists might collaborate to design a new research program, or sales teams might develop more effective marketing strategies. Regardless of the specific task at hand, effective coordination between team members is required to efficiently or successfully complete team efforts.

In cooperative pairs and teams, individual members' perceptions of one another, specifically regarding trust, is considered of critical importance (Bolman & Deal, 2017). *Trust* refers to a psychological state comprising the intention to accept vulnerability based upon positive expectations of the intentions or behavior of another (Rousseau et al., 1998). Greater trust is linked to increased willingness by team members to reveal information about themselves and their ideas, which in turn may enhance team performance when solving complex problems. Furthermore, two types of trust perceptions may differentially affect team performance, that of competence-based *cognitive trust* and relationship-based *affective trust* (McAllister et al.1995). Affective trust relates to the intensity of the relationship between two parties, based on perceived concern and benevolence towards one another. Meanwhile, cognitive trust is rational, where individuals judge trustworthiness based on others' competence, reliability, or familiarity with the task at hand. Trust is usually developed over time by observing or having experience with other team members' behaviors (Donnellon, 1996). However, new, short-lived dyads and teams whose members have no past history with one another lack the information to make experienced judgments about other team members' trustworthiness, only developing into distinct cognitive and affective components as teammates work together over time (Webber, 2008). Therefore, individuals may form impressions about teammates' trustworthiness based on a limited availability of competence cues or behaviors that display individual know-how, expertise, and confidence (Sniezek & Van Swol, 2001), as well as individual indicators such as assigned roles and social categories (Robert et al., 2009).

While pairs or teams of individuals coordinate to accomplish group tasks, as well as form impressions of trust towards each other, we do not fully know how coordination and trust perceptions affect one another. Both affective and cognitive trust among teammates independently enhance team performance (see De Jong et al., 2016, for a meta-analysis), but the mechanisms behind such relationships are likely distinct. We propose that coordination, or the process of reaching common ground (Clark, 1996), is effective in forming cognitive trust impressions. Thus, the purpose of this study is to investigate this relationship by evaluating pairs of individuals working together to solve coordination problems in the form of an augmented reality (AR) tangram matching task (Schober & Clark, 1989). Performance and levels of trust are compared across three rounds of the task as to capture any changes over time. In addition, we employ a novel approach to trust and collaboration research by using an actor-partner interdependence model (APIM; Kashy et al., 2000) to test for reciprocal relationships of trust perceptions (Serva et al., 2005) within pairs of teammates, whereby individuals' trust towards the other is predicted in part by the other's trust in them. Furthermore, roles within teams enhance task-oriented communication and coordination (Strijbos & Martens, 2004), and the specific task roles within the tangram matching task can influence the distribution of communication behaviors among teammates (e.g., Bortfeld et al., 2001). The impact of task roles on communication may additionally affect trust development, and therefore role is considered. This research uniquely tests trust development among zero-history small teams, as related to coordination effectiveness during an AR problem-solving task.

Literature Review

Joint Action Projects and Grounding

When team members work together, they engage in *joint action projects*, defined as any collaborative effort between two or more parties (Clark, 1996). Joint action projects can be as complex as internationally dispersed teams of specialists solving global policy issues or as mundane as one stranger asking another for directions to the bank. A goal of communication in joint action projects is to ensure that all parties involved have mutual understanding of the task at hand, or *common ground*, which is defined as the shared knowledge of what the joint project is in terms of beliefs, attitudes, expectations, etc. (Clark, 1996). Establishing something as part of the common ground, at least to the extent that is enough for the project's purpose, is called *grounding*, and is the mark of successful coordination (Clark, 1996).

Joint actions occur in small groups as team members are required to coordinate with one another to reach common goals (i.e., *coordination problems*; Schelling et al., 1980). Past research has shown that pairs of individuals perform better at solving coordination problems when they engage in joint action (Isaacs & Clark, 1987; Schober & Clark, 1989). In this context, the tangram matching task is a popular coordination task where one participant is designated as the "director," who must describe tangram shapes to another participant called the "matcher." The matcher's task is to identify tangram shapes in correct sequence, but only directors are privy to the target sequence. Matchers are more accurate in arranging target tangram shapes when directors and matchers coordinate on the task, rather than just overhearing the task-relevant information (Schober & Clark, 1989). Directors communicate more than matchers as they actively describe tangram shapes while matchers react to directors' instructions, in some cases directors using twice as many total words as matchers (Bortfeld et al., 2001).

For grounding to occur, communicators must successfully execute each of four sequential levels of communication acts in a *joint action ladder* (Clark, 1996). The action levels include first the articulation of utterances (mechanical level), that produce some meaning (signal level), that must be accepted (content/reference level), before a message's intent is interpreted (meta level). The ladder is sequential in that a higher level cannot be executed without successful execution of the preceding lower levels (Clark, 1996). Failure can occur at any level of the ladder, from being unable to vocalize due to physical constraint (mechanical failure) to a listener not recognizing the expected response implied by a speaker's request (meta failure). The tangram matching task exemplifies the grounding process within dyads (Schober & Clark, 1989). As directors describe tangram shapes, their words must be heard and meaning understood (mechanical and signal levels, respectively), such as describing a target shape as looking "like a nun." The matcher must then acknowledge the director's description and affirm the identity of the target shape among the set of shapes (content/reference and meta levels, respectively). Grounding is successful if each step is executed, and the process may be reiterated until consensus is reached (Schober & Clark, 1989). For instance, if the matcher in the previous example does not perceive any shape as looking "like a nun," the parties may attempt alternate perspectives until a shared interpretation is agreed on. Effective coordination will result in quicker and more accurate consensus on the identity of the target shape (Schober & Clark, 1989).

Grounding operates by the principle of least-collaborative effort, meaning that individuals will attempt to minimize the cognitive effort to establish common ground (Clark & Brennan, 1991). This suggests, in terms language use, speakers will convey only as much information as needed to get their meaning understood by listeners, in as few words as possible. Pragmatically, communicators can quickly and automatically develop conventions through which meaning is conveyed more efficiently (i.e., *conceptual pacts*; Brennan & Clark, 1996). For example, individuals completing the tangram task may spend time thoroughly coordinating on the identity of a specific shape before "agreeing" to call that shape a "dancer" for subsequent reference. Such conventions reduce the necessary number of utterances over time (Hawkins et al., 2017). In addition, nonverbal communication helps make the grounding process efficient, such as through gesturing to assist in representing ideas or to draw partner's attention (Fussell et al., 2004), similar to how eye gaze directs other's focus on problem solving tasks (Stein & Brennan, 2004). For collaborators who are remote from one another, grounding is more efficient when available communication channels offer greater visual fidelity (Gergle et al., 2004), where actions may be more effective than words in referential communication. Visual information about partners may be diminished in mediated communication settings (e.g., virtual environments, chatting systems, phones) or when individuals are in separate rooms.

Impression Formation in Small Teams

While grounding describes the process by which team members coordinate, individuals within collaborative teams also form interpersonal impressions of one another that may impact the cooperative process. Impressions of others are formed based on social categorization and personal perceptions (Fiske & Neuberg, 1990), where on the one hand individuals are initially perceived in line with the social categories that they represent through their physical appearance (e.g., skin color, clothing), stated labels (e.g., "Melissa is a banker"), category-consistent attributes towards a label (e.g., young, male, disheveled, defiant expression), or other information accessible upon initial perception. On the other hand, if an individual fails to confirm to initial categorization or to subsequent recategorization attempts, piecemeal integration of personal attributes will form individuals' impressions. If given sufficient time, mental resources, and motivation, an individual may form a personalized impression of another wherein relevant category labels serve as just additional attributes rather than form a generalized, category-based impression. How impressions of team members affect the grounding process is not certain, as individuals' perceptions of one another may help or hinder their ability to find consensus in a timely, effortless manner. For instance, specific impressions regarding others' cognitive trustworthiness could influence the perceived effort needed to establish common ground. Likewise, the (in)ability to establish common ground may influence impressions of teammates' cognitive or affective trustworthiness.

Regarding impressions based on social categories, expectation states theory suggests that culturally defined social categories, such as race and gender, influences individual behaviors and thoughts, such as who is selected for or accepted into leadership positions, based on differentiated performance expectations (Correll & Ridgeway, 2006). Individuals possess expectations about task-competence based on their own and each other's status, affecting subsequent behavior (Berger et al., 1972). For instance, the effect of expertise on performance in small group decision-making differs by gender (Ridgeway & Bourg, 2004), where higher expertise women are less influential and seen as less expert than similarly expert men, which leads to discounting women's expert contributions (Thomas-Hunt & Phillips, 2004). Though individuals within a team are likely to initially judge others based on highly salient characteristics like gender, age, and ethnicity (Milliken & Martins, 1996), over time individuals may rely on more subtle psychological attributes (Harrison et al., 2002), such as cognitive ability (Kalish & Luria, 2016). However, situations demanding that zero-history teams form to solve a problem quickly may not have the opportunity to develop impressions beyond initial, category-based judgements (Fiske & Neuberg, 1990). For instance, initial judgements of trust is unidimensional but expands into affective and cognitive levels over time (Webber, 2008). Early trust tends to rely on initial perceptions of role, social categories, or third-party recommendation if available, as well as personal disposition towards trust (Robert, 2009).

Another signal that may impact impression formation between dyads and team members relates to the roles individual members hold within a team. A role defines the assigned duties and responsibilities according to the needs of the organization or team (Belbin, 2012). Roles are a useful structuring device as individuals tend to perform the duties that they are assigned (De Wever & Schellen, 2008). Roles within teams have positive effects on team performance compared to unstructured teams (Mennecke & Bradley, 1998), enhancing task-oriented communication and coordination (Strijbos & Martens, 2004), and increasing awareness of members' contributions (Mudrack & Farrell, 1995).

In addition to the effects of performance expectations and task roles, teams must balance communication that advances task performance with socioemotional behaviors to maintain group solidarity (Bales, 1950). Leaders who express socioemotional elements through interpersonal interactions build emotion-based trust, while task-related interactions with subordinates enhance cognitive-based trust (Dirks & Ferris, 2002). For instance, task-oriented communication by managers is positively related to employee trust (Butler & Cantrell, 1994). In addition, communication by supervisors that supports in-groupness with subordinates (e.g., accommodation) can also improve perceived trustworthiness and, consequently, effectiveness as a leader (Willemyns et al., 2003). Within self-managed teams, individual perceptions of competence and warmth contributes to distribution of leadership roles (Cuddy et al., 2011; DeRue et al., 2015), impressions that may be linked to task and socioemotional communication.

Regarding types of impressions, trust perceptions are of special importance for small teams, where interdependence, close cooperation, teamwork, and flexibility are required (Salas et al., 2005). Trust is defined as entailing a level of risk, uncertainty, or vulnerability as one assumes how another (individual, group, organization) will behave in a particular situation, creating an *expectancy* of future behavior (Lewicki et al., 1998; Rousseau, 1998). Trust within team settings implies certain cooperation behaviors, such as open expression about one's work, accepting influence from others, and feeling involved with the team personally (Costa et al., 2001). Swift establishment of trust is necessary for small teams to be efficient, who often work under conditions of short deadlines and thus do not have time to develop relationships (Iacono & Weisband, 1997; Jarvenpaa et al., 1998). Cooperative behaviors may have implications for the grounding process as per the principal of least cooperative effort (Clark & Brennan, 1991), as greater cooperation behaviors may reduce the required effort of coordination.

Impressions such as trust is a dyadic phenomenon between trustors and trustees (Mayer et al., 1995) as the levels of trust experienced by one party of another is in some part dependent on perceptions of trustees (e.g., their ability, benevolence, and integrity) as well as trustors' propensity to trust (Yakovleva et al., 2010). Trust is reciprocal, where trustors signal their trust through risk-taking behaviors (actions that open trustors to the possibility of loss), which trigger trust in kind from trustees who then engage in their own risk-taking behaviors, continuously in a loop of trust signaling (Serva et al., 2005). Trustors therefore reevaluate and update trust moment to moment based on trustors' perception and on trustees' behaviors. To evaluate the reciprocal nature of trust, we use an actor-partner interdependence model (APIM) to represent dyadic trust perceptions across time.

Actor-Partner Interdependence Model

APIM is a method for analyzing the influence of one party's behaviors or cognitions on another's, called a "partner effect," and the associations between individuals' various cognitive and behavioral phenomena, or an "actor effect," and interactions between the two (Kashy et al., 2000). APIM is useful for when a meaningful factor can be used to order individual within a dyad, such as husband-wife, supervisor-supervisee, etcetera (Kenny et al., 2020). The model can evaluate between-dyad variables where scores may vary from pair to pair but not within pairs (e.g., length of time to complete a group task), within-dyad variables where scores for members of a pair may vary but not between pairs (e.g., percentage of talking time occupied by each member), and mixed variables where scores may vary from member to member and pair to pair (e.g., average level of trust per member, per dyad; Kenny, 1988). Variables that distinguish members of a dyad are necessarily within-dyad variables, such as gender among heterosexual couples (Garcia et al., 2015). Moreover, moderation can affect APIM relationships on a within-dyad, between-dyad, and mixed bases as well (Garcia et al., 2015). The model has been used to examine decision-making groups, families, and interpersonal/student groups (Ervin & Bonito, 2014).

As an example of actor effects, consider that the extent to which an *individual* substantively contributes to a group effort is negatively associated with that *individual's* assessment of *other's* group participation (Bonito, 2000). This is an actor effect because the *individual's* behavior is being related to their own attitudes. Meanwhile, an example of a partner effect would be how the amount of *other's* substantive contribution to a group effort will positively affect the *individual*'s assessment of *other*'s group participation (Bonito, 2000). In this case, the individual's attitude is predicted by another party's behavior, thus other's behavior has a partner effect on the individual's attitude. These effects may interact with one another (Campbell & Kashy, 2002), such as when an *individual's* actor effect changes depending on the actor effect for the *other* (an "actor-actor" effect), for instance if increases in a particular attitude from one time to another is stronger when an individual's partner's attitude similarly increases (i.e., a positive interaction effect). An individual's actor effect may also vary in response to their own partner effect on the other (an "actor-partner" effect), as well as in response to the other's partner effect on the individual's actor effect (a "partner-actor" effect). Partner effects may also interact with each other (a "partner-partner" effect).

APIM can also observe change in behavior and attitudes over time, such as predicting one partner's relationship satisfaction based on their own and their partner's relationship satisfaction at an earlier time (Perry et al., 2017). Repeated measure APIM (RM-APIM) is useful when researchers suspect that individuals' and partners' initial perceptions or actions will predict these attitudes or actions again in the future. With regard to coordination, grounding is an iterative process that becomes more efficient over time as pairs establish more conventions (Brennan & Clark, 1996). Convention adoption thus would have a cumulative effect, reflected in the fact that the number of words used by directors to complete repeated trials of the tangram task diminishes over time (Hawkins et al., 2020). Likewise, competence-based trust should in part depend on the cumulative observation of competence cues (Sniezek & Van Swol, 2001). As far as can be found, a RM-APIM approach to dynamic dyadic modelling has been used to examine relationships in therapeutic and family research, but not in dyadic task contexts. One goal of the present research thus is to extend the literature of this analytic method to interpersonal perceptions among dyadic pairs completing coordination problems.

Hypotheses and Research Questions

As seen above, the tangram task is the archetypal measure for common ground formation within small teams (Schober & Clark, 1989), but studies in that tradition have focused more on the grounding process instead of the development of trust among directors and matchers. This study therefore examines the relationship between self-reported interpersonal impressions of trust and performance on the tangram task by zero-history dyadic teams. Trust is measured along both cognitive and affective components (McAllister et al., 1995), as these two impressions may differentially relate to cooperation. For instance, cognitive trust relates to perceived task competence, which may be correlated with effort during the grounding process. Affective trust relates to perceived benevolence but tends to grow in importance to the function of a team over time (McAllister et al., 1995), so may not have an impact on impression formation after only a short duration. As performance on the tangram task represents a level of successful grounding (Schober & Clark, 1989), I predict that:

(H1) Increased cognitive trust within dyads will be associated with greater (a) tangram score performance and (b) reduced time to complete tangram tasks.

(H2) Increased affective trust within dyads will be associated with greater (a) tangram score performance and (b) reduced time to complete tangram tasks.

Specific features of the tangram task affecting trust perceptions may include role assignment. The tangram task involves assigning each participant to either the director or matcher role, defining responsibilities and providing structure to the team. As noted above, tangram directors communicate more than tangram matchers (Bortfeld et al., 2001). Directors' competence (or lack thereof) will therefore be highly salient to matchers, as matchers observe director's instruction round after round. Meanwhile, matchers must use the information conveyed by directors to accurately identify tangram shapes, but directors are not aware of matchers' ultimate selection. As competence relates to cognitive trust, matchers' cognitive trust in directors should be updated more regularly as they receive more competence cues from directors, while matchers do not convey as many competence cues to directors. For instance, matchers' responses tend to mostly consist of acknowledgements (Bortfeld et al., 2001). In APIM terms, the actor effect of matchers' change in cognitive trust towards directors should be more pronounced than vice versa. Therefore, I posit:

(H3) Matchers' cognitive trust towards directors are more likely to change than directors' cognitive trust towards matchers.

In APIM terms, a partner effect for trust between directors and matchers would represent the extent to which directors' trust towards matchers (or vice versa) at an earlier time predicts change in matchers' trust towards directors (or vice versa) over time. As trust is reciprocal (Serva et al., 2005), whether partner effects might emerge depend on the extent to which directors and matchers perceive cues for trust from their partner and return cues in kind. While such signals as ability, integrity, and benevolence communicates trustworthiness (Mayer et al., 1995), trust signaling behaviors involve opening oneself up to vulnerability through openness and honesty (Tschannen-Moran, 2014), such as offering personal perceptions or risking the appearance of ignorance. Grounding through the tangram task may encourage a degree of risk-taking behavior, such as by directors offering personal interpretations of shapes and matchers making clarifying remarks, examples of the joint action grounding process (Clark, 1996). Such exchanges may foster reciprocal trust between directors and matchers; therefore I predict:

(H4) Increases in cognitive trust by (a) matchers and (b) directors towards their partners will positively relate to partners' subsequent cognitive trust.

(H5) Increases in affective trust by (a) matchers and (b) directors towards their partners will positively relate to partners' subsequent affective trust.

Method

This study was conducted as part of a larger, ongoing investigation that collected survey, tangram task performance, voice audio, and electroencephalogram signal data. The present study focusses only on the aspects relevant to investigating trust and tangram task performance.

Participants

At the time of analysis, the study sample consisted of 104 participants comprising 52 partner pairs. Survey data was missing for six (5.77%) participants due to completion failure or technical error, resulting in 49 pairs to be observed for analysis. All participants were students recruited from a large US West Coast university who were rewarded class credit for their participation. Participants were 66.35% female, 24.04% male, and 3.85% nonconforming or transgender. Average age was M = 19.47, SD = 1.23. Ethnicities were 58.65% Asian or Pacific Islander, 15.38% White/Caucasian, 13.46% Hispanic or Latino, and 6.73% were either African American, American Indian, mixed race or other. To be eligible to participate, individuals were required to have normal or contact-corrected vision as the task required viewing small objects presented on a smartphone (described below) and have English as their first language. Requirements for larger, ongoing study required a neurotypical sample, thus participants were all right-handed and had no history of substance abuse, depression or other mental health diagnoses, loss of consciousness due to traumatic brain injuries, migraines, brain surgery, breathing problems, motion sickness, claustrophobia, or psychotropic medications.

Procedure and Measures

Participants were recruited from a student subject pool, gave consent, and answered eligibility questions on an online survey via Qualtrics. If they were eligible, participants were invited via email to take part in the laboratory experiment and report to separate locations to be kept visually anonymous from one another and avoid impressions based on physical appearance. Once arrived, the two participants were seated in adjoining rooms but out of sight from one another, as to be co-present but controlling for use of gestures (Hancock et al., 2001a, b). Participants were randomly selected to the within-dyad role variable of director or matcher in an AR tangram game, described below, and kept their roles across three rounds of game play. While between-dyad variables were tested, between-dyad outcome variables were the pair's number of tangram identification successes and time spent matching tangrams (Schober & Clark, 1989; Hancock et al., 2001b), recorded after each of three rounds of game play. Additionally, attributions of partner trustworthiness were measured via Qualtrics survey after each round and was treated as a within-dyad variable as no research question regarded differences in trust between dyads. Once completed, participants provided demographic information and were debriefed and dismissed.

This study used a custom programed AR tangram game for smartphones involving partners coming to mutual understanding through describing and selecting geometric shapes, as per the classic tangram task procedures (Schober & Clark, 1989). In this gamified version of the task, directors' and matchers' common goal was to have matchers select 11 shapes in the order that they appear to directors as quickly and accurately as possible. Sixteen shapes (3-dimensional digital objects) were presented on a grid-like “board” by viewing a QR code through the smartphone’s camera. The shapes’ orientation was not shared between matchers and directors, and participants were blind to each other’s board orientations. At the start of the game, directors saw one of the 16 shapes highlighted in green and marked with an “x”, indicating the current target shape, while matchers saw 16 unhighlighted shapes (see Figure 1). Matchers selected the shape they believed to be the target by pressing and holding over the intended shape on screen for more than a second, at which point the shape was highlighted in green and a new target shape become marked on directors’ screens. The game continued until matchers selected 11 of the 16 shapes, at which point a display presented the number of accurately selected shapes by matchers (up to 11) and the elapsed time from start to finish of the game (in seconds). This information was recorded manually by trained research assistants.

A survey adapted from McAllister et al.’s (1995) cognitive and affective trust measures was administered after each of the three rounds of game play. The context of the items were changed from a workplace setting to the AR tangram game setting where applicable (see Appendix A). We changed the language from the original for only one item of the affective trust scale, where “*work*” was replaced with “*play this game*” for the item “We would both feel a sense of loss if one of us was switched out and we could no longer *play this game* together.” The cognitive trust scale required more alterations, such as changing the wording from “This person approaches his/her *job* with professionalism and dedication” to “This person approaches his/her *game role* with professionalism and dedication.” The scales include five items measuring affective trust (time 1 *alpha* = .81, time 2 *alpha* = .82, time 3 *alpha* = .83) and six items for cognitive trust (time 1 *alpha* = .69, time 2 *alpha* = .66, time 3 *alpha* = .65). Additional testing of the scales with confirmatory factor analysis revealed that, by removing one item in the cognitive trust scale, “If people knew more about this individual's behavior, they would be concerned and monitor his/her game performance more closely,” the reliability of the remaining five items were improved but still below acceptable levels (time 1 *alpha* = .76, time 2 *alpha* = .78, time 3 *alpha* = .78). However, as main analyses performed with this scale produced a similar, albeit slightly weaker, pattern of results as the original scale, the six-item scale was retained.

Results

Preliminary Analyses

Before performing the main analyses, the data was investigated to identify its distribution and potential outliers. Table 1 reports the means and standard deviations of the affective and cognitive trust ratings for matchers and directors across the three tangram game rounds. Figures 2 and 3 further visualizes the distribution of these data and helps identifies outliers. While two outliers were detected regarding affective trust and one for cognitive trust (using the *identify_outliers* command in R version 3.6.1), they did not meaningfully affect the significance of outcomes for future analyses and thus these datapoints were not removed. In addition, affective and cognitive trust were significantly correlated (all p's $< .001$), but only moderately so (round 1 $r = .50$, round 2 $r = .43$, round 3 $r = .38$). To confirm the scales’ distinctiveness, confirmatory factor analyses was used to compare the goodness of fit indicators for a two-factor model (*CFI* = .97, *TLI* = .96, *RMSEA* = .05) versus a one-factor model (*CFI* = .85, *TLI* = .81, *RMSEA* = .10). The two-factor model had more favorable fit results, thus affective and cognitive trust were considered distinct enough to be treated independently. Additionally, while score and time were slightly but significantly correlated after round 1 ($r = .30$, $p = .01$) and round 2 (r =

.24, *p* = .03), they were not significantly correlated by round 3 (*r* = -.20, *p* = .07). These variables were therefore also distinct.

Main Analyses

To answer whether cognitive (H1) and affective (H2) trust within dyads would be (a) positively associated with tangram scores and (b) negatively associated with completion time of tangram puzzles (b), I conducted four regression analyses with either game score or completion time as an outcome variable and cognitive or affective trust as predictor variables. Data collected at each time point was treated as a new case in the sample, thus game round served as an additional grouping variable. Interaction effects between trust variables and game round were also included as predictor variables. Regarding H1, results of the analysis modelling tangram game score revealed a significant, positive association with cognitive trust (β = 1.79, *SE* = 0.61, *p* = .004; see Table 2). There were no significant relationships between score and game rounds, nor any interaction effects. Figure 4 represents the significant effect between score and cognitive trust via the relatively severe, positive slope whereby both cognitive trust and scores increased together. Then, I tested completion time's relationship with cognitive trust, game round, and tested for potential interactions, but none were significant (see Table 3). Figure 5 displays the relatively flat slopes, indicating a null main effect of cognitive trust, while the similar slopes across each round suggests no interaction effects with game round. These results supported H1a as cognitive trust had a significant, positive relationship with score, but H1b's predicted relationship with completion time was not supported.

Regarding H2, the results indicated that score did not differ by affective trust, game round, nor showed interactions between affective trust and game round (see Table 4). Figure 6 represents the relationship between score and affective trust for each of the three rounds, and though scores were generally lower during round one, they were not significantly different from the other rounds, and nor were the slopes sufficiently different to represent a significant interaction with game round. I then conducted the same analysis again but modeled for completion time, which revealed a significant difference between round one and round three, where time was lower at round three than at round one (β = -213.10, *SE* = 98.50, *p* = .032; see Table 5). Figure 7 shows consistent disparity in time between rounds one and three. However, neither affective trust nor affective trust's interaction with game rounds were significant. These two analyses fail to support H2, as affective trust did not show a relationship with tangram score nor tangram completion time.

The third hypothesis (H3) predicted that matchers' cognitive trust towards partners would show more change (positive or negative) than directors' trust towards partners, therefore I calculated change scores for cognitive trust from round one to round two, and from round two to round three. Table 1 includes the mean and standard deviation in change values across directors and matchers for cognitive trust as well as for affective trust. H3 was investigated with Welch's two-sample t-tests to see whether change scores for directors and matchers were indeed different between rounds. Results indicated that neither change scores of cognitive trusts from rounds one to two ($t(91.98) = .56$, $p = .58$) nor from round two to three ($t(95.72) = -.42$, $p = .68$) were significantly different between roles, thus failing to support H3.

We also predicted that increased cognitive trust by (H4a) matchers' and (H4b) directors towards their partners would result in increased subsequent cognitive trust by partners in kind, and likewise for affective trust (H5a & H5b). To test these hypotheses, we constructed four repeated measures APIM path models (Perry et al, 2017) using R version 3.6.1, and lavaan version 0.6-9 software package (see Figure 8 for the hypothesized model template). Change scores were calculated for affective trust similarly to how cognitive trust change scores were. All models input change scores as endogenous (outcome) variables and raw trust scores as exogenous (predictor) variables, and only included similarly typed trust variables (e.g., cognitive trust was not included in the same models as affective trust).

Before examining the hypothesized partner effects, we considered within-participants change (or actor effects), first for cognitive trust towards partners from round one to round two to determine whether initial trust ratings predicted cognitive trust in the second round. Matchers' cognitive trust towards directors after round one did not predict change in cognitive trust towards directors at round two (β = .07, *SE* = .10, *p* = .51), but director's cognitive trust towards matchers were negatively predictive of change in cognitive trust toward matchers at round two (β = -.36, *SE* = .09, p < .001). That is, directors with high levels of cognitive trust towards matchers after round one experienced less change in cognitive trust after round two, while directors with the lowest cognitive trust after round one experiences the greatest cognitive trust change after round two. A similar APIM model tested the change in cognitive trust for both roles from round two to round three, and it revealed significant negative actor effects for directors (β = -.31, *SE* = .09, *p* = .001) and matchers (β = -.18, *SE* = .07, *p* = .01). As between rounds one and two, cognitive trust at round three was less likely to change if cognitive trust was high after round two, and more likely to change when cognitive trust was lower.

Regarding partner effects predicting that cognitive trust should have a reciprocal, positive effect for both matchers (H4a) and directors (H4b), these models failed to reveal a significant relationship between rounds one and two: matchers' cognitive trust's effect on change in directors' cognitive trust (β = .16, *SE* = .11, *p* = .14), and directors' cognitive trust's effect on change in matchers' cognitive trust (β = .05, *SE* = .08, *p* = .53). However, there was a significant partner effect from round two to round three, whereby directors' cognitive trust towards matchers was negatively related to change in matchers' cognitive trust towards directors (β = -.17, *SE* = .08, *p* = .03), but not for matchers' cognitive trust towards directors on directors' change in cognitive trust (β = ,12, *SE* = .08, *p* = .12). See Figure 9 for a representation of this path model. This negative relationship suggests that higher cognitive trust by directors after round two predicted less change in matchers' cognitive trust after round three, while lower cognitive trust by directors after round two predicts more change in matchers' cognitive trust after round three. This, however, did not support H4.

To test for H5a and H5b, which respectively predicted that affective trust would be mutually improved by matchers and directors' affective trust, additional APIM analyses were conducted. Regarding within-participant change (actor effects) from round one to round two, affective trust after round one significantly and negatively predicted change in affective trust after round two for matchers (β = -.24, *SE* = .10, *p* = .014) but not directors (β = -.16 *SE* = .08, *p* = .06). Meanwhile, the hypothesized partner effects were not supported as matchers' affective trust at round one did not affect change in directors' affective trust at round two (β = .06, *SE* = .08, *p* = .49), nor did directors' affective trust at round one affect change in matchers' affective trust at round two (β = -.07, *SE* = .10, *p* = .50). The analysis for change in affective trust from rounds two to three revealed no significant relationships either: neither the actor effect for matchers' affective trust after round two on matchers' change in affective trust after round three (β = -.01, *SE* = .07, *p* = .91), nor the actor effect for directors' affective trust after round two on directors' change in affective trust after round three (β = -.06, *SE* = .06, *p* = .27) were significant. Likewise, partner effects for matchers' affective trust after round two on directors' change in affective trust after round three (β = .02, *SE* = .06, *p* = .69) and for directors' affective trust after round two on matchers' change in affective trust after round three (β = .01, *SE* = .07, *p* = .90) were not significant.

Discussion

This study examined the development of trust between partners as they solved coordination problems in an AR game context. Th results supported the prediction that cognitive trust would be positively related to performance on coordination problems, though affective trust was not. We also described the relationship between individuals' trust development and the roles they serve within a specific, popular coordination task, as well as tested whether individuals' trust development affected their partners' trust development.

Performance on the tangram task was represented by both accuracy and completion time (Schober & Clark, 1989), as both relate to the grounding process. Accuracy is directly related to successfully scaling the action ladder to reach mutual understanding (Clark, 1996), whereas completion time is associated with the enhanced efficiency brought on by establishing linguistic conventions (Brennan & Clark, 1996). That is, when partners agree to mutually identify a specific figure as, for instance, a "dancer," they are able to reference that figure with fewer utterances later on, reducing the time to communicate (Hawkins et al., 2017). However, patterns of accuracy and completion time performance differed from one another in our results. For instance, there was a difference in time needed for tangram round completion between rounds one and three, but not for accuracy scores. Thus, this result may be indicative of participants' greater familiarity over time with the tangram game, the AR app, and other experimental procedures independent of the grounding process. Enhanced individual familiarity with study procedures from round one to round three could explain why participants were able to speed up their performance without substantively improving on the accuracy of performance over time.

Our hypotheses for affective trust's positive relationship with tangram task accuracy and completion time were not supported. Likely, affective trust ratings among participants reflected an assumed level of trust based on individual propensity for trust as well as perceived social categories (Robert et al., 2009), to the extent that such categories could be detected from non-visual information. Moreover, the tangram matching task may not require affective trust for participants to fulfil the task's objectives. Group interaction is comprised of both task-oriented and socioemotional communication (Bales, 1950), where task-oriented communication, such as asking for or offering task related opinions, suggestions, or information (Bales, 1970) is correlated with cognitive trust (Butler & Cantrell, 1994; Dirk & Ferrin, 2002). Meanwhile, affective trust is positively linked to socioemotional communication (Dirks & Ferrin, 2002), such as showing solidarity or friendliness, relieve tension, or express agreement, but negatively related to messages that express disagreement, or increase tension or antagonism (Bales, 1970). Different tasks may demand specific levels of each type of communication, and thus beget different levels of affective or cognitive trust. It is possible that the tangram matching task may be more conducive to task-oriented messages and cognitive trust perceptions than to socioemotional messages and attributions of affective trust, and further investigation into the prevalence of each communication type is needed to confirm their relevance to performance on the present AR task.

Additionally, individuals require time to establish interpersonal relationships with teammates and develop affective trust (Webber, 2008). Past research on trust within short-lived teams confirm that trust as unidimensional early in a team's lifespan (Dirks, 1999), with early trust based on familiarity, general competence, and likability and cognitive and affective trust emerging over time (Webber, 2008). As zero-history partners would have sparce information to evaluate each other's benevolence (McAllister et al., 1995), we assume that in the present AR tangram matching task individuals would rely primarily on competence cues to establish cognitive trust judgements (Sniezek & Van Swol, 2001). Given the short duration of the tangram matching task, the insignificant relationship between affective trust and tangram task performance was to be expected.

In addition, teammates with higher cognitive trust were more accurate in identifying shapes in the tangram task, though cognitive trust did not relate to tangram round completion time. This result supports a connection between cognitive trust and grounding. It is possible that cognitive trust increased with common ground through behaviors that serve as both competence cues and supports grounding. For instance, establishment of linguistic conventions is integral to the grounding process (Hawkins et al., 2017), and doing so may correlate with a mutual boost in perceived competence, in that conventions remove uncertainty and increase confidence in a given context by establishing a common lexicon. Since competence cues relate to perceived confidence (Sniezek & Van Swol, 2001), and established linguistic conventions may enhance confidence, then linguistic conventions may indicate a level of perceived competence as well.

However, as the relationship between cognitive trust and tangram completion time was not significant, any increases in communication efficiency (i.e., fewer words with greater meaning) suggested by the principle of least-collaborative effort (Clark & Brennan, 1991) may not have been associated with impressions of competence. Regardless, our null completion time results should be reconciled with the positive association between cognitive trust and task accuracy. It is possible that some communication behaviors enhance cognitive trust without increasing the efficiency of completing the task at hand. For instance, linguistic elements that cue task competence include verbal fluency, speaking rate, and modulation of voice tone (Berger et al., 1998), which inspire perceived competence and enhanced influence on teammates (Driskell et al., 1993). Such competence cues may be apparent during the grounding process at the mechanical or signal levels, where clarity of voice and meaning are involved (Clark, 1996). Competence displays may therefore serve as antecedents to common ground. Linguistic analysis should be used to confirm the presence of verbal competence cues and relate them to coordination task performance.

The hypothesized effect of director or matcher role on trust was based on how matchers were more likely to express acknowledgments above other types of utterances, as well as directors' tendency to speak more than their partners (Bortfeld et al., 2001). While our results failed to detect significant differences between roles on level of trust change, directors' cognitive trust towards matchers were linked to an increase in matchers' cognitive trust towards directors, but not vice versa. This effect was counter to descriptions of trust as reciprocal (Serva et al., 2005) where trust in one partner should foster trust in return. This implied that directors' trust signaling differed from matchers' trust signaling. One possibility was that differences in directors and matchers' communication behaviors (Bortfeld et al., 2001) impacted the quantity and/or quality of trust signaling. As directors are the primary speaker in the dyad, they are in the more vulnerable position in that they express more information and thus are at greater risk to appear ignorant. Matchers who receive these signals may enhance their level of trust towards directors, but do not have as many opportunities to signal their trust back, thus limiting the trust directors might have otherwise developed towards matchers. Future research should work to confirm this disparity of utterance types between the two tangram task roles, and their relationship with trust development. The negative relationship between directors' cognitive trust and matchers' change in cognitive trust may also be the result of a ceiling effect. The negative relationship indicates that higher levels of trust were associated with no change in subsequent trust, rather than decreases, while lower levels of trust improved over time. Therefore, there appears to be a limit to which trust may be increased in the present context, wherein lower levels of trust may raise from one round to the next, but not when trust was already relatively elevated.

The findings of this study are subject to possible limitations. Methodologically, the reliability of the six-item cognitive trust scale was only moderate, which may have made accurately detecting effects less likely if indeed they were present or result in falsely identified significant effects. In a separate test, an alternative five-item version of the scale was analyzed, revealing a similar pattern of results, though with slightly weaker relationships. This alternate scale suffers the same limitation however, as *alphas* were still in the moderate range rather than meeting the *alpha* = .80 standard for high reliability (Cortina, 1993).

This study is also limited in that the sample was comprised entirely of college students, thus restricting result generalization to only other highly educated, young adult populations. There is practical merit to studying cooperation and trust in college students as partner and small team situations occur in academic settings, but our results should be applied to more professional populations cautiously. Such factors as age and work experience affects individual's propensity to trust (Zeffane, 2018) as older adults tend to have greater maturity and adjustment over their emotions (Rhodes, 1983). Meanwhile age may also affect the grounding process, for instance young adults tend to spend less words and gestures when communicating mutually known content with a partner, as compared to older adults (Schubotz et al, 2019). Future research on trust development should aim to examine a more experienced population in professional fields of work to confirm the generalizability of our results.

As cooperation among teammates continues to be a vital element to success within professional contexts, it is important to understand how impressions of trust are formed in support of effective coordination. In summary, by investigating the relationship between different kinds of trust and coordination performance in terms of tangram matching accuracy and completion time, we observed that increased cognitive trust was indicative of greater accuracy, though not in completion time. Meanwhile, affective trust did not relate to coordination performance, emphasizing the importance of perceived competence over emotional connection when it comes to solving coordination problems. Additionally, trust given to one's partner begets trust from the partner in return, but potentially only when the role of the trustor supports more and varied communication. Future research into teams and cooperative pairs is needed to better understand the trust-boosting behaviors potentially associated with successful coordination.

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Figures, Tables, and Graphs

Figure 1

Tangram layout in the ARTgram game app (Left: Director view, Right: Matcher view)

Table 1

Summary of Trust data by Role across Rounds

Role	Time	Variable	n	mean	sd	change, m	change, sd
Director	Round 1	AT	39	3.30	0.81	-	-
Matcher	Round 1	AT	39	3.32	0.81	-	-
Director	Round 2	AT	41	3.49	0.81	0.11	0.40
Matcher	Round 2	AT	41	3.52	0.74	0.21	0.52
Director	Round 3	AT	44	3.64	0.78	0.14	0.30
Matcher	Round 3	AT	44	3.67	0.83	0.16	0.33
Director	Round 1	CT	39	3.91	0.65	-	-
Matcher	Round 1	CT	39	4.01	0.51	-	-
Director	Round 2	CT	41	4.08	0.56	0.12	0.43
Matcher	Round 2	CT	41	4.09	0.59	0.07	0.35
Director	Round 3	CT	44	4.20	0.53	0.12	0.35
Matcher	Round 3	CT	44	4.20	0.57	0.15	0.33

Figure 2: Affective Trust

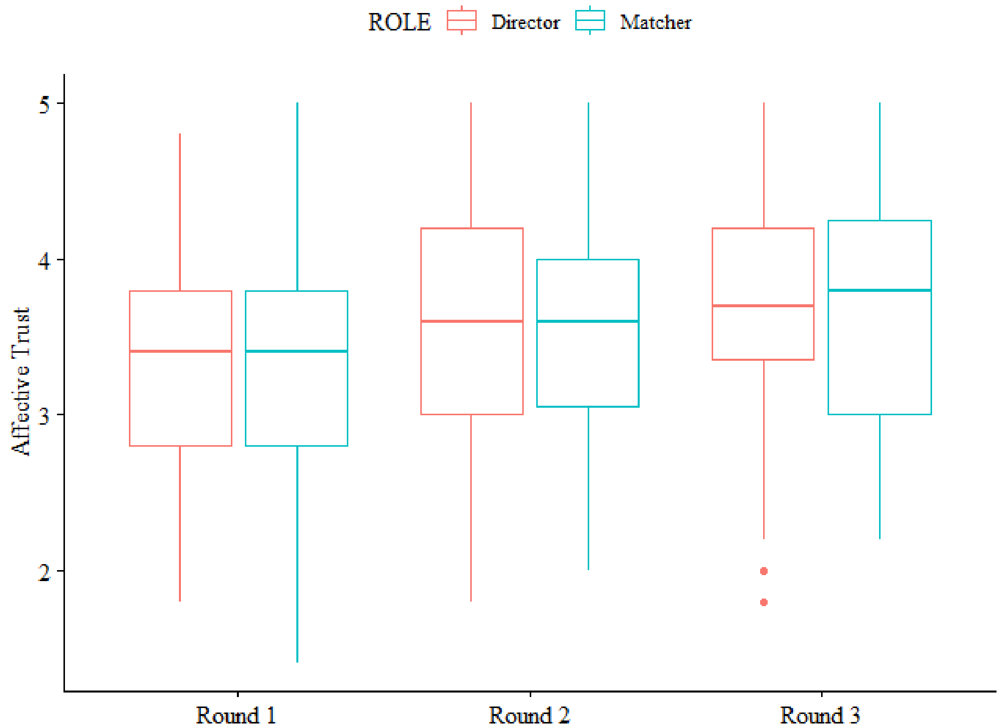


Figure 3: Cognitive Trust

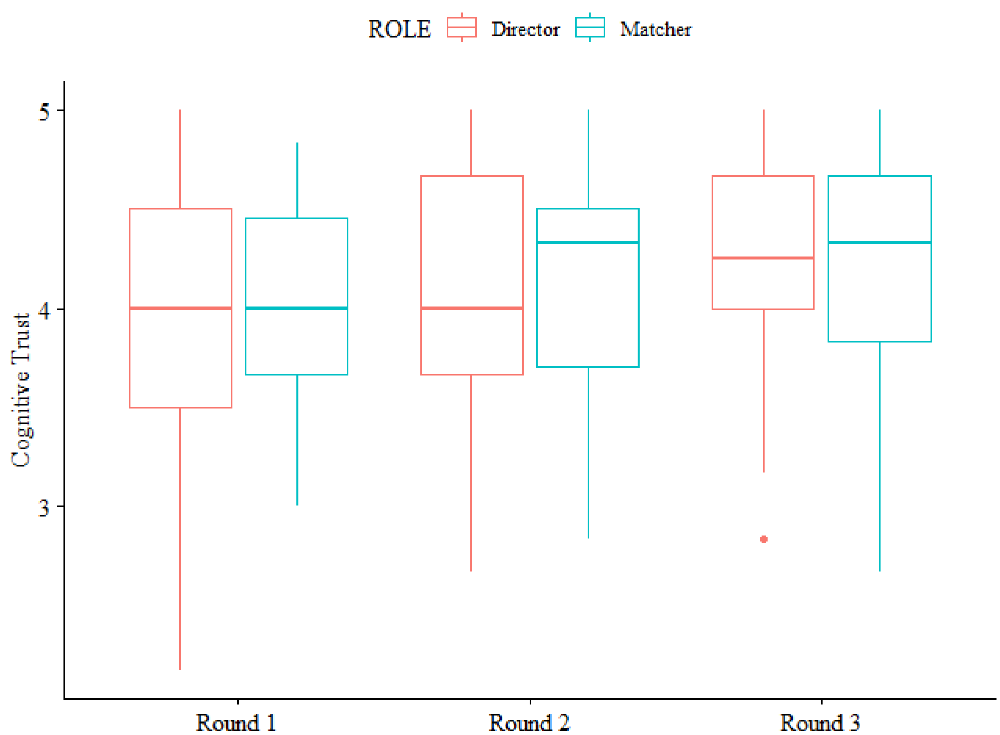
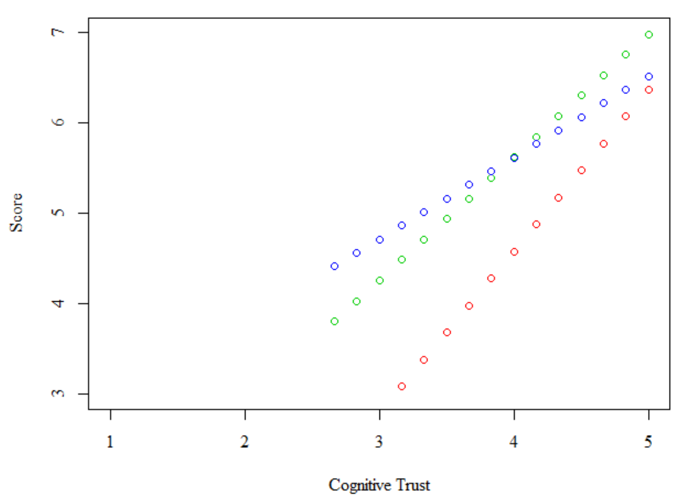


Table 2

Score Predicted by Cognitive Trust and Game Round, with Interactions

	Estimate	SE	t-value	p-value
(Intercept)	-2.58	2.47	-1.04	0.30
CT	1.79	0.61	2.92	0.004
Round 2	2.76	3.56	0.78	0.44
Round 3	4.59	3.52	1.30	0.19
CT:Round 2	-0.43	0.87	-0.49	0.62
CT:Round 3	-0.89	0.85	-1.04	0.30
F stat	Df	p-value	Res SE	Adj R-sqr
4.86	5(236)	<.001	3.03	0.07

Figure 4: Score by Cognitive Trust and Round



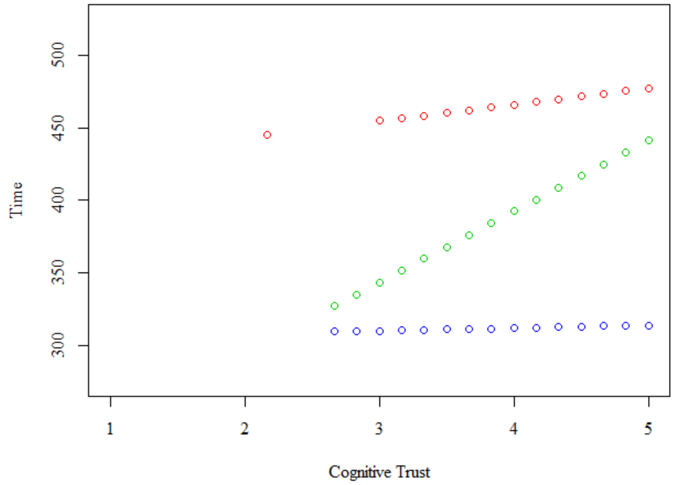
Red = round 1, green = round 2, blue = round 3

Table 3

Time Predicted by Cognitive Trust and Game Round, with Interactions

	Estimate	SE	t-value	p-value
(Intercept)	421.19	114.70	3.67	<0.001
CT	11.21	28.53	0.39	0.70
Round 2	-225.14	165.27	-1.36	0.17
Round 3	-116.84	163.57	-0.71	0.48
CT:Round 2	37.86	40.46	0.94	0.35
CT:Round 3	-9.34	39.66	-0.24	0.81
F stat	df	p-value	Res SE	Adj R-sqr
10.36	5(236)	<0.001	140.90	0.16

Figure 5: Time by Cognitive Trust and Round



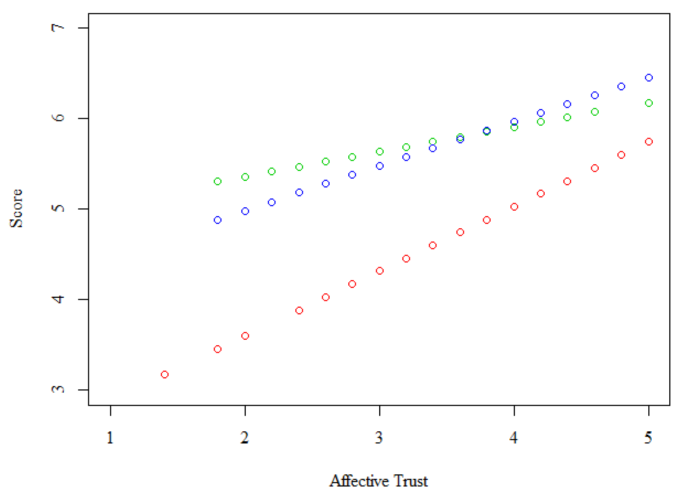
Red = round 1, green = round 2, blue = round 3

Table 4

Score Predicted by Affective Trust and Game Round, with Interactions

	Estimate	SE	t-value	p-value
(Intercept)	2.18	1.53	1.42	0.16
AT	0.71	0.45	1.60	0.11
Round 2	2.64	2.22	1.19	0.24
Round 3	1.83	2.18	0.84	0.40
AT:Round 2	-0.44	0.63	-0.70	0.49
AT:Round 3	-0.22	0.61	-0.37	0.71
F stat	df	p-value	Res SE	Adj R-sqr
2.509	5(236)	.031	3.10	.03

Figure 6: Score by Affective Trust and Round



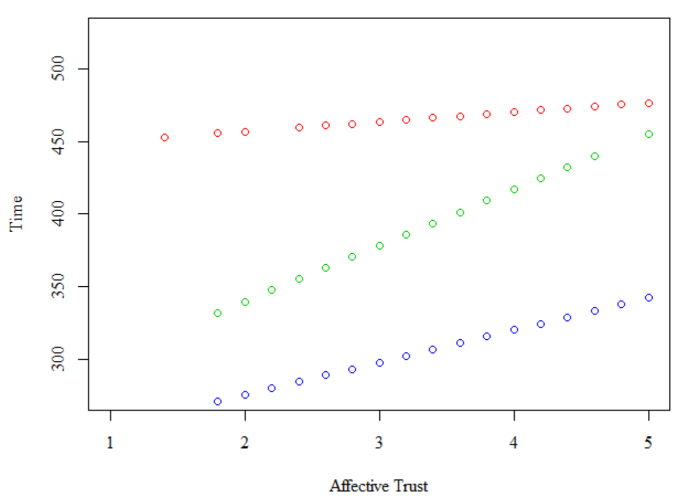
Red = round 1, green = round 2, blue = round 3

Table 5

Time Predicted by Affective Trust and Game Round, with Interactions

	Estimate	SE	t-value	p-value
(Intercept)	443.85	69.10	6.42	<.001
AT	6.61	20.22	0.33	0.74
Round 2	-181.33	100.37	-1.81	0.07
Round 3	-213.10	98.50	-2.16	0.03
AT:Round 2	31.98	28.64	1.12	0.27
AT:Round 3	15.697	27.592	0.569	0.5700
F stat	df	p-value	Res SE	Adj R-sqr
10.85	5(236)	<.001	140.30	0.17

Figure 7: Time by Affective Trust and Round



Red = round 1, green = round 2, blue = round 3

Figure 8: Template APIM for Change in Trust

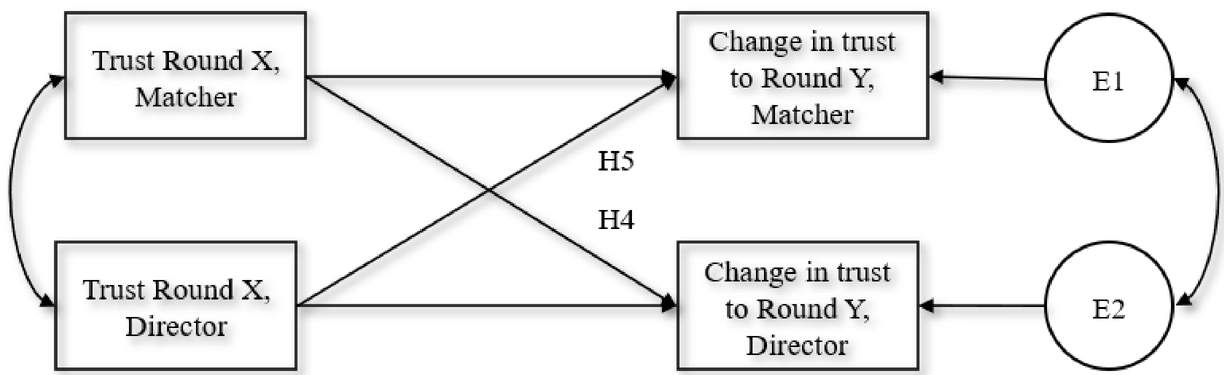
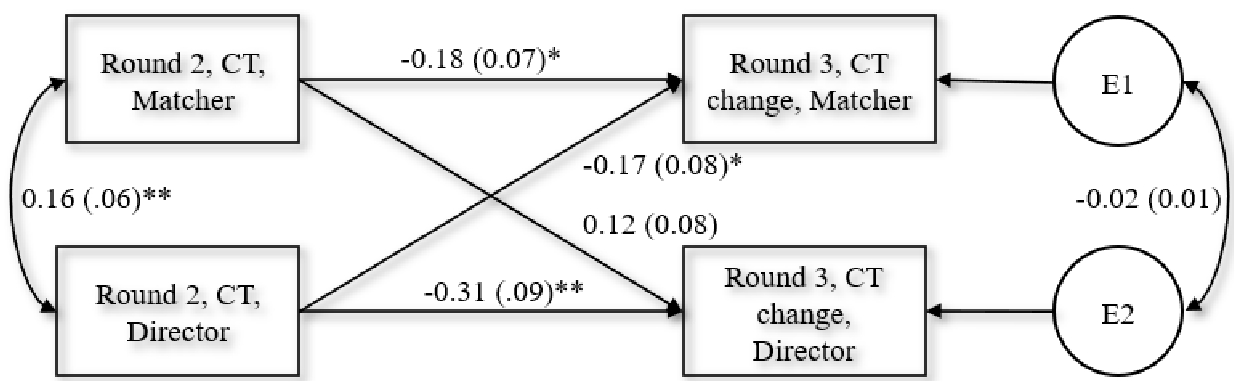


Figure 9: APIM for Change in Cognitive Trust from Rounds 2 to 3



** $p < .01$, * $p < .05$

Appendix A

Adapted McAllister et al. (1995) measure.

Affective Trust items

1. We have a sharing relationship. We can both freely share our ideas, feelings and hopes.

Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree

2. We can talk freely to this individual about difficulties I am having and know that (s)he will want to listen.

Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree

3. We would both feel a sense of loss if one of us was switched out and we could no longer play this game together.

Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree

4. If I shared my problems with this person, I know (s)he would respond constructively and caringly.

Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree

5. I would have to say that we have both made considerable emotional investments in our team relationship.

Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree

Cognitive Trust Items

6. This person approaches his/her game role with professionalism and dedication.

Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree

7. Given this person's behavior, I see no reason to doubt his/her competence and preparation for playing the game.

Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree

8. I can rely on this person not to make my game role more difficult by careless work.

Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree

9. Most people, even those who aren't close friends of this individual, trust and respect him/her.

Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree

10. Other individuals who must play this game with this individual would consider him/her to be trustworthy.

Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree

11. If people knew more about this individual's behavior, they would be concerned and monitor his/her game performance more closely.

Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree