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Predictors of Peer Perceptions of Teamwork Competence: A Field study of Virtual Teams

By

Timothy Allen Oxendahl

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APPROVED, THESIS COMMITTEE

Margaret Beier
Chair
Professor of Psychological Sciences

Eduardo Salas
Professor of Psychological Sciences
Allyn R. & Gladys M. Cline Chair in Psychology
Department Chair

Fred Oswald
Professor of Psychological Sciences and
Herbert S. Autrey Chair in Social Sciences

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ABSTRACT

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Peer ratings of team member competence, or the extent to which fellow team members are perceived to be capable of contributing to a team, are an important predictor of team viability and success. Drawing on trait activation theory (Tett & Burnett, 2003), this study examines the influence of personality and psychological safety on peer ratings of teamwork competence, along with the mediating influence of objectively measured speaking time via path analysis. I hypothesized that a) speaking time would be positively related to peer perceptions of teamwork competence, b) the personality traits of extraversion, emotional stability, and conscientiousness as well as individual perceptions of team psychological safety would be positively related to both speaking time and peer perceptions of teamwork competence, and that c) these traits and attitudes would be indirectly related to peer perceptions of teamwork competence via speaking time. Data for this study came from student (110 individuals distributed across 21 teams) teams working on complex, open-ended team design projects over the course of the spring 2021 semester. This longitudinal dataset contained self-report and peer-report data, as well as objective speaking behaviors extracted from naturally occurring virtual team meetings. The results showed significant relationships between speaking time and teamwork competence and between psychological safety and teamwork competence. However, no significant indirect effects were found (e.g., the effect of personality and psychology safety on teamwork
competence via speaking time). This study sheds light on the ways in which individual attitudes and behaviors influence how people are perceived in a team.
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Introduction

Organizations increasingly rely on teams to accomplish complex tasks, and successful teamwork requires coordination and communication. Teams, groups of interdependent individuals working toward a common goal (Sundstrom et al., 1990), harness the collaborative potential of human interaction, thereby increasing an organization’s adaptability and productivity (Deloitte, 2016). The way that team members communicate in team meetings, in particular, can positively impact team satisfaction and productivity (Kauffeld & Lehmann-Willenbrock, 2012) and can influence the team’s overall affect (Schneider et al., 2018). Moreover, an individual’s social behavior can influence how they are perceived by others (Ambady & Rosenthal, 1992). Clearly, an effective, competent team member possesses not only the relevant knowledge, skills, and abilities to accomplish tasks but also effectively interacts with their teammates (Loughry et al., 2007).

In teams, the extent to which people communicate (e.g., knowledge sharing, seeking feedback, asking for help, talking about errors) and, in turn, contribute to a team, may be influenced both by their personality traits, as well as their perceptions of how safe the team is to take various interpersonal risks, known as psychological safety (Edmondson, 1999). The benefits of how various personality traits work together (e.g., affective states, behavioral processes; Bell et al., 2018) and psychological safety (e.g., creativity, information sharing; Frazier et al., 2017) in teams are numerous. However, despite recent research suggesting that psychological safety may be differentially beneficial to people depending on personality traits (Sherf et al., 2021) and calls for research on the interaction of personality and psychological safety (Newman et al., 2017), relatively few studies have explored this topic.
Additionally, though technological advances in unobtrusive (non-invasive) methods provide multiple options for capturing real-time, objective teamwork processes (Mathieu et al., 2019), the majority of team research continues to rely on cross-sectional research designs using self-report data (Kozlowski & Chao, 2018). However, the increase of virtual teams in recent years in conjunction with advances in meeting technology provides both unique challenges as well as opportunities to research objective synchronous teamwork behaviors. These circumstances, which include a shift to remote education and technology-mediated collaboration precipitated by the COVID-19 pandemic, provide the opportunity to explore my research question: how do individual personality traits and attitudes, along with conversational behavior in team meetings, influence how individuals are perceived by their teammates?

The current study builds on past research, which has relied mostly on either self-report measures or controlled laboratory settings, to assesses student teams working on engineering and computer science design projects, oftentimes in conjunction with real-world organizations, over the course of a semester (Kozlowski & Chao, 2018). Using the framework of trait activation theory (Tett & Burnett, 2003), this study explores the time-lagged dispositional and attitudinal antecedents of objective behavior, as well as peer perceptions of teamwork competence (see Figure 1) over the course of a semester. In particular, speaking time behavior extracted from transcripts produced via video conferencing technology in naturally occurring team meetings was analyzed in conjunction with self- and peer-report data to better understand how subjective psychological phenomenon (personality, psychological safety) and objective behaviors (speaking time) relate to effective teamwork (peer perceptions of teamwork competence).
Literature Review

In this section, I will review the bodies of literature related to the variables in Figure 1. The effect sizes mentioned in this section (e.g., small, moderate, large) are based on Cohen’s (1992) standards of .1, .3, and .5, respectively.

Peer Ratings of Teamwork Competence

Fellow team members (i.e., peers) are both an important source of information regarding a person’s performance in a team and are a useful tool for development. Indeed, the perspective of fellow team members may paint a different picture compared to self-report measures. For example, Mann et al. (2012) studied undergraduate students engaged in team projects over the course of 12 weeks and found that peer assessments of counterproductive workplace behaviors were significantly higher than self-assessments. Additionally, receiving peer feedback can have a positive impact on individual behavior in teams, as evidenced by Donia et al. (2018), who used a time-lagged study of undergraduate students who were working full time to reveal that peer ratings of teamwork effectiveness from team-based school projects was positively related to subsequent ratings of organizational citizenship behaviors. Moreover, Román-Calderón et al. (2021) studied 3,587 students distributed across 669 virtual teams participating in an international consulting competition over the course of eight weeks and found that students’ effort increased over time in response to decreased peer ratings. Finally, even the process of giving peer feedback can have a positive impact on teamwork behaviors, as shown by Dominick et al. (1997), who showed that observer-rated teamwork behaviors of collaboration, communication, decision making, and self-management were higher in teams that either gave and received peer feedback or only gave peer feedback compared to a control group that had no exposure to peer feedback.
Peer assessments that use behaviorally anchored rating scales (BARS) are effective in measuring team processes such as coordination, cooperation, and communication (Delice et al., 2019). One such scale, the BARS version of the Comprehensive Assessment for Teamwork Effectiveness (CATME-B), is a peer-rating system used widely in higher education throughout the world (Ohland et al., 2012). This scale is based on the work by Loughry et al. (2007), who developed the original 87-item CATME scale (with Likert-style questions) based on a comprehensive search of teamwork literature. These researchers distilled the various types of teamwork contributions into five categories: contributing to the team’s work, interacting with teammates, keeping the team on track, expecting quality, and having relevant knowledge, skills, and abilities. Building on the work of Loughry et al. (2007), Ohland et al. (2012) developed a behaviorally anchored rating scale version of the CATME, which they referred to as the CATME-B. Their findings revealed that the BARS was a reliable alternative to the original scale.

Past research has not only confirmed the psychometric reliability of this measure (Chhabria et al., 2019), but also its ability to predict team outcomes. Studying undergraduate students over the course of the semester, Ohland et al. (2012) found that composite CATME-B scores (the average of the peer ratings for each of the five dimensions) were moderately positively related to student grades. A follow-up study by the same researchers, which involved a larger sample size, revealed that ratings on the five different CATME-B scores accounted for a significant proportion of the variance in the extent to which teammates would want to work with their teammates again in the future. Therefore, the CATME-B is not only predictive of team member performance, but also team viability. These findings suggest that the long-term success of a team is dependent upon the extent to which peers consider their team members to be competent. Further, when individuals view their team members as competent, they are more
likely to be satisfied with and want to continue working in that team. Additionally, Thomas et al. (2020) explored the relationship between dyad-level perceptions of competence (measured via the CATME-B) and dyad-level perceptions of viability in a large-scale study of college students. This study showed that perceptions of competence positively predicted the extent to which team members would like to continue working with each other (e.g., viability).

Based on past findings, researchers have called for investigations into the factors that may predict individual perceptions of other teammates (see Loignon et al., 2017; Thomas et al., 2020). For example, communication, which is a key part of teamwork processes (Prewett et al., 2009), may influence the way people rate each other as communication signals interest, demonstrates engagement, and shows participation in learning behaviors in a team. In fact, Lievens et al. (2008) surveyed workers across multiple professions and found that the relative importance assigned to the way coworkers interact with each other was higher for peer raters compared to supervisors. As such, a person’s communication patterns may leave a lasting impression on team members, thereby influencing the peer ratings they receive. Consequently, much can be gained by studying objective behaviors in conjunction with rater perceptions of team member competence.

Communication

Interactions among team members, referred to as lateral or horizontal communication, are important for team commitment and cohesion (Kim et al., 2016) and are becoming increasingly relevant as organizational structures continue to flatten (Tariska-Semegine, 2012) and embrace teamwork. Additionally, of the ways that people influence the perceptions of others is through communication. Indeed, a review by Bonaccio et al. (2016) showed that physical expressions, including speech, are important predictors of interpersonal outcomes. In particular, regardless of
the speech content, individuals can communicate simply through the amount of time they speak (categorized as a form of chronemics), and this behavior can play an important role in impression formation. Moreover, a review by Kozlowski and Chao (2018) concluded that, in addition to being somewhat intrusive, retroactive self-report measures of team processes, which include interaction, collaboration, and the exchange of knowledge across team members, are subject to bias. When attempting to measure communication patterns within teams, one noteworthy objectively quantifiable behavior is speaking time. According to Pentland's (2004) framework of non-linguistic vocalization patterns, speaking time corresponds with “activity” and represents a person’s level of interest in the person with whom they are interacting.

Multiple laboratory studies emphasize the importance of speaking time in influencing the perceptions of others. For example, Bass (1951) studied the behavior of undergraduate students in leaderless group discussions by having company representatives observe and rate the competence of the participants. Their findings showed the amount of time a person spoke during the group discussion had a large positive correlation with the number of times they were chosen by a company representative as a suitable job candidate. Additionally, Curhan and Pentland (2007) conducted an employment negotiation simulation study with graduate students in which participants were either assigned the role of a middle manager or a vice president. They found that the amount of speaking time exhibited by the participants within the first five minutes of the negotiation positively predicted the number of negotiation points received by vice presidents. Frauendorfer et al. (2014) conducted a hiring simulation using randomly selected people from the public and found that, controlling for age and gender, the average speaking turn duration of applicants was positively related to perceptions of hire-ability rated by professional recruiters.
Laboratory research shows that speaking time may also influence peer evaluations in teams. Sorrentino and Boutillier's (1975) experimental group study, in which a confederate systematically changed their speaking patterns, demonstrated that verbal interaction quantity was significantly related to peer perceptions of competence, confidence, interest, influence, task leadership ability, and socioemotional leadership ability. Studying undergraduate problem-solving teams, Littlepage et al. (1995) found that the amount of time a person talked during a problem-solving team task was strongly positively correlated to other-rated perceptions of expertise and team influence and that perceived expertise mediated the relationship between the amount of time person talked and the influence they had on the team. Additionally, Nikoleizig et al. (2021) conducted a laboratory study on teamwork using a moon landing problem solving simulation with undergraduate students. Controlling for task competence and psychical expressiveness, speaking time positively predicted team member performance evaluations and speaking time mediated the relationship between task competence and peer ratings of performance.

Communication quantity also presents implication for team performance. For example, Johnson et al. (2006) studied undergraduate students working together in teams on a computer-simulated decision-making task across two time points and found that frequency of information sharing (operationalized via the total number of times teammates shared information with the team) was moderately positively related to the team’s accuracy. Additionally, Foushee and Manos (1981) analyzed voice recordings from 12 cockpit crews participating in a simulation study to find that the number of statements made in a crew was strongly negatively related to the number of errors that were made. Although these studies were conducted in controlled lab settings, they provide important insight into the influence that objectively measured speaking
time can have on the impressions of team members. These findings suggest that the way that people communicate and interact with others influences both the perceptions of others as well as team outcomes. Therefore, I make the following hypothesis:

_Hypothesis 1:_ Speaking time will be positively related to peer ratings of teamwork competence.

**Personality, Teamwork Competence, and Speaking Time**

Based on the relative importance of speaking time in relation to peer evaluations in team settings, the various factors that influence individual communication behaviors should be considered. One of these factors is personality. Personality refers to an individual’s “configuration of cognitions, emotions, and habits activated when situations stimulate their expression” (Triandis & Suh, 2002, p. 136). The activation of these internal dispositions can be understood through Trait Activation Theory (Tett & Burnett, 2003), which provides a framework for understanding how personality traits result in observable behaviors in teams. According to this theory, traits are latent potentials that are expressed when cues or demands in the environment activate situation-relevant traits. These demands can originate from multiple sources, including the organization, the immediate social context, or even the demands of the task that needs to be executed. Additionally, Tett and Burnett (2003) posited that the same observed behavior could be determined by multiple internal dispositions. For example, a manager’s expressed behavior of providing direction to subordinates could be an expression of their achievement motivation, methodicalness, or even their paternalism (Tett, 1995). Consequently, the same behavior (e.g., speaking time) could be the result of various traits being activated through various demands (e.g., socially based, task based).
Personality traits can impact how individuals work together and communicate within teams, and although past research shows that personality in teams is related to team outcomes such as performance (Bell, 2007), meta-analytic findings suggest that team processes, such as communication, may be more closely related to personality traits than team performance (Prewett et al., 2009). In other words, personality traits may be more related to how a team accomplishes tasks rather than what they accomplish. These teamwork behaviors, in contrast with task performance, are related to how people interact with their fellow coworkers and teammates and may even encompass behaviors that are not necessarily used as metrics for task performance at work (Motowildo et al., 1997). These behaviors are especially important for teams who must collaborate and learn together.

This study will focus on the traits of extraversion, emotional stability, and conscientiousness, as these traits have theoretical relevance to both speaking time in team meetings and peer perceptions of teamwork competence. Teamwork, for example, activates extraversion, conscientiousness, and emotional stability because teamwork requires individuals to engage socially with other teammates, accomplish team-based goals and tasks, and engage in the vulnerable act of learning in a team setting, behaviors that are especially motivating to people high in these traits (Tett et al., 2021). In fact, in a review conducted by Barrick and Mount (2009), conscientiousness and emotional stability were identified as the two key personality traits that are important for teamwork and collaboration, and Judge and Zapata (2015) found that extraversion was positively related to job performance in positions requiring strong social skills. Furthermore, Staiano et al. (2011) used various machine learning algorithms (e.g., Naïve Bayes, Hidden Markov Models, Support Vector Machines) to model the Big Five personality traits based on conversational behaviors (e.g., speaking time) extracted from video recordings of
people participating in a team-based decision making task. They found that the traits of extraversion, emotional stability, and conscientiousness were the best-recognized traits based on verbal behavioral qualities. Despite the potential for the demands of working together as a team activating agreeableness, such that peer ratings of teamwork competence may be positively related to agreeableness, past research suggests that agreeableness is negatively related to speaking up in team contexts (LePine & Van Dyne, 2001). Additionally, although the teamwork cues for producing new ideas and solutions to problems may activate openness, such that speaking time may be positively related to openness, past research suggests that highly open people prefer to work autonomously (Kamdar & Van Dyne, 2007). Because openness and agreeableness lack relevance to the outcomes of interest, I do not make specific hypotheses about them.

*Extraversion*

Extraversion is relevant to teamwork, as it is a trait that is activated in social situations (Judge & Zapata, 2015). Highly extraverted people tend to engage in socially-oriented behavior, are gregarious and assertive, and thrive in situations in which they may receive social attention (Ashton et al., 2002). Indeed, a quantitative review and meta-analysis conducted by Wilmot et al. (2019) demonstrated that extraversion is positively related to promotion regulatory focus, organizational commitment, and contextual performance. Therefore, in a team context, extraversion may be activated by the opportunities for social interaction and the possibility of exhibiting agency by ascending to a leadership position within the team.

Controlled laboratory research indicates that the social proclivities of extraverts translate to interpersonal behaviors and perceptions. Conducting an observational laboratory study with 87 undergraduate student dyads, Cuperman and Ickes (2009) found that extraversion was negatively
related to observer ratings of the use of first-person singular pronouns and self-report ratings of self-consciousness during the interaction, which they interpreted as an indication that, in social situations, the awareness of highly extraverted people tends to be directed outward, rather than inward. The researchers also found that extraversion was positively related to self-reports of taking the lead in the conversation, rating the interactions as feeling relaxed and natural, a belief that their partner would like to interact with them in the future, feeling comfortable with their partner, and a belief that their partner perceived them to be likable. These findings align with early psychological research regarding the activation of extraversion in social situations. For example, Campbell and Rushton's (1978) laboratory study, in which college students participated in videotaped group discussions, revealed that not only two different self-report measures of extraversion, the Eysenck Personality Inventory and the Cattell Personality Factor Questionnaire, but also teacher-report measures of the students’ extraversion were moderately positively related to speaking time.

Past research also suggests that highly extraverted people may have a predilection for expressing their opinions. Avery (2003) predicted that the opportunity to express one’s opinions would allow extraverts to not only express themselves but also to influence others. Using a cross-sectional design that controlled for gender, student classification, core self-evaluations, and the other Big Five traits, results revealed that extraversion positively predicted an individual’s value of voice. Unsurprisingly, Wolff and Kim (2012) discovered that extraverts also perceive themselves as being skilled networkers and enjoy establishing interpersonal connections with others.

When working in teams, highly extraverted people tend to engage in change-oriented communication, often referred to as voice (Chamberlin et al., 2017). For example, LePine and
Van Dyne (2001) conducted a laboratory team study with undergraduate students in which participants worked in teams on a computer-based decision-making simulation. Each team member was in their own cubicle and all communication took place via a computer messaging system which was text-based (no verbal communication was used). Voice behavior was operationalized as any messages sent from one teammate to another that consisted of constructive suggestions or of ideas about how to work more effectively. Results revealed that extraversion was moderately positively related to voice behavior and that the correlation between extraversion and voice behavior was significantly stronger than the relationship between extraversion and task performance. Moreover, Maynes and Podsakoff (2014) found that other-reports of extraversion, as rated by graduate students who were prompted to think of a co-worker, were positively related to supportive voice, which they defined as “the voluntary expression of support for worthwhile work-related policies, programs, objectives, procedures, and so on, or speaking out in defense of these same things when they are being unfairly criticized” (p. 92). Additionally, Liu et al.’s (2014) study of teams from an information technology corporation’s research and development department showed that, controlling for conscientiousness, neuroticism, and the amount of time working for their supervisor, an individual’s level of extraversion was positively related to their team supervisor’s evaluation of prohibitive voice, defined as an employee’s expression of concern about work practices that may be harmful to an organization.

Based on the findings above, the opportunity to work in a team activates extraversion such that highly extraverted teammates value opportunities to provide constructive suggestions and to engage with their teammates. In team meetings, these internal states will manifest as the
amount of time that individuals speak and will positively impact how they are perceived in the team. I, therefore, make the following hypotheses:

*Hypothesis 2:* Extraversion will be positively directly related to a) speaking time and b) peer ratings of teamwork competence and will c) be indirectly related to peer ratings of teamwork competence through its relationship with speaking time.

**Emotional Stability**

Emotional stability refers to a person’s propensity to be calm, self-confident, and composed whereas low emotional stability, often referred to as neuroticism, refers to tendencies toward being anxious, apprehensive, and insecure (Costa & McCrae, 1992). Additionally, emotional stability connotes much more than just the absence of anxiety and interpersonal apprehension. Specifically, a review by Barrick and Mount (2009) elucidated that emotional stability (along with conscientiousness) was the most consistent personality predictor of performance motivation, that highly emotionally stable individuals achieve high productivity and performance via self-regulation (e.g., emotional control, maintaining focus), and that highly emotionally stable people experience greater job satisfaction and organizational commitment. In relation to teamwork, Driskell et al. (2006) theorized that two aspects of emotional stability, adjustment and self-esteem, are especially relevant to working with others. According to the authors, adjustment refers to a general freedom from anxiety and tolerance of interpersonal stressors whereas self-esteem represents an individual’s sense of self-worth. Both these aspects of emotional stability come into play when an individual must work together with others in a team, which may result in what Bradley et al. (2013) describe as a “relaxed yet active approach” (p. 387).
Emotional stability may be activated in teams for several reasons. For example, when open-ended problems involving a high level of uncertainty need to be solved, this type of job demand could provide an opportunity for someone to exhibit calmness in the face of potentially stressful stimuli (Tett & Burnett, 2003). Additionally, interpersonal interaction during teamwork, in which people may need to navigate through conflict/discuss differing ideas, could also provide an opportunity for emotionally stability to be activated through conflict resolution and facilitation of conversation and collaboration (Bradley et al., 2013). High stress/high demand situations and adapting to change (something that project teams must deal with as they work on open-ended projects) may also activate emotional stability (Tett et al., 2021).

Findings from non-team-based research may provide additional insight as to how emotional stability manifests in interpersonal interactions in teams. Brinsfield (2013) surveyed employees at a manufacturing firm to gain insight as to the reasons why they might withhold information from their direct supervisor. Their results revealed that neuroticism had small positive relationships with deviant silence, a form of counterproductive work behavior represented by “the intentional withholding of important information” (p. 681), anddiffident silence, which refers to a person’s hesitancy to speak up due to internalized insecurities, self-doubt, or the fear of embarrassment. Additionally, a meta-analysis by Huang et al. (2014), which included 71 samples and which defined adaptive performance as “the proficiency with which an individual alters his or her behavior in response to the demands of a new task, event, situation, or environmental constraints” (p. 163) and the reactive component of adaptive performance as the handling of crisis situations or being flexible by adapting to different people, revealed a positive relationship between emotional stability and adaptive performance and, more specifically, a positive relationship between emotional stability and reactive performance. Moreover, a cross-
sectional study of real-world employees by Nikolaou et al. (2008) found that neuroticism (the negative end of emotional stability), negatively predicted the extent to which people speak up about important topics at work. Based on these findings, individuals who are highly emotionally stable may be willing to speak up about difficult topics and respond positively to the dynamic challenges inherent in teamwork.

Emotional stability thus may be activated in teams. For example, the previously described study by LePine and Van Dyne (2001) found that neuroticism had a small negative relationship with both cooperative behavior and voice behavior, suggesting that the opportunity for people to work together collaboratively and speak up with constructive input in team settings may activate emotional stability. Additionally, Porter et al.’s (2003) laboratory team study of undergraduate students working on a decision-making task revealed a significant interaction of perceived legitimacy of a recipients need for backup assistance and the backup provider’s level of emotional stability in predicting the demonstration backup behaviors (i.e., the extent to which a team member helps others perform their roles), such that team members who were high on emotional stability were more likely to come to the aid of their teammates who had legitimate needs, compared to those who were low on this trait. Furthermore, studying undergraduate business students over the course of a semester, Bradley et al. (2013) found that high levels of emotional stability in teams moderated the relationship between task conflict and team performance, assessed by instructors at the end of the semester, such that task conflict positively predicted team performance in teams that had high levels of emotional stability. Together, these findings suggest that the demands related to working in a team, which include adapting to difficult situations, helping others, and resolving conflict, are opportunities for emotional
stability to be expressed through communication which will, in turn, influence how a person is perceived by their teammates. Therefore, I make the following hypotheses:

_Hypothesis 3:_ Emotional Stability will be positively directly related to a) speaking time and b) peer ratings of teamwork competence and will c) be indirectly related to peer ratings of teamwork competence through its relationship with speaking time.

**Conscientiousness**

Highly conscientious individuals are aspirational, strive for achievement, and work diligently to achieve their goals (Costa & McCrae, 1992). In fact, according to a recent meta-analysis, conscientiousness is the strongest non-cognitive predictor of job performance (Wilmot & Ones, 2019). Although Judge and Zapata (2015) surmised that highly conscientious individuals are driven to accomplish their own goals, based on findings that conscientiousness predicted performance more strongly in jobs requiring independence, meta-analytic findings by Wilmot and Ones (2019) showing a positive relationship between conscientiousness and interpersonal citizenship behaviors, suggest that a persistent theme of conscientiousness includes a sense of responsibility for shared goals and that conscientiousness is “distinguished by reliable execution of socially prescribed interactions and willingness to collaborate with and lead others to accomplish collective ends” (p. 23007). As a result, the shared goals that are a part of teamwork, as well as opportunities to demonstrate diligence and achievement, may activate conscientiousness and, as a result, positively relate to the level of engagement exhibited in team interactions by highly conscientious individuals.

Due to their desires to attain high achievement, conscientious people may tend to be highly active in team meetings. For example, an observational study of software development teams conducted by Sonnentag (2001) revealed that team members in self-managed teams who
were identified as high performers not only demonstrated higher participation activity (operationalized via the average percentage of statements made during a meeting) overall, but that they also made more statements (marginally significant), most often about process regulation (e.g., goal setting, seeking feedback, problem solving) in unstructured (as opposed to structured) meetings, compared to lower performers. These differences were even stronger in teams in which the high performers were also the designated leaders. The results of this study suggest that high performance team members (who also tend to be highly conscientious) are likely to be highly active in team meetings, especially when they can regulate team processes and provide direction.

Additionally, people who cultivate high levels of task knowledge and skills, such as highly conscientious individuals, tend to contribute to a team’s essential processes. To explore this concept, Sonnentag and Volmer (2009) conducted a longitudinal study of real-world software development teams. Their correlational analysis showed that expertise (measured at Time 1), operationalized as supervisor-rated task knowledge and skills measured, was moderately positively correlated to peer-ratings of goal specification and problem analysis, which were collected one year after the expertise ratings (Time 2). Moreover, using hierarchical linear modeling, their results revealed that expertise significantly positively predicted both peer ratings of individual contributions to problems at Time and goal specification at Time 2, after controlling for gender, professional experience, position on the team, and Time 1 peer ratings. These findings further support the notion that the more an individual is invested in the success of the team, the more they will participate in the team’s processes. The sense of shared responsibility as well as the opportunity to produce high quality work will active conscientiousness such that highly conscientious individuals will actively participate in team
meetings and, consequently, be viewed as a competent team member by their peers. Therefore, I make the following hypotheses:

_Hypothesis 4:_ Conscientiousness will be positively directly related to a) speaking time and b) peer ratings of teamwork competence and will c) be indirectly related to peer ratings of teamwork competence through its relationship with speaking time.

**Psychological Safety, Teamwork Competence, and Speaking Time**

Beyond the trait-activating social and task demands of teamwork, trait activation theory also acknowledges that people’s perceptions of situations may exert main effects on behavior (Tett & Burnett, 2003). One such variable that is conducive to team performance by inducing individuals to engage in communicative behavior is team psychological safety, which represents the perception that a team is safe for taking various interpersonal risks, such as asking difficult questions, sharing knowledge, and admitting mistakes (Edmondson, 1999). Psychological safety positively relates to one’s motivation to share knowledge (Siemsen et al., 2009), and when team members feel psychologically safe, they are more willing to speak up about ways to improve team processes and are more likely to also express their concerns about existing practices, behaviors which increase a team’s overall effectiveness (Chamberlin et al., 2017).

Psychological safety can be examined at the individual, team, or organizational level. At the individual level, it is understood as individual perceptions of a group or an organization. At the team level, it is understood as _shared_ perceptions about the climate of a team. At the organization level, it refers to the overall climate of the organization. The latter two operationalizations of psychological safety are calculated by averaging individual ratings of the unit of interest (e.g., team, organization). This study, however, will assess individual perceptions of team psychological safety. Per Edmondson and Lei (2014), “the similarities in essential
findings across levels of analysis are striking” (p. 37). Psychological safety predicts learning and performance at all three levels of analysis. Additionally, the effect sizes of the antecedents and outcomes of psychology safety demonstrate identical homology across individual and group levels of analysis. For example, a comprehensive meta-analysis by Frazier et al. (2017) demonstrated that the impact of psychological safety on outcomes will be similar regardless of the level at which it is measured (e.g., individual perceptions vs. shared team perceptions). Using Chen et al.'s (2005) typology of homology theory, they found identical homology, meaning that the relationships across levels were identical in both magnitude and direction. Hence, these findings suggest that one may generalize inferences at the team level to that of the individual level (and vice versa).

Psychological safety in a team is essential for team learning and performance. Combining qualitative and quantitative approaches to develop and test the validity of a team psychological safety scale, Edmondson's (1999) seminal study built on past research regarding group learning (e.g., groups as information processing systems) to explore the relationship between psychological safety and team learning behaviors (e.g., seeking feedback, sharing information, asking for help, talking about error, experimentation) using a sample of 51 teams (sales, manufacturing, and staff services) in a manufacturing company. Results showed that team learning was positively related to team performance and that team psychological safety was positively related to self-reported and observer-rated team learning, even when controlling for the effects of team efficacy, context support, and team leader coaching. Moreover, team learning mediated the positive relationship between team psychological and team performance.

In addition to predicting team learning behaviors, psychological safety positively relates to one’s motivation to share their knowledge. For example, Siemsen et al. (2009) surveyed
employees from three different sectors (web services, aircraft manufacturing, food service) and discovered that psychological safety was positively related to a person’s motivation to share their knowledge with their co-workers. Their analyses additionally revealed a negative interaction effect between psychological safety and one’s confidence in their knowledge, indicating that psychological safety is especially important for knowledge sharing when individuals do not feel confident about their own knowledge. Furthermore, they found a significant positive quadratic effect for the relationship between psychological safety and motivation to share knowledge, indicating that high levels of psychological safety have an increasingly greater impact on one’s motivation to share knowledge. Research by Zhang et al. (2010) demonstrated a similar impact of psychological safety in virtual groups, such that psychological safety was positively related to one’s intention to continue sharing knowledge in their virtual group, and Brinsfield (2013) also discovered that employees who intentionally withheld important information at work tended to feel psychologically unsafe.

When considering learning as a social process that takes place through social interaction and conversational exchange between people (Kozlowski & Ilgen, 2006), assessing communication and interpersonal relationships in conjunction with psychological safety is key. For example, Schulte et al.’s (2012) study of real-world teams working in a federally-funded national service program demonstrated that individual perceptions of team psychological safety positively predicted the number of times someone went to a teammate for advice, as well as the extent to which they considered themselves to be friends with their teammates. Also, individuals who considered their team to have a low level of psychological safety also reported having more difficult relationships with their teammates. Carmeli et al.’s (2009) time-lagged study of individuals working in a variety of industries, on the other hand, revealed that perceptions of
high-quality relationships positively predicted perceptions of psychological safety at Time 2 (3 weeks later) and that psychological safety was positively related to learning behaviors. They also discovered that psychological safety partially mediated the relationship between high-quality relationships and learning behaviors.

Due to the interdependent, collaborative nature of teamwork, these findings suggest that psychological safety can facilitate team success by encouraging individuals to engage in communicative learning behaviors, which can leave a lasting impression on their peers by improving the team’s functioning and gaining social capital (van Emmerik et al., 2011). Therefore, I make the following hypotheses:

*Hypothesis 5:* Psychological safety will be positively directly related to a) speaking time and b) peer ratings of teamwork competence and will c) be indirectly related to peer ratings of teamwork competence through its relationship with speaking time.

**The Joint Effects of Personality and Psychological Safety**

Beyond the main effects of personality and individual perceptions (e.g., psychological safety), trait activation theory accounts for instances in which perceptions of a situation may reduce the salience of personality traits, which is referred to as a *constraint*. Elucidating this concept, Kamdar and Van Dyne (2007) analyzed field data from software engineers and found that self-rated perceptions of the quality of team member relationships and interactions (team member exchange) moderated the relationship between coworker-rated personality (conscientiousness and agreeableness) and coworker-rated helping coworkers such that the relationship was stronger when team member exchange was low and that the inclusion of interaction terms in their regression model increased the overall explained variance beyond the main effects. These findings suggest that the helping behaviors of highly agreeable and
conscientious individuals are less influenced by the quality of their relationships compared to employees low in those traits. In other words, people who are low in these traits may benefit more (e.g., begin to demonstrate these desirable behaviors) from high quality team member relationships.

Similar to the effects of team member exchange, past research also suggests that psychological safety, in particular, may constrain the effects of personality. Kuo et al. (2019) conducted a two-wave survey with employees at a fitness center and found that the interaction of proactive personality (a tendency to take initiative) and psychological safety (reported at Time 1) significantly predicted job satisfaction 3 months later and, more specifically, that proactive personality was positively related to job satisfaction when psychological safety in teams was low, rather than high. Based on these results, the authors concluded that psychological safety may act as a substitute for proactivity. Connecting these findings to trait activation, a psychologically unsafe environment may operate as a cue for people to express their proactivity whereas a psychologically safe environment may constrain that relationship.

Past research confirms that when people do not feel psychologically safe, they are more likely to withhold information because of insecurities and self-doubt, when they are afraid of the threats or risks to which they will be exposed if they speak up, or if they are afraid of harming interpersonal relationships (Brinsfield, 2013). Consequently, psychological safety is important to mitigate self-doubt, the fear of reprisal, and the fear of harming relationships with teammates. Indeed, the aforementioned studies by Zhang et al. (2010) and (Siemsen et al., 2009) found that self-consciousness was negatively related to psychological safety and that psychological safety is important for people who lack confidence, respectively. As such, the trait of emotional stability/neuroticism may be particularly relevant to psychological safety.
Albeit minimal, the research on the Big Five personality correlates of psychological safety suggests that emotional stability/neuroticism is of particular importance. For example, Edmondson and Mogelof (2006) collected longitudinal data (3 time points over the course of 6 weeks to 10 months) from teams in the real world from various industries (technology, chemicals/pharmaceuticals, consumer products) and found that, of all the Big Five traits, neuroticism was the only trait that was related to psychological safety, suggesting that people who are low in emotional stability may tend to see situations as psychologically unsafe and, therefore, may not feel comfortable fully engaging with their teammates right away. Specifically, self-reports of neuroticism were moderately negatively correlated with individual perceptions of team psychological safety across all time points. Additionally, using multivariate general linear modeling, they found that neuroticism (Time 1) negatively predicted psychological safety at Time 2 and Time 3. Despite acknowledging that most past research has suggested that personality is not relevant to psychological safety due to the assertion that social processes are the primary influencers of this psychological state, the authors conclude that people who are lower in emotional stability may benefit from environments that are psychologically safe, thereby feeling safe to express their ideas.

The notion that psychological safety is relevant to emotional stability/neuroticism is echoed by other researchers. Making the distinction between perceived impact (perceptions regarding the extent to which a someone can induce change in their environment), which is based on the behavioral activation system, and psychological safety, which is based in the behavioral inhibition system, Sherf et al.'s (2021) meta-analysis, for example, found that psychological safety exhibited a stronger relationship with the intentional withholding of information, also known as silence, than it did with perceived impact and that psychological safety explained 85%
of the variance in silence, whereas perceived impact explained only 11% of the variance. These findings, which were further supported by a follow-up survey-based study, demonstrate that psychological safety is more strongly related to silence (suppression of ideas and concerns) than to voice (expression of ideas and concerns) and that personality traits that predispose people to withholding information due to concerns about the risks associated with speaking up, such as neuroticism, may be more greatly impacted by psychological safety compared to other traits. Indeed, past research by LePine and Van Dyne (2001) showed that neuroticism had a small negative correlation with voice and cooperative behavior, and Judge & Zapata's (2015) findings that emotionally stable people thrive in jobs requiring social skills and dealing with unpleasant or angry people further suggest that people who are low in emotional stability may struggle to work in teams and speak up with constructive input in a team setting. Consequently, the activation of emotional stability in team meetings, expressed via speaking time, may be differentially impacted by perceptions of psychological safety. In other words, perceptions that a team is psychologically unsafe may activate emotional stability, resulting in increased participating in a team meeting and, ultimately, influencing the other team members. As such, people who are low in emotional stability may benefit more from a psychologically safe environment compared to those high in this trait. Therefore, I make the following hypothesis:

Hypothesis 6: Psychological safety will moderate the indirect relationship between emotional stability and peer ratings of teamwork competence, mediated by speaking time, such that the relationship will be stronger when psychological safety is low.

Method

The data used for this study were collected during the spring 2021 semester at Rice University as a part of a larger project. Prior to the start of the semester, instructors of courses in
which students participated in design projects (e.g., engineering, computer science) were
recruited based on previously established connections made by the research team and through
snowball sampling. Meetings were conducted with interested instructors to determine if their
student team had the following characteristics: self-managed leadership structure, project teams
working on complex and interdependent tasks, engaged in real-time social interaction, had at
least one common goal, and had a team size of approximately 3 to 6 team members. Teams were
engaging in authentic project-based learning, working with a client on a highly complex open-
ended design or analysis project, which was curated by an instructor (Beier et al., 2019).
Examples of these projects include engineering solutions for global health initiatives, innovative
medical products, and machine learning-based models for complex data analysis. Data were
collected via self- and peer-report surveys, as well as communication patterns extracted from
Zoom transcripts. In this study, Time 1 is the personality survey, which ranged from February
12, 2021 – March 24, 2021. Time 2 is the psychological safety survey, which took place between
March 24, 2021 – April 14, 2021. Time 3 is the period between the psychological safety survey
and the final peer evaluation survey. Time 4 is the administration of the final peer evaluation
survey, which took place between April 26, 2021 – May 6, 2021.

Procedure
At the start of the semester, the research team visited each class online to explain the
study and answer any questions. Students were told that they would receive a $10 gift card for
completing the first survey, which consisted of a consent form and attitude and demographic
questions. To move forward with the study, however, students were told that consent was
required from all team members. As part of informed consent, students were told that only
conversational patterns would be analyzed. Meeting content was not analyzed due to the
sensitive nature of the information discussed in the team meetings. For example, multiple teams were working with real-world organizations who required non-disclosure agreements prior to participation in the study. Teams were also given a set of instructions, which stated that they were to use the Zoom link for all naturally occurring team meetings (meetings in which only the student team members were in attendance).

Once consent was received from all team members, a unique Zoom link was sent to each team. This Zoom link ensured an automatic recording of audio and video content and Zoom produced a transcript for all recorded meetings. The consent form for the study is included in Appendix A, the recruitment flyer is included in Appendix B, and the participant Zoom instructions are included in Appendix C.

Throughout the semester, students were given the opportunity to respond to three surveys that included the CATME-B (Ohland et al., 2012), administered by the professor of each course, and the measure of psychological safety (Edmondson, 1999). Compensation was dependent on the completion of CATME-B surveys during the semester (initial survey plus all three CATME-Bs: $50; initial survey and one CATME-B: $10; initial survey and two CATME-Bs: $20; and an additional bonus for individuals who are on a team in which all team members complete all surveys: $25).

**Missing Data**

Upon completion of the data collection, a number of participants were excluded upfront. One person did not answer any of the personality questions. Additionally, six people had no speaking time data. One entire team had no speaking time data ($n = 5$) because they did not speak in English and, hence, there were no transcripts. Additionally, two individuals did not have any speaking time data because they did not attend any meetings. Thus, they were also removed.
At the team level, an inspection of the outliers in terms of meeting length were assessed. Subsequently, the final dataset for this study contained 110 individuals across 21 teams and 105 Zoom recordings.

After the initial data exclusion, a secondary data missingness assessment was conducted. Although the personality data were complete, 7% (8 participants) did not have cognitive ability data and 7% (8 participants) of the participants did not have psychological safety data. Although 6% (7 participants) did not respond to the CATME-B survey, there was no missing data for reputation scores, as they were calculated for each person based on the other teammates. In total, the dataset had 1.9% missingness (98.1% of the data were present).

Data were inspected for missingness patterns to determine if the data were missing completely at random (MCAR), which means that the missingness is unrelated to the missing data values, missing at random (MAR), which means that the missingness patterns in the data can be explained by other data points, or missing not at random (MNAR), which means that the missingness is related to the values of the missing data (Rubin, 1976). Little’s test (Little, 1988) determined that the data were not MCAR. Therefore, additional inspections were conducted to determine if the data were MAR or MNAR. In particular, the data were assessed for systematic patterns of missingness to determine if the missing data could be predicted by other information in the dataset (MCAR) or if the missingness was specifically related to the value of the missing data (e.g., a participant did not complete the psychological safety measure because they did not feel psychologically safe; MNAR). Based on these evaluations, it was determined that the data were most likely not MNAR. This assessment, combined with the acknowledgement that modern statistical procedures do “reasonably well in the face of moderate departures from MAR
assumptions” (Loehlin & Beaujean, 2017, p. 82) along with the relatively low percentage of missing data, the analyses were conducted under the assumption of MAR.

Participants

The average team size was 5 members ($SD = 1.7$), with the smallest team being 3 members and the largest team being 11 members. The distribution of gender was as follows: 44% of the participants identified as female and 56% identified as male. Approximately 11% of the students were in their first year of undergraduate studies, 4% were in their second year, 15% were in their third year, 59% were in their fourth year, and 11% were graduate students. Approximately 46% of the students reported their race as Asian, 28% White, 10% Latino, 4% Black, and 12% reported multiple racial identities. Student majors included engineering, humanities, natural sciences, social sciences, and undecided.

Measures

Personality

All personality variables were measured at Time 1 via 10 items rated on a scale of 1 (very inaccurate) to 5 (very accurate; Goldberg, 1992), with the following instructions: “Please use the rating scale provided to describe how accurately each statement describes you. Describe yourself as you generally are now, not as you wish to be in the future. Describe yourself as you honestly see yourself, in relation to other people you know of the same sex as you are, and roughly your same age.”

Extraversion. Sample from the extraversion scale include: “Feel comfortable around people” and “Start conversations” ($\alpha = .89$).

Emotional Stability. Sample items from the emotional stability scale include: “Relaxed most of the time” and “Seldom feel blue” ($\alpha = .86$).
Conscientiousness. Sample items from the conscientiousness scale include: “Always prepared” and “Pay attention to details” (α = .81).

Agreeableness. Sample items from the agreeableness scale include: “Interested in people” and “Sympathize with others’ feelings” (α = .77).

Openness. Sample items from the openness scale include: “Have a vivid imagination” and “Quick to understand ideas” (α = .78).

Psychological Safety

Psychological Safety was measured at Time 2 via seven items on a scale of 1 (very inaccurate) to 7 (very accurate) (Edmondson, 1999). Sample items include “Members of this team are able to bring up problems and tough issues” and “It is safe to take a risk on this team” (α = .70).

Speaking Time

Speaking time was calculated based on the average normalized speaking time of each individual team member (individual speaking time in proportion to the total meeting time). Individual speaking time, in proportion to total meeting time, was calculated for each individual between Time 2 and Time 4 and the average of these proportions was calculated. R (R Core Team, 2022) code was written to extract this information from the Zoom transcripts. Although the speaking time variable had a positive skew, neither the degree of skewness (1.6) nor the degree of kurtosis (3.83) indicated strong departures from normality (Kline, 2016). Additionally, when group-mean centered speaking time was regressed on the predictor variables, the residuals showed a high level of normality. Consequently, this variable was not transformed, in alignment with past research assessing speaking time (e.g., MacLaren et al., 2020; Nikoleizig et al., 2021; Sanchez-Cortes et al., 2013).
Peer Ratings of Teamwork Competence

The outcome variable of the study, peer perceptions of teamwork competence, measured at Time 4, was operationalized via the CATME-B (Ohland et al., 2012). This behaviorally anchored rating scale consists of five dimensions of teamwork (Keeping the Team on Track; Contributing to the Teams’ Work; Interacting with Teammates; Having Relevant Knowledge, Skills, and Abilities; Expecting Quality) rated on a scale of 1 (low) to 5 (high), for which each team member rated their other team members. To obtain a single measure for the peer ratings a person received from their teammates, a multi-item interrater agreement index ($r_{WG(J)}$; James et al., 1984; LeBreton & Senter, 2008) was assessed, in which a reliability score based on the five CATME-B items was calculated for each group of team members rating a teammate, revealing an average reliability score of .91 based on a uniform null distribution and .86 based on a slightly skewed distribution, suggesting a high level of interrater agreement (Newman & Sin, 2020). Moreover, tests of statistical significance were conducted based on the approach defined by Cohen et al. (2009) in which a 95th percentile critical value was calculated based on 5,000 simulations, revealing that both values were higher than the cutoff (.83), suggesting statistical significance. These findings, combined with a high level of internal consistency ($\alpha = .89$) for the five items, provided support for the aggregation of the five items into an overall measure of teamwork competence. Hence, a composite variable was calculated from these five items, which was then averaged for all raters and assigned to each individual ratee. Finally, although there were no hypotheses related to CATME-B self-ratings ($\alpha = .86$), this composite measure was included in the zero order correlations as an exploratory analysis.
Controls Variables

*Personality: Agreeableness and Openness*

Based on past research showing a positive relationship between agreeableness and teamwork behaviors (LePine & Van Dyne, 2001), agreeableness was entered as a control variable in the regression analysis in which the endogenous variable was teamwork competence. Additionally, openness was entered as a control variable in the regression in which the endogenous variable was speaking team but was not entered in the regression with teamwork competence as the endogenous variable, based on past research showing that highly open people may have tendencies to speak up in team meetings but may prefer to work autonomously (Kamdar & Van Dyne, 2007).

*Cognitive Ability*

Considering that cognitive ability is positively related not only to problem-solving skills (DeYoung et al., 2008) but also team performance (Devine & Philips, 2001), cognitive ability was used as a control variable in the analyses. In particular, participants’ self-reported ACT and SAT scores, which are shown to be strongly correlated with general mental ability (Koenig et al., 2008) were used to operationalize cognitive ability. Because some participants only took the SAT while others only took the ACT, all SAT scores were converted to ACT scores so that the scale for the ability measure were consistent (ACT, n.d.)

Data Analysis

*Multilevel Considerations*

Based on the clustered nature of the dataset (e.g., individuals nested within teams), preliminary analyses were conducted to determine if between-teams variance in the study variables should be accounted for in the hypothesis testing. To this end, multiple analyses were
conducted to assess the Intraclass Correlations (ICC1; Bartko, 1966) of the variables in the model. Additionally, an unconditional means model, which was a mixed effects model, was compared against a fixed effects model to determine if the reduction in error was statistically significant (Garson, 2019). The results showed that 6% of the variance in teamwork competence scores, ~1% of the variance in speaking time, and ~9% of the variance in psychological safety resided between groups. However, when compared against fixed effects null models, none of these ICC values showed a statistically significant reduction in model error (see Table 1 for a full list of the variables).

Moreover, although there is no absolute cutoff regarding the number of level 2 clusters needed to detect a cross-level interaction, past research provides some guidelines for making this determination. For example, Maas and Hox (2005) suggest that a level 2 sample size of 50 or fewer may result in biased estimates, whereas Kreft and De Leeuw (1998) noted that 20 groups of at least five individuals per group may be the lower limit for multilevel analysis. On the other hand, Mathieu et al. (2012) who's review found a median level 2 sample size of 51 in studies with cross-level interactions, suggest that that the power to detect a cross-level interaction may be not as straightforward and may be more dependent on the number of people in each group as opposed to the number of groups, thereby allowing for a smaller level 2 size. Hox et al. (2018) suggest a minimum of 50 groups with 20 individuals per group if cross-level interactions are of interest whereas McNeish and Kelley (2019) conclude that the general recommendation for a level 2 sample size is 30. Consequently, cluster-robust standard errors (McNeish et al., 2017), clustered at the team level, were used to account for potential heteroscedasticity and non-independence resulting from team membership. To test the hypothesized models, path analysis using the lavaan package in R (Rosseel, 2012) with full information maximum likelihood
(FIML) was used to account for missing data, based on the assumption that data are missing at random (Enders, 2022).

**Results**

**Descriptive Statistics and Correlations**

Table 2 displays descriptive statistics, correlations, and internal consistency reliabilities. Extraversion was positively related to speaking time \((r = .21, p < .05)\), but not significantly related to peer ratings of teamwork competence. Conscientiousness \((r = .24, p < .05)\) and psychological safety \((r = .33, p < .01)\) were positively related to peer ratings of teamwork competence, but not related to speaking time. Speaking time \((r = .40, p < .01)\) was positively related to peer ratings of teamwork competence. Additionally, although self-ratings of teamwork competence were not included in the hypotheses, the variable was included in the correlational analysis as an exploratory component. Extraversion \((r = .21, p < .05)\), speaking time \((r = .26, p < .01)\), and peer ratings of teamwork competence \((r = .26, p < .01)\) were positively related to self-ratings of teamwork competence. Although the effect sizes from the correlational analysis, based on Cohen's (1992) standards ranged from small to moderate (e.g., small: .1, moderate: .3, large: .5 or greater) recent research by Gignac and Szodorai (2016) shows that, for individual differences research, the heuristics for effect sizes may be different (e.g., small: .1, medium: .2, large: .3 or greater). Based on these updated standards for individual differences research, the effect sizes of the correlations ranged from moderate to large.

**Hypothesis Testing**

The initial path analysis, which contained all the main effects (excluding the interaction term), revealed the following significant paths. Speaking time was positively related teamwork competence \((\beta = .372, p = .005)\), supporting hypothesis 1. Extraversion was positively related to
saying time ($\beta = .187, p = .056$). Although this relationship was only significant ($p < .10$), the results show marginal support for hypothesis 2a. Finally, psychological safety was positively related to teamwork competence ($\beta = .312, p = .010$), supporting hypothesis 5b. Table 3 contains the parameter estimates of the model. This model (Figure 2) explained 10% of the variance in speaking time ($R^2 = .094$) and 30% of the variance in teamwork competence ($R^2 = .298$).

Additionally, percentile bootstrapped confidence intervals (MacKinnon et al., 2004) were calculated based on 10,000 draws, revealing no significant indirect effects (see Table 4).

Overall, the model fit indices suggested that the model demonstrated good fit. The model $\chi^2$ statistic ($\chi^2 = 2.469, DF = 2, p = .291$), CFI (0.980), RMSEA (0.043), SRMR (0.015) showed good fit (Hu & Bentler, 1999). Additionally, the Tucker Lewis Index (TLI; Tucker & Lewis, 1973) of 0.893 was just below Hu & Bentler’s (1999) cutoff of .90. However, considering that this index is prone to rejection in small sample sizes (Hu & Bentler, 1999), that it can be impacted by the degrees of freedom (Wang & Wang, 2020), and that it was very close to the cutoff, this index was not considered to be problematic.

To test hypothesis 6, which stated that psychological safety would moderate the indirect relationship between emotional stability and teamwork competence, via speaking time, a second model was analyzed which contained added an interaction term (psychological safety x emotional stability). A comparison of the two models, as shown in Table 5, showed that the reduced model (the model without the interaction) was the better-fitting model (AIC of reduced model = 1325.369; AIC of model with the interaction = 1407.162), and the interaction term was not statistically significant (see Appendix D for the regression results). Together, these findings fail to support hypothesis 6.
Although an a priori power analysis was not conducted for this study, the discussion of power is warranted. Indeed, multiple approaches to determining power for structural equation modeling and path analysis exist, with “rules of thumb” including minimum sample sizes of 200, 5-10 individuals per parameter estimated, and 3-6 individuals per variable, etc. (Wang & Rhemtulla, 2021). Therefore, based on some of these standards, this study may have been underpowered. As such, the Type II error may have been inflated, such that parameter estimates that exist in the population were not detected by this analysis. That said, the model fit indices suggested good fit, even though Shi et al. (2019) demonstrated that the CFI, TLI, and RMSE model fit indices tend to show worse fit in small sample sizes. Even if this model did suffer from a lack of power, it must be noted that statistically significant paths were detected, suggesting a robust effect for each of these variables (the effect of both psychological safety and speaking time on peer perceptions of teamwork competence and the marginally significant effect of extraversion on speaking time). Moreover, as previously discussed, this study was likely underpowered to detect any level 2 effects (e.g., the effect of team membership). Therefore, future research may build on these findings by recruiting larger sample sizes at both the individual and team level.

**Exploratory Analyses**

**Change Over Time**

In this section, three focal variables in the study, psychological safety, speaking time, and peer perceptions of teamwork competence will be assessed for patterns of growth throughout the semester. For the analyses of psychological safety and peer perceptions of teamwork competence, Time 1, Time 2, and Time 3 will represent the different time points at which these variables were collected, which correspond roughly with the beginning, middle, and end of the
semester. However, the time points referenced in the speaking time analyses correspond with the weeks in the semester (e.g., week 9, week 11, week 12, week 14, week 14).

**Psychological Safety.** According to Tuckman's (1965) model of team development, teams tend to go through stages of development, including: forming, storming, norming, and performing. Forming refers to the process of coming together as a team, storming refers to a phase in which individuals may clash as they seek to understand how to best work together, norming represents a phase in which team members develop a shared understanding of group processes and performing refers to a state in which the team is optimally functioning, working toward a common goal. Such a process overall suggests a linear pattern of team development over time. Although examined as a predictor variable in the main analyses, psychological safety will now be explored as a dependent variable. Therefore, the individual trajectories of perceptions of team psychological safety were examined. To explore this subject further, a multilevel longitudinal analysis was conducted, based on the following research questions:

*Research Question 1:* Does psychological safety change over time?

*Research Question 2:* If psychological safety does, in fact, change over time, how do individual differences relate to this change?

Of the 110 participants in the dataset, 96 had complete psychological safety data at all three time points. After removing individuals who had the same exact score across all time points \((n = 12)\), the final dataset contained 84 individuals with three matched responses across the semester. A portion of the individual trajectories are shown in Figure 3 and the means, standard deviations, and zero-order correlations of psychological safety at all three time points are displayed in Table 6. Based on a visual inspection, it appeared that there may be both intercept and slope differences among individuals. Considering the theoretical and empirical relationship
to psychological safety (Edmondson & Mogelof, 2006; Frazier et al., 2017), emotional stability was chosen as the predictor of psychological safety. To explore these dynamics, a multi-step model comparison approach (Bliese & Ployhart, 2002) was conducted.

The first step involved an examination of the dependent variable, psychological safety. Specifically, a null model was estimated to determine the extent to which the variance in psychological safety is related to the nested structure of the data (ICC). The ICC for individuals was .61, indicating that 61% of the variance in psychological safety is explained by individuals. Additionally, considering that the data were nested multiple ways (e.g., individuals and teams), a model comparison was conducted that compared a mixed effects model, which only included individuals as a random effect, to a mixed effects model, which included both individuals and teams as a random effect. Based on the non-significant result of this test ($\chi^2$ difference $= 0.202, p = .654$), it was concluded that a 2-level growth analysis (e.g., level 1 = time, level 2 = individual) would be conducted.

The second step modeled time. In particular, a mixed effects model assessing the fixed relationship between time and psychological safety, in which individuals were included as a random effect, was assessed. Due to the exploratory nature of these analyses, both a linear and a quadratic effect were tested. An examination of the fixed effects indicated that the average level of psychological safety at Time 1 was 6.20 and that there was a marginally significant linear relationship between time and psychological safety, such that psychological safety decreases by .06 each time period ($B = -0.06, p = .059$). The quadratic trend was not statistically significant ($B = -0.39, p = .305$).

The third step modeled slope variability. A limitation of the previous model was that it assumed a constant relationship between time and psychological safety for all participants (e.g.,
each individual’s psychological safety decreases by .06 at each time point). Therefore, an alternative model, which allowed the slopes to vary, was assessed. Based on the significant result of this test (Log Likelihood Ratio = 14.060, \( p < .001 \)), it was concluded that the model that allowed the slopes between time and psychological safety to vary fit the data significantly better than the previous model, which fixed the slopes for all individual participants.

The fourth step involved the modeling of error structures, namely, autoregressive structure with serial correlations and heterogeneity of the error structures. This step is important because the significance tests may be impacted if the structure of the errors is not specified properly. A model that allowed for autocorrelation did not fit the data better than the model that did not assume autocorrelation (Log Likelihood Ratio = 2.569, \( p = .109 \)). However, a model that accounted for the heterogeneity of the error structures did, in fact, fit the data better than the model that did not account for it (Log Likelihood Ratio = 4.292, \( p = .038 \)). Hence, the model that allows for heterogeneity in the error structures was used in the subsequent steps.

The fifth step involved an examination of the factors that may explain the variation in the intercepts among individuals (e.g., what factors explain why some participants have a high level of psychological safety whereas other individuals do not feel psychologically safe). The Big Five (Goldberg, 1992) personality variable of emotional stability was used as a predictor of the psychological safety intercept in this model. The results suggested that emotional stability was not related to initial levels of psychological safety (\( B = .087, p = .315 \)).

Moving beyond intercept variability, the final step assessed the extent to which emotional stability was related to slope variability among participants (the time-psychological safety slope). In this model, an interaction term of time x psychological safety was added to the model. The interaction between time and psychological safety was marginally significant (\( B = .096, p = \ldots \))
As such, the interaction was probed, based on high (+1 SD) and low (-1 SD) levels of psychological safety. Figure 4 shows that people who are high in emotional stability tend to maintain high levels of psychological safety over the course of a semester. However, although there were not statically significant intercept differences, it appears that people who are low in emotional stability tend to experience decreases in psychological safety over the course of time (these effects are marginally significant at the $p < .10$ level).

**Speaking Time.** The extent to which a person speaks in team meetings has been shown to be positively related to leadership emergence (MacLaren et al., 2020), suggesting that the more a person verbally participates in team meetings, the more likely other team members are to defer to that individual. As such, being highly active in the initial phases of a team’s development may result in increasingly levels of responsibility and leadership, such that the verbal participation of a leader in team meetings may increase over time. Therefore, the individual trajectories of speaking time were examined. To explore this subject further, a multilevel longitudinal analysis was conducted, based on the following research questions:

*Research Question 3:* Does speaking time change over time?

*Research Question 4:* If speaking time does, in fact, change over time, how do individual differences relate to this change?

All 110 participants in the dataset were initially included in the following analysis. However, the speaking time data across the semester were relatively unstructured. For example, date on which teams began recording their meetings via the Zoom link provided varied, due to the fact that participation in the study was contingent upon all team members consenting to participated. Additionally, as there were no requirements regarding the regularity or frequency of the meetings, the meeting participation varied greatly across individuals. Moreover, there were
multiple instances in which teams met more than once on a single day. To account for the
unstructured nature of the data, the following steps were taken. For any individual who attended
more than one meeting on a given day, a single day speaking time number was calculated (e.g.,
the proportion of time that an individual spoke in relation to each meeting time was averaged
across all meetings on a given day).

Accounting for all the days/weeks in the semester, approximately 45% of the data were
missing, because the naturally occurring meetings did not follow a prescribed schedule (see
Figure 5). Therefore, considering that the last date on which a team received a zoom link was 03-
24-2021, which corresponded with the ninth week of the semester, this week was used as Time 1
in the following analyses. Additionally, considering that most classes ended by the 05-02-2021,
which corresponded with the 14th week of the semester, this week was used as the final time
point. Finally, no teams met during the 10th week of the semester. Therefore, the following
analyses assess changes over time across five time points: week 9, week 11, week 12, week 13,
and week 14. Based on these time points, 3 of the 110 participants only had speaking time data at
one time point and were, thus, excluded from the analyses, resulting in a sample size of 107. The
individual trajectories are shown in Figure 6 and Table 7 contains the descriptive statistics and
zero-order correlations of speaking time across these five time points. Considering the theoretical
and empirical relationship to speaking time (Lepri et al., 2012) and leadership (Wilmot et al.,
2019), extraversion was chosen as the predictor of speaking time. To explore these dynamics, a
multi-step model comparison approach (Bliese & Ployhart, 2002) was conducted.

The first step involved an examination of the dependent variable, speaking time.
Specifically, a null model was estimated to determine the extent to which the variance in
speaking time is related to the nested structure of the data (ICC). The ICC for individuals was
.56, indicating that 56% of the variance in speaking time is explained by individuals.

Additionally, considering that the data were nested multiple ways (e.g., individuals and teams), a model comparison was conducted that compared a mixed effects model, which only included individuals as a random effect, to a mixed effects model, which included both individuals and teams as a random effect. Based on the non-significant result of this test ($\chi^2$ difference = 0.000, $p$ = 1.00), it was concluded that a 2-level growth analysis (e.g., level 1 = time, level 2 = individual) would be conducted.

The second step modeled time. In particular, a mixed effects model assessing the fixed relationship between time and speaking time, in which individuals were included as a random effect, was assessed. Due to the exploratory nature of these analyses, both a linear and a quadratic effect were tested. An examination of the fixed effects indicated that the average level of speaking time at Time 1 was .10 (the proportion of the meeting time a person spoke) and that there was a neither a significant linear relationship between time and speaking time ($B = -0.000$, $p = .706$), nor a significant quadratic trend ($B = -0.037$, $p = .540$). Because the analyses failed show a trend over time, these analyses did not progress beyond this point.

**Peer Perceptions of Teamwork Competence.** A team member who is invested in the success of a team will have a desire to make increasingly meaningful contributions toward collective goals over time, especially as the end of a team project approaches (Larson et al., 2020). Indeed, team process theories suggest that engagement in team activities may increase over time (Marks et al., 2001). Moreover, Gersick's (1988) theory of punctuated equilibrium suggests that team activities increase both at the midpoint of a team project as well as toward the end of a project. Therefore, the individual trajectories of peer ratings of teamwork competence
were examined. To explore this subject further, a multilevel longitudinal analysis was conducted, based on the following research questions:

Research Question 5: Do peer perceptions of teamwork competence change over time?

Research Question 6: If peer perceptions of teamwork competence do, in fact, change over time, how do individual differences relate to this change?

All 110 participants had peer ratings at all three time points. The individual trajectories are shown in Figure 8 and the descriptive statistics, and zero order correlations can be found in Table 8. Based on a visual inspection, it appeared that there may be both intercept and slope differences among individuals. Considering the theoretical and empirical relationship to teamwork (Sonnentag & Volmer, 2009), conscientiousness was chosen as the predictor of peer ratings of teamwork competence. To explore these dynamics, a multi-step model comparison approach (Bliese & Ployhart, 2002) was conducted.

The first step involved an examination of the dependent variable, peer perceptions of teamwork competence. Specifically, a null model was estimated to determine the extent to which the variance in speaking time is related to the nested structure of the data (ICC). The ICC for individuals was .75, indicating that 75% of the variance in peer perceptions of teamwork competence is explained by individuals. Additionally, considering that the data were nested multiple ways (e.g., individuals and teams), a model comparison was conducted that compared a mixed effects model, which only included individuals as a random effect, to a mixed effects model, which included both individuals and teams as a random effect. Based on the significant result of this test ($\chi^2$ difference = 4.464, $p = .035$), it was concluded that a growth analysis including random effects for both individual and time would be conducted.
The second step modeled time. In particular, a mixed effects model assessing the fixed relationship between time and peer perceptions of teamwork competence, in which individuals and teams were included as a random effect, was assessed. Due to the exploratory nature of these analyses, both a linear and a quadratic effect were tested. An examination of the fixed effects indicated that the average level of peer perceptions of teamwork competence at Time 1 was 4.27 (rated on a scale of 1 to 5) and that there was a neither a significant linear relationship between time and speaking time ($B = -0.01$, $p = .610$), nor a significant quadratic trend ($B = 0.15$, $p = .551$). Because the analyses failed show a trend over time, these analyses did not progress beyond this point.

**Discussion**

By taking advantage of the rise in virtual teamwork, this study revealed the importance of objectively measured individual behaviors as well as subjective perceptions of psychological safety in virtual teams. The results showed that both individual psychological safety and speaking time positively predicted peer perceptions of teamwork competence, as rated by other teammates. These findings are particularly impactful in a world in which workplaces are increasingly embracing teamwork, and nearly 60% of employees who have the option to work remotely choose to do so (Parker et al., 2022), which has implications for the long-term success of virtual teams.

Complementing past research on personality in teams (Bell et al., 2018), this study showed that individual perceptions of team psychological safety were directly related to peer perceptions of teamwork competence. However important a team’s personality composition, these findings suggest that psychological safety is an important driver of perceptions of competence in teams. Organizations should, therefore, invest in team psychological safety
initiatives, regardless of the overall team-level disposition. Indeed, the cultivation of psychological safety in a virtual environment is relatively unexplored, but researchers have suggested that organizations who employ virtual teams may foster both psychological safety and a sense of inclusion by taking steps such as allocating time for each team member express their thoughts, cultivating a better understanding of the personal challenges team members are facing, and seeking to develop deeper connections via the existing technological platforms being used for teamwork (Feitosa & Salas, 2021). Such efforts may not only enhance team member's sense of connection and safety but, as this study shows, may also positively impact the way they are perceived by their teammates.

This study demonstrated the importance of speaking time in virtual team meetings, which also positively predicted peer perceptions of teamwork competence. Clearly, the amount of time a person speaks, in relation to the overall meeting time, can leave lasting positive impression on their teammates. As advancements in behavior tracking increase, however, organizations must thoughtfully interpret and respond to the data generated from such methods (Gavett, 2016). For example, simply advising a non-talkative person to talk more during team meetings is likely an insufficient response to such behavioral data. Instead, behavioral patterns assessed in team meetings can inform organizations as to how they can improve individual perceptions of team psychological safety via strategic interventions. Objectively measured behavior, therefore, may best be used as a diagnostic tool rather than an evaluative one.

Additionally, the marginally significant positive relationship between extraversion and speaking time suggests that virtual team meetings may activate the behavioral tendencies associated with extraversion. The understanding that some people may be predisposed to
speaking up in team settings more than others can help organizations strategically staff teams and provide more context for evaluating interpersonal teamwork behaviors.

Finally, the exploratory analyses showed the people who are low in emotional stability may tend to experience decreases in psychological safety over time. However, this linear effect was only marginally significant. Nonetheless, these findings shed light on the connection between individual differences and psychological safety and indicate that people with certain dispositional tendencies may potentially benefit more, over time, from organizational practices that foster a sense of psychological safety. The additional exploratory analyses failed to detect either linear or quadratic effects of speaking time and peer perceptions of teamwork competence over time.

**Limitations and Future Directions**

Despite the significant relationships found in this study, the limitations of this research should be noted. For example, the sample was relatively small and limited to students. Although the sample size may limit the analysis of team-level phenomenon, the sample did, in fact, permit examination of individual-level relationships of interest. By recruiting larger sample sizes (both at the individual and the team level), future research may assess team-level phenomenon as well as individual-level, answering calls for more research on cross-level effects in teams research (Newman et al., 2017). Additionally, it must be noted that the participants in the study consisted of student teams working together within the context of a structured educational program. As such, the generalizability of these findings to real-world teams may be limited. However, because students were working on relatively complex open-ended engineering problems (often with an industry partner) over a relatively long period (i.e., over the course of a semester), I
contend that the sample is, perhaps, more reflective of teams working within organizations than would be shorter-term teams working on circumscribed tasks in a laboratory setting.

Remote engagement via Zoom (i.e., computer-mediated communication) may also have limited the expression of personality traits in this study (e.g., media richness theory; Daft & Lengel, 1986). Although video conferencing technology may be a “richer” form of communication compared to emails or phone calls, it may still be limited in its capacity to convey important non-verbal, physical cues, compared to face-to-face interactions. For example, Zoom may limit the extent to which non-verbal dynamics such as prosody, backchannelling, facial expressions, and other bodily movements may be expressed and observed, thereby inhibiting the trait activating potential of such behaviors. However, it is likely that – with the ubiquity of remote work due to the pandemic – teams will be increasingly interacting via computer-mediated methods.

Furthermore, the extent to which speaking time influenced peer perceptions of teamwork competence should be considered. Indeed, the results showed that individual perceptions of psychological safety directly impacted peer perceptions and that this relationship was not mediated via speaking time. As such, the mechanism whereby psychological positively impacts peer perceptions should be explored. It may be that the content of one’s speech may also have an impact on the way a person is perceived by their teammates. For example, people who feel psychologically safe may ask the tough, important questions, improve team outcomes by voicing their opinions, or help to facilitate accountability by acknowledging when they’ve made mistakes. Although I was not able to analyze content in this study due to concerns about confidentiality, future research may build on these findings by conducting content analyses in conjunction with behavioral assessments. Other channels through which psychologically safe
individuals communicate should also be considered. Although we were not able to analyze such channels in this study, future research may provide additional insight by assessing behaviors such as email communication frequency and informal messaging (e.g., Microsoft Teams, Slack).

Although speaking time emerged as a significant indicator of peer-rated teamwork competence, it must also be noted that speaking time in teams may not always have a positive linear effect on team outcomes. For example, some high performing teams may actually engage in more implicit coordination vs. explicit coordination (Cannon-Bowers & Salas, 2001), such that speaking time may not be relevant in such teams. That said, the sharing and processing of tacit (compared to explicit) knowledge, occurs through social interactions, thereby underscoring the importance of verbal communication in the development of shared mental models (Curşeu et al., 2008). Further, the lack of opportunities for informal interactions in virtual teams compared to in-person teams underscores the importance of explicit communication during virtual team meetings, which can serve as a vehicle for the development of implicit coordination (Rico et al., 2008), a subject that has greatly increased in relevance since the onset of the COVID-19 pandemic (Whillans et al., 2021). Moreover, the types of task dependence (e.g., pooled, sequential, reciprocal) may also have implications for the relative importance of communication and coordination in virtual teams (Sutanto et al., 2011).

Additionally, although peer reviews, the outcome variable in this study, are an important source of information and are projected to be increasingly used in the workplace (Fiore & Souza, 2021), it should be noted that this study did not assess objective performance outcomes. Indeed, although a person is perceived to be competent by their teammates, such perceptions could also be matched to objective contributions to the team’s success. Consequently, future research should assess peer perceptions in conjunction with objective performance indicators. Finally, the
teams in this study were limited to leaderless, self-managed teams. Although such teams are increasingly used in organizations today (Schumann, 2019), many organizations still rely on role-based, hierarchical structures, which may limit the extent to which individual differences manifest as behavior in team meetings. Therefore, future research can build on these findings by examining the role of personality and psychological safety in various types of teams.

**Conclusion**

Based on these findings, psychological safety and speaking time are important factors in teams. These insights provide educators and employers with helpful information regarding peer assessments. This study answers multiple calls for research on unobtrusive, real-time methods for assessing team processes and the interaction of personality and psychological safety. Additionally, the time-lagged data collection allowed addressed concerns related to common method bias, which have been raised in past research (Newman et al., 2017). Finally, the novel use of unobtrusive methods for studying teams is a unique contribution to the field of team research.
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Table 1

*Intraclass Correlation Coefficients and Null Model Tests of Significance*

<table>
<thead>
<tr>
<th>Variable</th>
<th>ICC(1)</th>
<th>Log Likelihood Ratio</th>
<th>Significance Level (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teamwork Competence</td>
<td>.06</td>
<td>1.87</td>
<td>.17</td>
</tr>
<tr>
<td>Speaking Time</td>
<td>.01</td>
<td>0.01</td>
<td>.91</td>
</tr>
<tr>
<td>Psychological Safety</td>
<td>.09</td>
<td>1.12</td>
<td>.29</td>
</tr>
<tr>
<td>Extraversion</td>
<td>.00</td>
<td>0.00</td>
<td>.99</td>
</tr>
<tr>
<td>Emotional Stability</td>
<td>.07</td>
<td>1.27</td>
<td>.26</td>
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<tr>
<td>Conscientiousness</td>
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<td>2.50</td>
<td>.11</td>
</tr>
<tr>
<td>Agreeableness</td>
<td>.06</td>
<td>0.81</td>
<td>.37</td>
</tr>
<tr>
<td>Openness</td>
<td>.00</td>
<td>0.00</td>
<td>.99</td>
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</tbody>
</table>

*Note. N = 110 individuals, 21 teams. ICC refers to the Intra Class Correlation. The Log Likelihood Ratio refers to the test of statistical significance in the reduction of error between a fixed effects null model and a random effects null model.*
### Table 2

**Means, Standard Deviations, and Correlations with Confidence Intervals**

<table>
<thead>
<tr>
<th>Variable</th>
<th>$M$</th>
<th>$SD$</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<th>7</th>
<th>8</th>
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<th>10</th>
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</thead>
<tbody>
<tr>
<td>1. Extraversion T1</td>
<td>3.04</td>
<td>0.67</td>
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<tr>
<td>2. Conscientiousness T1</td>
<td>3.52</td>
<td>0.55</td>
<td>-0.06</td>
<td>(0.81)</td>
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<td>[-.25, .13]</td>
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<tr>
<td>3. Emotional Stability T1</td>
<td>3.25</td>
<td>0.66</td>
<td>0.27**</td>
<td>0.05</td>
<td>(0.86)</td>
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<td>[.08, .43] [-.14, .23]</td>
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<tr>
<td>4. Agreeableness T1</td>
<td>3.93</td>
<td>0.42</td>
<td>0.22*</td>
<td>0.19</td>
<td>0.05</td>
<td>(0.77)</td>
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<td>[.04, .39] [-.00, .36] [-.13, .24]</td>
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<tr>
<td>5. Openness T1</td>
<td>3.59</td>
<td>0.48</td>
<td>0.36**</td>
<td>0.11</td>
<td>0.25**</td>
<td>0.28**</td>
<td>(0.78)</td>
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<td>[.19, .52] [-.08, .29] [.07, .42] [.10, .45]</td>
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<tr>
<td>6. Cognitive Ability T1</td>
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<td>4.35</td>
<td>0.11</td>
<td>0.06</td>
<td>0.07</td>
<td>0.05</td>
<td>0.08</td>
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<td>[-.08, .30] [-.13, .26] [-.13, .26] [-.24, .15] [-.12, .27]</td>
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<tr>
<td>7. Psychological Safety T2</td>
<td>6.21</td>
<td>0.56</td>
<td>0.16</td>
<td>0.23*</td>
<td>0.07</td>
<td>0.17</td>
<td>0.10</td>
<td>0.07</td>
<td>(0.70)</td>
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<td>[-.04, .34] [.04, .41] [-.12, .26] [-.03, .35] [-.10, .29] [-.13, .27]</td>
</tr>
<tr>
<td>8. Speaking Time T3</td>
<td>0.10</td>
<td>0.08</td>
<td>0.21*</td>
<td>0.07</td>
<td>0.04</td>
<td>0.16</td>
<td>0.20*</td>
<td>0.03</td>
<td>0.15</td>
<td></td>
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</tr>
<tr>
<td>9. Teamwork Competence T4 (Peer-Rated)</td>
<td>4.26</td>
<td>0.46</td>
<td>0.01</td>
<td>0.24*</td>
<td>0.04</td>
<td>0.12</td>
<td>-0.01</td>
<td>0.02</td>
<td>0.33**</td>
<td>0.40**</td>
<td>(0.89)</td>
<td></td>
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<tr>
<td>10. Teamwork Competence T4 (Self-Rated)</td>
<td>4.32</td>
<td>0.50</td>
<td>0.21*</td>
<td>-0.06</td>
<td>0.10</td>
<td>0.18</td>
<td>0.07</td>
<td>0.05</td>
<td>0.13</td>
<td>0.26**</td>
<td>0.26**</td>
<td>(0.86)</td>
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</tbody>
</table>

*Note.* $N = 110$ individuals, 21 teams. $M$ and $SD$ are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. * indicates $p < .05$. ** indicates $p < .01$. Cronbach’s alpha is listed on the diagonal.
Table 3

Path Analysis Regression Results

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Speaking Time</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Teamwork Competence</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>SE</td>
<td>β</td>
<td>p</td>
<td>Fit</td>
<td>B</td>
<td>SE</td>
<td>β</td>
<td>p</td>
<td>Fit</td>
<td>B</td>
<td>SE</td>
<td>β</td>
<td>p</td>
<td>Fit</td>
</tr>
<tr>
<td>Emotional Stability</td>
<td>-0.018</td>
<td>0.013</td>
<td>-0.144</td>
<td>.170</td>
<td>0.035</td>
<td>0.042</td>
<td>0.049</td>
<td>.416</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Psychological Safety</td>
<td>0.014</td>
<td>0.012</td>
<td>0.098</td>
<td>.251</td>
<td>0.251</td>
<td>0.098</td>
<td>0.312</td>
<td>.010</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extraversion</td>
<td>0.023</td>
<td>0.012</td>
<td>0.187</td>
<td>.056</td>
<td>-0.078</td>
<td>0.056</td>
<td>-0.114</td>
<td>.164</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conscientiousness</td>
<td>0.008</td>
<td>0.014</td>
<td>0.053</td>
<td>.575</td>
<td>0.106</td>
<td>0.066</td>
<td>0.127</td>
<td>.109</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Agreeableness</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>0.064</td>
<td>0.011</td>
<td>.853</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Openness</td>
<td>0.027</td>
<td>0.014</td>
<td>0.156</td>
<td>.058</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cognitive Ability</td>
<td>0.000</td>
<td>0.006</td>
<td>-0.004</td>
<td>.969</td>
<td>-0.003</td>
<td>0.032</td>
<td>-0.010</td>
<td>.916</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speaking Time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.049</td>
<td>0.722</td>
<td>0.372</td>
<td>.002</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

R² = .094

Note. N = 110 individuals, 21 teams. Cluster-robust standard errors were used to account for the nested nature of the dataset (individuals nested within teams).
Table 4

*Indirect Effects on Teamwork Competence, via Speaking Time*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>SE</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Psychological Safety</td>
<td>0.029</td>
<td>0.023</td>
<td>-0.045, 0.091</td>
</tr>
<tr>
<td>Emotional Stability</td>
<td>-0.038</td>
<td>0.023</td>
<td>-0.085, 0.006</td>
</tr>
<tr>
<td>Extraversion</td>
<td>0.047</td>
<td>0.034</td>
<td>-0.004, 0.125</td>
</tr>
<tr>
<td>Conscientiousness</td>
<td>0.016</td>
<td>0.030</td>
<td>-0.041, 0.087</td>
</tr>
</tbody>
</table>

*Note. N = 110 individuals, 21 teams. 95% confidence intervals are based on 10,000 bootstrapped samples.*
Table 5

Model Comparison: Full Model with No Interaction, Full Model with an Interaction

<table>
<thead>
<tr>
<th>Model</th>
<th>$\chi^2$</th>
<th>SRMR</th>
<th>CFI</th>
<th>TLI</th>
<th>RMSEA</th>
<th>AIC</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>$p$ value</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>df</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full Model:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Interaction</td>
<td>2.469</td>
<td>.291</td>
<td>2</td>
<td>.015</td>
<td>.986</td>
<td>.043</td>
</tr>
<tr>
<td>Full Model:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With Interaction</td>
<td>5.567</td>
<td>.135</td>
<td>3</td>
<td>.024</td>
<td>.922</td>
<td>.057</td>
</tr>
</tbody>
</table>

*Note. N = 110 individuals, 21 teams. The Yuan-Bentler correction was used for the chi-square test statistic. Robust CFI, TLI, and RMSEA are reported.*
Table 6

Means, Standard Deviations, and Correlations with Confidence Intervals for Psychological Safety

<table>
<thead>
<tr>
<th>Variable</th>
<th>$M$</th>
<th>$SD$</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Psychological Safety T1</td>
<td>6.19</td>
<td>0.57</td>
<td>(.66)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Psychological Safety T2</td>
<td>6.21</td>
<td>0.56</td>
<td>.60**</td>
<td>(.70)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>[.46, .71]</td>
<td></td>
</tr>
<tr>
<td>3. Psychological Safety T3</td>
<td>6.11</td>
<td>0.68</td>
<td>.62**</td>
<td>.77**</td>
<td>(.73)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>[.49, .73]</td>
<td>[.68, .84]</td>
</tr>
</tbody>
</table>

Note. $N = 84$ individuals, 21 teams. $M$ and $SD$ are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation.

* indicates $p < .05$. ** indicates $p < .01$. Cronbach’s alpha is listed on the diagonal.
### Table 7

**Means, Standard Deviations, and Correlations with Confidence Intervals of Speaking Time**

<table>
<thead>
<tr>
<th>Variable</th>
<th>M</th>
<th>SD</th>
<th>1</th>
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<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Speaking Time Week 9</td>
<td>0.10</td>
<td>0.08</td>
<td>0.10</td>
<td>0.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Speaking Time Week 11</td>
<td>0.10</td>
<td>0.09</td>
<td>.55**</td>
<td>[.31,.72]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Speaking Time Week 12</td>
<td>0.09</td>
<td>0.08</td>
<td>.63**</td>
<td>.63**</td>
<td>[.44,.76]</td>
<td>[.48,.75]</td>
</tr>
<tr>
<td>4. Speaking Time Week 13</td>
<td>0.11</td>
<td>0.10</td>
<td>.50**</td>
<td>.46**</td>
<td>.46**</td>
<td>[.27,.61]</td>
</tr>
<tr>
<td>5. Speaking Time Week 14</td>
<td>0.09</td>
<td>0.08</td>
<td>.71**</td>
<td>.51**</td>
<td>.51**</td>
<td>.62**</td>
</tr>
</tbody>
</table>

*Note.* $N = 107$ individuals, 21 teams. Speaking time was measured as the proportion of the meeting time that an individual spoke. $M$ and $SD$ are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. * indicates $p < .05$. ** indicates $p < .01$.  

Table 8

Means, Standard Deviations, and Correlations with Confidence Intervals for Peer Perceptions of Teamwork Competence

<table>
<thead>
<tr>
<th>Variable</th>
<th>M</th>
<th>SD</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Teamwork Competence T1</td>
<td>4.27</td>
<td>0.37</td>
<td>(.85)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Teamwork Competence T2</td>
<td>4.25</td>
<td>0.46</td>
<td>.75**</td>
<td>.90</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[.65, .82]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Teamwork Competence T3</td>
<td>4.26</td>
<td>0.46</td>
<td>.72**</td>
<td>.78**</td>
<td>.89</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[.62, .80]</td>
<td>[.70, .85]</td>
<td></td>
</tr>
</tbody>
</table>

Note. N = 107 individuals, 21 teams. M and SD are used to represent mean and standard deviation, respectively.
Values in square brackets indicate the 95% confidence interval for each correlation. * indicates p < .05.
** indicates p < .01. Cronbach’s alpha is listed on the diagonal.
Figure 1

Conceptual Model

Time 1
- Emotional Stability
- Extraversion
- Conscientiousness

Time 2
- Psychological Safety

Time 3
- Speaking Time

Time 4
- Peer Perceptions of Teamwork Competence
Figure 2

Path Analysis Results

Note. N = 110 individuals, 21 teams. Standardized coefficients are in parentheses. † indicates p < .10. * indicates p < .05. ** indicates p < .01. χ² (2) = 2.469, p = .291; CFI = .980; TLI = .893; RMSEA = .043; SRMR = .015; R² (Speaking Time) = .094, R² (Teamwork Competence) = .298. Control variables (Agreeableness, Openness, Cognitive Ability), disturbances, and covariances among exogenous variables are not shown.
Figure 3

Psychological Safety Over Time - Individual

Note. $N = 84$ individuals from 21 teams matched across time points.
Figure 4

The Interaction of Emotional Stability and Psychological Safety Over Time

Note. N = 84 individuals, 21 teams. The interaction term was marginally significant (p = .059).
Figure 5

*Individual Speaking Time Over the Course of a Semester*

*Note.* $N = 107$ individuals, 21 teams.
Figure 6

*Speaking Time Over Time - Individual*

*Note.* $N = 107$ individuals, 21 teams.
Figure 7

Peer Perceptions of Teamwork Competence Over Time

Note. $N = 110$ individuals, 21 teams.
Appendix A

Consent Form

Due to your enrollment in a course that includes an open-ended, long-term team-based project, you may be eligible to take part in a research study titled “Fostering successful collaboration in design teams”. This study is led by Dr. Margaret Beier, Professor of Psychology at Rice University.

This form gives you important information about the study. It describes the purpose of the research, the risks and possible benefits of participating in the study.

**Purpose:** The purpose of this research is to better understand how team interactions affect an individual’s experience in project teams working in a remote setting.

**Eligibility:** You must be enrolled in an open-ended long-term team-based project in a participating class. You must be able to speak and read in English, be at least 18 years of age and be a student at Rice University. You must also have internet access and access to a computer with video and audio capabilities.

**Requirements:** If you agree to participate, you will be asked to:

1) Complete a personality and attitude assessment. This assessment should take no longer than 15 minutes to complete. In order to participate in this study, all your team members must complete this assessment.

2) Using a designated Zoom link when participating in naturally occurring team meetings on Zoom. This link will automatically record audio, transcripts and video from these meetings. We will use the transcripts, audio and video recordings to assess team processes. We will not examine the content of speech but rather the duration of individual speaking turns and team conversation patterns (e.g., turn taking). Only authorized personnel working on this project (the PIs and research assistants) will have access to the video recordings.

3) Complete the Comprehensive Assessment for Team-Member Effectiveness (CATME) survey three times throughout the semester. All data will be kept strictly confidential and accessible by authorized Rice personnel only.

**Risks:** We believe there are no known risks associated with this research study; however, as with any online related activity the risk of a breach of confidentiality is always possible. To the best of our ability your answers to the survey and activities in remote meetings will remain confidential. We will minimize any risks by only allowing authorized Rice personnel to access the experimental data.

**Benefits:** You may not directly benefit from this research; however, we hope that your participation in the study may be of value to humanity.
Compensation: Individuals who complete the initial survey and all three CATME surveys will receive $50. Individuals who are on a team in which all team members complete all surveys will receive an additional $25 (total compensation potential for individuals: $75). If participants fail to complete all surveys they will be compensated as follows: $10 Amazon gift card for the initial survey and one CATME survey, or $20 Amazon gift card for the initial survey and two CATME surveys.

Ending Your Participation: Your participation in this study is completely voluntary and you can withdraw at any time. You are free to skip any question that you choose.

Questions: If you have questions about this project or if you have a research-related problem, you may contact the researchers, Dr. Margaret Beier (beier@rice.edu), Dr. Lisa O’Bryan (obryan@rice.edu), and Tim Oxendahl (to11@rice.edu).

For questions about your rights as a research participant, or to discuss problems, concerns or suggestions related to the research, or to obtain information or offer input about the research, contact if you have questions pertaining to your rights as a research participant; or to report objections to this study, you should contact the IRB Administrator at Rice University via email (irb@rice.edu) or telephone (713-348-3586).

Consent: By continuing with the survey, you are indicating that you adhere to the eligibility requirements, have read and understood this consent form, and agree to participate in this research study. Please print a copy of this page for your records.
Appendix B

Recruitment Flyer

TeamDNA
Fostering Successful Collaboration in Teams

Spring Semester | 2021

Opportunity to take part in a paid study

About our Study
The Adult Skills and Knowledge Lab, headed by Dr. Margaret Beier (Department of Psychological Sciences, Rice University), is conducting a semester-long study on the individual and group characteristics and behaviors underlying successful team collaboration. The purpose of the TeamDNA project is to understand how team interactions are related to important outcomes like team satisfaction, cohesion, and performance.

What Participation Looks Like
- Completing an initial attitude assessment/consent form. In order to participate in this study, all your team members must complete this assessment.
- Using a designated Zoom link when participating in naturally occurring team meetings
- Completing three Comprehensive Assessment for Team-Member Effectiveness (CATME) surveys throughout the semester

Initial Survey/Consent Form: https://riceuniversity.co1.qualtrics.com/jfe/form/SV_0p5frioQsytK72Z

Location: This study will be conducted virtually via your own computer.

Compensation: Participants will be compensated based on individual and team survey completion throughout the semester. The total compensation potential for individuals is $75 (distributed at the end of the semester).

Eligibility: Enrollment in an open-ended long-term team-based project in a participating class, ability to speak and read in English, at least 18 years of age, student at Rice University, and access to the internet and a computer with video and audio capabilities

Questions: Contact Tim Oxendahl at to11@rice.edu

This research has been reviewed and approved by the Rice University Institutional Review Board. If you have concerns regarding this study or questions regarding your rights as a study participant, please contact the Rice Compliance Administrator — IRB at Rice University (irb@rice.edu, 713-348-3586)
Appendix C

Participant Zoom Instructions

Participation Information
Thank you for being a part of our TeamDNA study! Below is some important information regarding your participation. If you run into any issues or if you have any questions throughout the semester, please contact Tim Oxendahl at to11@rice.edu.

Zoom Meetings
Your Team's Zoom Link:
Any time your team meets outside of your main class sessions, we ask that you use this Zoom link. The Zoom meetings are set up to be automatically audio and video recorded and to produce a meeting transcript. We will not analyze any of the meeting content. Rather, we will be looking at interaction patterns.

Surveys
In addition to the initial survey/consent form, you will be asked to complete three CATME peer evaluation surveys throughout the semester. Your instructor will inform you of the CATME schedule.

Important Things to Remember:
- Use the Zoom link for every naturally-occurring team meeting throughout the semester. "Naturally occurring" refers to meetings involving only you and your fellow student team members which take place outside the main class time.
- The amount of compensation you receive will depend on both your individual and team completion of the surveys throughout the semester.

Compensation Plan:
- Individuals who complete the initial survey and all three CATME surveys will receive $50.
- Individuals who are on a team in which all team members complete all surveys will receive an additional $25.
- Total Compensation Potential for Individuals: $75
- If participants fail to complete all surveys they will be compensated as follows: $10 Amazon gift card for the initial survey (or the initial survey and one CATME survey), $20 Amazon gift card for the initial survey and two CATME surveys.
- All compensation will be distributed at the end of the study (early May, 2021).
### Appendix D

Regression Results: Full Model with Interaction

*Path Analysis Regression Results – Full Model with Interaction*

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Speaking Time</th>
<th></th>
<th></th>
<th></th>
<th>Teamwork Competence</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>SE</td>
<td>β</td>
<td>p</td>
<td>Fit</td>
<td>B</td>
<td>SE</td>
<td>β</td>
<td>p</td>
</tr>
<tr>
<td>Emotional Stability</td>
<td>-0.018</td>
<td>0.013</td>
<td>-0.143</td>
<td>.174</td>
<td>0.035</td>
<td>0.042</td>
<td>0.049</td>
<td>0.416</td>
<td></td>
</tr>
<tr>
<td>Psychological Safety</td>
<td>0.014</td>
<td>0.012</td>
<td>0.095</td>
<td>.265</td>
<td>0.251</td>
<td>0.097</td>
<td>0.312</td>
<td>0.010</td>
<td></td>
</tr>
<tr>
<td>Psychological Safety x Emotional Stability</td>
<td>-0.002</td>
<td>0.020</td>
<td>-.009</td>
<td>.915</td>
<td>0.023</td>
<td>0.188</td>
<td>.059</td>
<td>0.109</td>
<td></td>
</tr>
<tr>
<td>Extraversion</td>
<td>0.023</td>
<td>0.012</td>
<td>0.188</td>
<td>.049</td>
<td>-0.078</td>
<td>0.056</td>
<td>-0.114</td>
<td>0.162</td>
<td></td>
</tr>
<tr>
<td>Conscientiousness</td>
<td>0.008</td>
<td>0.014</td>
<td>0.053</td>
<td>.575</td>
<td>0.105</td>
<td>0.066</td>
<td>0.127</td>
<td>0.109</td>
<td></td>
</tr>
<tr>
<td>Openness</td>
<td>0.027</td>
<td>0.014</td>
<td>0.158</td>
<td>.059</td>
<td>0.027</td>
<td>0.064</td>
<td>0.011</td>
<td>0.851</td>
<td></td>
</tr>
<tr>
<td>Cognitive Ability</td>
<td>0.000</td>
<td>0.006</td>
<td>-0.002</td>
<td>.984</td>
<td>-0.003</td>
<td>0.031</td>
<td>-0.008</td>
<td>0.930</td>
<td></td>
</tr>
<tr>
<td>Agreeableness</td>
<td>0.012</td>
<td>0.064</td>
<td>0.011</td>
<td>0.851</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speaking Time</td>
<td>2.049</td>
<td>0.722</td>
<td>0.372</td>
<td>0.005</td>
<td>0.094</td>
<td>0.298</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

_Note. N = 110 individuals, 21 teams. Cluster-robust standard errors were used to account for the nested nature of the dataset (individuals nested within teams)._