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CAN I GET A WORD IN? THE IMPACT OF TURN-TAKING AND GENDER ON ENGINEERING DESIGN STUDENTS' PSYCHOLOGIAL SAFETY

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ABSTRACT

Psychological safety and turn-taking have both been listed as key factors needed for collaboration in teams to emerge. Specifically, prior work has shown that increased communication in teams can lead to high psychological safety. Prior work on turn-taking as a measure of communication has mostly focused on its inclusivity in a team rather than its frequency. While the gender composition of the team can impact both participation as well as team psychological safety, there is a lack of research at the individual level. As such, this study provides the first attempt at connecting turn-taking, gender, and psychological safety through the analysis of members of fifteen engineering design student teams during the concept generation stage of their project. Specifically, we gathered video data to study how the number of turns and self-turns in a team impact psychological safety at both the individual and the team levels. We also examined how gender impacts participation and individual perceptions of psychological safety. The results found that turns and self-turns have a significant positive impact on an individual's perception of the team's psychological safety. However, no such relationship was found at the team level, indicating that there may be additional underlying factors in team level psychological safety. While we found that gender did not impact individual turn-taking, it did affect an individual's perception of their psychological safety. These results provide quantitative evidence of the role of team communication on psychological safety.

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Chapter 1

Introduction

Imagine a nurse being too afraid to call a doctor on their day off about a life-threatening issue or a young pilot fearing that they will upset a superior if they raise a concern about possible misjudgment in the cockpit [1]. These examples, described by Amy Edmondson, identify why individuals may be less likely to speak up or take the path of less interpersonal resistance, resulting in harmful consequences. One way to make sure individuals are able to provide crucial feedback in these tough situations is through fostering psychological safety, which is defined as, “the shared belief that a team is safe for interpersonal risk-taking [2].” Psychological safety is not just about being nice, but about being candid enough to challenge group norms through interpersonal risk-taking [1, 2]. Above other factors, psychological safety was found to be the key contributing factor of team success [3] in a study of Google teams. Multiple research studies conclude that psychological safety positively impacts teams’ performance, creativity, and vitality [4-6].

A contributing factor of high psychological safety stems from team members’ mutual respect and trust for one another, which is built through exchanging personal information [2, 7]. In fact, trust is one of the core factors contributing to psychological safety and can influence knowledge sharing between team members, which bridges the gap between creativity and psychological safety by allowing team members to express their opinions [5, 8, 9].

In conjunction with psychological safety, the gender composition of the team can also affect how individuals in a team communicate and share their ideas [10]. Prior work has argued that gender diversity, like psychological safety, can help to improve group collaboration and foster radical innovation [11, 12]. Focusing on communication, one study reported that females in male-dominant teams were less likely to participate in the discussion due to a lack of confidence within the team [13]. Although there is a lack of research on how gender affects an individual's psychological safety directly, females have been found to report higher levels of trust, a direct link to psychological safety, than their male teammates [14]. Edmondson stated that psychological safety can help control any potential communication difficulties by serving as a moderator between diversity (such as gender) and collaboration, since it creates a safe space to speak for the team members [1].

To have high psychological safety within a team, it is important that individuals do not fear of being judged by their other team members [2]. If individuals are afraid of being criticized for their ideas or opinions, they may choose to remain silent and not participate [4]. This lack of communication can be detrimental to team success, as researchers have indicated that psychological safety influences team effectiveness through productive communication and shared empathy [3]. From the perspective of communication, turn-taking is an important quantitative aspect that has been found to increase a teams' collective intelligence and team performance [11, 15]. Additionally, equality in turn-taking across teams was one similarity Google found across high psychological safety teams [3]. This substantiates the importance of investigating turn-taking in combination with psychological safety.

While prior work showed a positive relationship between psychological safety and communication frequency, how this translates to the engineering design environment remains unclear [16]. Specifically, engineering design teams must be able to communicate effectively when sharing ideas, or design output could suffer. To further understand these topics while building upon prior research, the objective of this paper was to explore the relationship between turn-taking and psychological safety at both the individual and team levels during the concept generation stage of the design process. In addition, we highlighted the role of gender in impacting individual perceptions of psychological safety.

Chapter 2

Related Literature

The aim of this research was to investigate the relationship between gender, turn-taking, and psychological safety in engineering design student teams. Before we discuss our research question, we first review the prior work studying psychological safety, communication, and gender. Following this, we will describe an experiment to study these factors.

Psychological Safety and Communication

A psychologically safe environment is one where individuals "feel safe at work in order to grow, learn, contribute, and perform effectively in a rapidly changing world" [17]. As such, it's no surprise that psychological safety has been shown to affect an individual's willingness to engage within a team [18]. This engagement may show up through a variety of factors, such as their participation in the team through communication and knowledge-sharing [5, 8, 9]. This is particularly important in an engineering context as prior work on the peer reviews of engineering student teams showed that an increase in positive comments about the team's communication during concept generation resulted in higher psychological safety scores [19]. This study, however, relied on perceptions of communication, rather than documented conversations. Nevertheless, this study highlights the potential role of communication frequency (real or perceived) and psychological safety.

While communication can be viewed through many different lenses such as conversational dominance or number of overlaps, turn-taking was listed with psychological safety as two of the top ten conditions needed for collaboration to emerge [20]. Not only does turn-taking help to increase a team's collective intelligence, it also helps to identify teams with high and low psychological safety when turns are evenly spread within the teams [3, 11]. Past research has mostly focused on the inclusivity of turn-taking within a team in relation to psychological safety instead of the frequency of total turns. This is problematic since frequency measures could help to give insight on psychological safety across all teams instead of each team individually.

Turn-taking was first mentioned by Goffman in 1955 and then again by Harvey Sacks in the 1960s, but was not explored in depth until 1974 by Sacks et. al [21]. Goffman described a turn as "an opportunity to hold the floor, not what is said while holding it" [22]. On the other hand, Brown defined a turn as what one participant says before the next participant begins [23]. During a conversation, participants must process the information quickly as well as predict the time of the next turn so they can interject with their ideas [24]. When an individual takes a turn, it demonstrates their understanding of the previous turn as they give context for the next turn. Similar to findings with psychological safety [3], one study showed that as turns between team members become more even, they have a better chance of becoming high performing [11]. In a team, turns can help to prevent dominant personalities from overshadowing quieter members of the team [25]. While engineering design research has analyzed turn-taking in different contexts such as its positive impact on collaboration quality and creative fluency, existing work has not expanded to include psychological safety [26].

To investigate turn-taking in engineering design teams, several models and factors exist to explore communication patterns. Specifically, factors such as length, frequency, or quality of turns can represent and measure turns in conversation [25, 27, 28]. Edelsky labeled conversation as either a singly developed floor where one person speaks at a time, or a collaboratively developed floor where participants are free to speak when they wish [29]. In contrast, Sacks et. al deemed turn-taking as a form of organization in conversation by developing a set of rules to categorize turns [30]. Specifically, one person speaks at a time and overlaps are minimized [30]. At a *transition relevance place*, a speaker can self-select to begin their turn. Or, they can give a signal such as a nonverbal cue to another participant [30].

While turn-taking focuses on speaking up as a whole, a self-turn is a subset of turns and occurs when a single speaker begins to speak again without interruptions from their other team members within an interval of their previous turn [31]. Self-turns may be related to self-selection, which is a common occurrence with overlapping speech. Self-selection describes when a speaker decides when to speak, instead of being appointed by someone else [32]. Specifically, self-selection is defined as, "an indication of the way the participants perceive their discursive role" [33]. In other words, self-selection is how comfortable individuals feel influencing the pre-set roles in the conversation [33]. Self-turns can be seen as a specific instance of self-selection when a person chooses to speak up (again) without a response from another participant [31]. Importantly, in a study on self-selection for guests on a talk show, the number of self-turns a guest took was positively related to their level of fame [33].

Although self-selection can represent the confidence an individual has in their environment, it also has a downside as reflected in competitive self-selection where an individual speaks excessively to gain control of the floor [34]. While having the confidence to speak up within a team is an important characteristic of a psychologically safe team, competitive self-selection may have a negative impact on team conflict and psychological safety [2, 35]. An increase in an individuals' self-turns can also come across as monitoring to their other team members, which stems from a lack of trust that their team members will properly complete their tasks [36]. This overcommunication can also negatively affect the trust of the other team members as they may become self-protective or defensive from the monitoring of their team members [36, 37]. Trust, a core factor of psychological safety, could be another possible link between self-turns and psychological safety, as team members must trust one another to feel safe in their teams [2].

This prior work demonstrates the importance of the inclusivity of turns within a team, models to define turns, and the effect of self-turns. This research has not studied the frequency of turns across teams in conjunction with psychological safety. As such, one goal of this study was to characterize how the number of turns affects both an individual's perception and a team's psychological safety.

Can Gender Impact Participation and Psychological Safety?

While the previous section outlined the potential relationship between psychological safety and communication, it failed to discuss the impact of individual differences. One individual difference that is particularly important in the engineering domain is the gender of the participant. Recently, researchers have sought to find ways to increase the retention of women in engineering [38-42]. Because of the extreme paucity of women engineers, it is rare for an engineering team to be female dominant [43]. Increasing gender diversity within the field is necessary, as heterogeneous teams have been shown to strengthen team performance and processes [43, 44].

While not studied in the context of psychological safety, there has been a plethora of research on the impact of gender on communication For example, studies by DeFrancisco and Ghilzai showed that in conversations, females are oftentimes more curious, leading to an increase in turn taking, especially in mixed gender conversation [45, 46]. This difference in turns that has been observed in the past has also been related to an increase in interpersonal sensitivity for females instead of a lack of assertiveness [47]. In addition to sharing their ideas, females are known to give a greater number of minimal responses such as saying, "right," to show support or interest for their team members [48].

In a study of the conversations of unacquainted college students about television programs, male experts were often perceived as more dominant and occupied the floor more often than females with a similar level of expertise [49]. Although this study does not touch on turn-taking directly, it contrasts with Ghilzai's [46] findings , where females were more dominant than males in conversation. Also, Zimmerman and West concluded that males interrupted females more in conversation than the reverse [50]. An additional study focused on turn-taking in an English classroom found that females were more successful in holding the floor, while men were more successful at getting the floor [51].

In an engineering domain, one study showed that first year undergraduate engineering females oftentimes lack the confidence to contribute within their team during the beginning stages [52], which may impact early participation. In addition, another study showed that females often take the less technical roles in engineering teams such as secretarial work [53], which could affect how the other team members perceive and appreciate their contributions [53, 54], or the type of communication they do in the team (after all how much talking can you do if you're taking notes too?).

While there have been various conclusions on the role of gender in team conversational participation, past research has also found varying conclusions on how gender affects the psychological safety in a team. For example, research has shown that creating gender-diverse teams can help to mitigate the harmful impacts of a psychologically unsafe environment on creativity compared to a gender-dominant team [55]. Specifically, females placed in majority female groups tend to feel less anxious compared to when they are the minority [13]. This may be because females often define more risk than males in relation to within-group competition [56]. In general, females are oftentimes more risk averse, which could impact their rating of their perception of psychological safety or how comfortable they feel taking interpersonal risks [57]. In addition, research has shown that female team members often require an increase in positive social interaction before they are comfortable engaging in knowledge sharing [58], which is a result of psychological safety [2, 59]. In contrast, another study found that there wasn't a significant change in a team's psychological safety as they increased the gender diversity by adding more females [60]. Although not studied on psychological safety, research has shown that females are more likely to underrate themselves, while men are more likely to overrate themselves [61], which may impact self-ratings of psychological safety.

Overall, prior research has shown that participation and perceived psychological safety may be impacted by the gender of the participant. This effect could be exaggerated in engineering where women represent a mere 20.9% of the undergraduate population [62]. However, there has been limited evidence of this effect in engineering teams. As such, this paper seeks to investigate gender and its effect on psychological safety and communication patterns in engineering design teams.

Chapter 3

Research Objectives

The main objective of this paper was to explore how gender and frequency of turns in a concept generation brainstorming session affects the psychological safety of the individual and the team. In particular, the following three research questions (RQs) were explored:

RQ1: Does the gender of the participant impact turn-taking and perceptions of psychological safety in engineering design student teams? Our hypothesis was that female team members would participate more in their teams through a greater number of turns. This is based on prior work showing that females took more turns in a conversation compared to their male counterparts [46]. In addition, we predicted that male participants would rate their perception of psychological safety higher than their female teammates. This is because prior research has found that males are often more confident and tend to overrate their performance compared to females who are more critical and underrate their performance [61, 63, 64]. Relating this to psychological safety, we hypothesized that females would be more likely to underestimate their team's collaboration at the start, having a lower perception of psychological safety. This is because research in the healthcare domain found that females reported lower psychological safety than their male counterparts due to status issues stemming from gender [65].

RQ2: Does the number of turns between team members or self turns an <u>individual</u> engages in affect perceptions of psychological safety? Our hypothesis was that as an individual's number of turns and self turns increased, their perception of their psychological safety would also increase. This is because prior research found that knowledge-sharing, and communication help to bridge the gap between creativity and psychological safety by allowing team members to express their opinions [5, 8, 9]. As this study focuses on a concept generation discussion within a team, it is crucial that team members have open communication to suggest creative and practical ideas. Therefore, for team members to feel comfortable sharing their opinions and have high psychological safety, we predicted they must partake in a higher number of turns. We also predicted that an individual with a higher number of self-turns would result in a higher perception of psychological safety, as an increase in self-turns indicates the individual's level of confidence influencing the conversation [33].

RQ3: Does the number of turns between team members and self turns a team takes affect team psychological safety? Our hypothesis was that as a team's total number of turns and self turns increases, their psychological safety will also increase. Similar to RQ2, we predicted that the same logic will hold true at the team level. Communication is a key factor in fostering high psychological safety in teams that output creative ideas by openly expressing their opinions [5, 8, 9]. Therefore, we predict, an increase in communication reflected by the total number of turns between team members and self-turns in a team would result in an increase in psychological safety.

Chapter 4

Methodology

To answer the research questions of this study, the concept generation stage of a team design project in a first-year engineering design course was recorded. The following section summarizes the methodology of this study.

Participants

Participants for this study were recruited from three sections of a first-year cornerstone engineering design course at a large northeastern university. In total, 53 students (34 males and 19 females) consented to participate in this study and were separated prior to the study into seventeen engineering design teams with three (N = 7) and four (N=8) team members. The three-person teams consisted of 14 male participants and 6 female participants. The 4-person teams consisted of 19 male participants and 13 female participants. Table 1 depicts details of the gender composition of the teams. Students in the course were invited to participate in the study that was reviewed and approved by the Institutional Review Board. Consent was attained from participants.

TABLE 1: Distribution of participants and gender composition within 3 and 4 person teams. Gender-dominant teams consist of only a single gender, while gender-diverse teams have a combination.

# Team Members	# Teams	# Gender-dominant teams	# Gender-diverse teams
3	7	4	3
4	8	1	7
Total	15	5	10

Procedure

Participants took part in a graded project over the course of a typical 15-week semester in Spring 2020. At the start of the semester, students were assigned to 3- and 4- person teams based on the 32-item Kirton's Adaption-Innovation (KAI) inventory to assess their cognitive styles. While not the focus of this study, half of the teams were assigned with homogeneous scores (within a 10-point range), while the other half were assigned with heterogenous scores [66]. Teams were then given a design problem to work through for the remainder of the course, focusing on the need to "ensure healthy lives and promote well-being for all through addressing diseases, pollution, and traffic injuries." Table 2 details the makeup of each class.

TABLE 2: Class size, and number of teams per instructor.

Instructor	Sample Size (n)
A	31 students; 9 teams
B	22 students; 6 teams

The project was divided into 5 distinct time points: Start of the project, concept generation, concept selection, prototyping, and final deliverables. We attempted to balance the authenticity of the design process while running a research study. At the end of each time point, students completed the psychological safety survey. During time point 1, students wrote their problem statements after listening to two lectures on customer needs and creativity in engineering design.

In time point 2, concept generation, participants were given 15-minutes to individually brainstorm solutions to their problem statements. The goal was to come up with creative solutions that were both unique and novel [67]. Specifically, this study focused on the second part of time point 2, team concept generation, where students were asked to come together to develop unique new ideas or a combination of ideas from the individual session. To collect data, teams were spread throughout the room and video cameras with audio capture were set up at each table. Any non-consenting teams also had video cameras, but they were not turned on as to not give away which teams had consented. While we collected audio data and were able to conduct a turn-taking analysis, the exact words that were spoken were difficult to interpret given the classroom environment. The instructors provided cue cards with leading questions to help guide the team discussion such as, "Envision the details of how and where the product will be used and fit the product to its context. Alternatively, redesign the product to function in a new context. This can specialize the product for target user groups." Teams were mostly left to brainstorm on their own, but instructors or teaching assistants stepped in only to answer questions about the task. They did not interfere with the brainstorming, and the portions of discussion involving the professor or teaching assistant were not analyzed. On average, team concept generation lasted 12.39 ± 1.31 minutes. The combined team brainstorming time for concept generation was 3.10 hours.

Similar to time point 1, at the end of the session, each team member took the seven-question psychological safety assessment developed by Amy Edmondson as well as an open-ended survey to write about their positive and negative team interactions during this stage of the design process. The psychological safety survey included questions such as, "If you make a mistake on this team, it is often held against you" [2]. All of the questions helped to form a picture of how comfortable each participant felt in the team while focusing on topics such as making mistakes, having difficult conversations, and feeling like a valued team member [2]. Their responses were then used for the individual analysis and then aggregated as an average value for the team analysis. The remainder of the project was described and analyzed as part of a larger investigation focused on the longitudinal trajectory of psychological safety in engineering design courses [68].

Once the data was collected, two graduate students (raters) used a media annotation software (DARMA) with a Logitech Extreme 3D Pro Joystick to analyze the team conversations [69]. The program collects ratings continuously throughout the video length and is commonly used in social science research to capture observable behavior. The raters assigned each participant to a different quadrant and moved the joystick to their quadrant when they began to speak. Moving the joystick from one quadrant to another represented a change in speaker (turn). From this analysis, the raters were able to analyze the number of self-turns and turns between team members. While this study only defines a turn as a form of verbal communication, past research has included non-verbal cues such as head-nodding to indicate a turn [70]. A button was held down on the joystick to represent silent time in the discussion. To test the validity of this analysis, one of the raters manually collected the speaker times for 2 of the videos. The interrater reliability between the DARMA output and the manual output was above 70%, which is sufficient.

Metrics

Several metrics were utilized in the analysis of this study such as self turns, turns between team members, and psychological safety. The following section presents how each metric was calculated.

Participation

To explore the impact of participation on psychological safety, two metrics were developed. These were based on prior work with sociometric badges [31].

Self Turns: A turn was identified as a self-turn when one speaker spoke again within 10 seconds of their previous turn without interruptions from their other team members [31].

Turns Between Team Members: A turn between team members was counted when a team member spoke within 0.5-10s following a different team member's speaking segment [31].

Psychological Safety

Psychological safety can be analyzed at the individual, group, or organizational level [17]. Across all levels, it is related to both team learning and team performance [17]. Analysis on the individual level is often expanded to include information on participants' growth and satisfaction in their roles [17]. Even though research has been conducted at all three-levels, Edmonson stated that psychological safety is a group-level construct [2]. Interrater agreement (rwg) must be checked to ensure that aggregating individual-level data to the team-level is justifiable [71]. To explore the factors related to psychological safety, the following metrics were used.

Individual Perception of Psychological Safety was calculated using the average of responses from Amy Edmondson's seven question psychological safety scale.

Team Psychological Safety is defined as the belief that members of a team are safe for interpersonal risk-taking [2]. A team's psychological safety score was calculated based on the average individual psychological safety scores from concept generation described above.

$$Team\ Psychological\ safety = \frac{\sum_{i=1}^{K} X_i}{K}$$

where X_i is individual *i's* psychological safety score during concept generation and K is the number of team members.

Chapter 5

Results and Discussion

During the study, 53 students in 15 engineering design teams, engaged in an average of 122.80 ± 64.73 turns per team and 34.21 ± 20.45 turns per person during a 12.39 minute average concept generation activity. The following section outlines the results of the study in relation to the research questions. The statistical data was analyzed via SPSS v.27 and statistical significance was based off $p<.05$.

RQ1: Does the gender of the participant impact their participation or an individual's perception of their psychological safety?

Our first research question was developed to understand the impact of gender on participation and individual perceptions of psychological safety. Our hypothesis was that female participants would participate more, but male participants would have a higher perception of psychological safety. This is because in past studies, females took more turns in conversation, but tended to underrate their performance compared to their male counterparts who were more likely to overrate themselves [46, 61, 63, 64]. To examine this relationship, two independent one-sided T-tests were computed because we were only interested in if there was a difference in a specific direction. For participation, we predicted that females would take more turns, and for psychological safety, we predicted that males would have a higher perception. All statistical assumptions were tested before completing the analysis. Specifically, there were no outliers based on a visual inspection of a boxplot, and individual perceptions of psychological safety for each gender were normally distributed according to a Shapiro-Wilk's test (p >.05). Finally, there was homogeneity of variances between genders as assessed by Levene's test for equality of variances (p =.214). As such, the analysis proceeded.

Results of the one-sided T-test found that a male's individual perception of psychological safety was 0.35 (SE=.19) higher on average than a female's perception. In other words, there was a statistically significant difference in mean perceptions of psychological safety between males and females, $t(50) = 1.807$, $p = .038$. Specifically, male participants gave an average psychological safety score of 6.28 (SD = .61), while females had an average score of 5.93 (SD = .78) as seen in Figure 1.

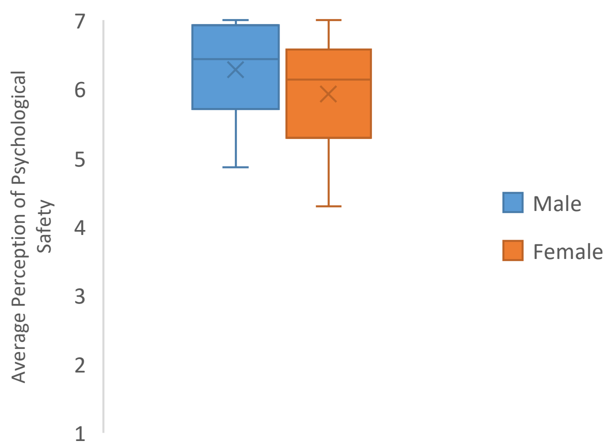

Figure 1: Average perception of psychological safety between genders. The maximum possible psychological safety score is 7.

Two more one-way independent t-tests were run to determine if there were differences in participation between males and females. The total number of turns between team members and self-turns were used as a measure for participation. All assumptions were met before completing the analysis. There was not a statistically significant difference between the total number of turns between male and female participants, $t(51)=-1.027$, $p = .155$. There was a similar nonsignificant finding of the difference in self-turns between male and female participants, $t(51)=.187$, $p = .426$. Therefore, even though male's rate themselves higher in terms of psychological safety, they do not participate differently than their female counterparts.

To summarize, the results showed that male team members had a higher perception of their psychological safety than female team members, which aligned with our original hypothesis. As concluded by prior research, males are often more confident in their abilities, while females are more critical in self-assessments [63, 64]. This pattern can be seen in this study as well where the male team members might have a more positive outlook on the team collaboration or in other words, might be blind to conflict that is arising within the team [63, 64].

We can see this pattern occurring in the post-discussion survey where participants were asked to describe the positive and negative interactions within their team. Team 56 is a 4-person team with 2 females and 2 males. Both male team members commented that there were no negative interactions, while one female team member wrote, "sometimes an idea is negated," and another female wrote, "we just bounce around a lot of random unrealistic ideas for the region however we quickly stay away." This pattern is also apparent in Team 67, which also has 2 females and 2 males. The male team members once again did not cite any negative interactions, while both females did. One of the female participants said, "some people have trouble thinking of ideas," which insinuates an unspoken sense of frustration within the team. In conclusion, gender affects an individual's perception of their psychological safety, but did not influence the number of turns an individual took during the concept generation discussion.

RQ2: Does the number of turns between team members and self turns an <u>individual</u> engages in affect perception of psychological safety?

Our second research question was developed to understand the impact of the number of turns between team members and self-turns on an individual's perception of psychological safety. Our hypothesis states that an individual's perception of psychological safety would increase as their number of turns between team members and self-turns increased. This is based on previous research that showed that psychological safety increased with the frequency of communication [72]. After running a Pearson's product-moment correlation, there was a moderate correlation between self turns and turns between team members, $r(53) = .319$, $p<.05$. Therefore, self-turns and turns between team members were run in two separate models to predict an individual's perception of psychological safety. All statistical assumptions were met prior to the analysis including linearity by visually inspecting the two scatterplots of self turns and turns between team members against individual psychological safety. In addition, there was homoscedasticity and normality of residuals. From the analysis, both turns between team members and self turns were positively related to individual perceptions of psychological safety.

For the first linear regression, the prediction equation was: individual perception of psychological safety = 5.757 + 0.013*turns between team members. Turns between team members significantly predicted individual psychological safety, $F(1,51) = 6.900$, p=.011 with $R^2 = .121$ and adjusted $R^2 = .104$. This supports our hypothesis that turns between team members and psychological safety would have a positive relationship.

The second linear regression had individual perceptions of psychological safety as the independent variable and self-turns as the dependent variable. Similar to turns between team members, self turns also had a positive relationship with psychological safety, F(1,51) = 5.205, p=.027 with $R^2 = .094$ and adjusted $R^2 = .076$. The regression equation was: individual perception of psychological safety = 5.948 + 0.042*self turns. This again supports our hypothesis that self-turns, and psychological safety have a positive relationship.

To summarize, as the number of turns between team members and the number of self-turns that an individual takes increased, the greater the likelihood that an individual would have a higher perception of psychological safety at that time point. These findings support the importance of communication and knowledge sharing in building psychological safety. A turn might just be a participant saying, “yes,” to agree with their teammate, but this small gesture helps the teammate understand that the participant is engaged in the conversation. As an individual stays engaged in the conversation and is listening and responding to their team members, they are more likely to feel psychologically safe within their team. The second part of the analysis states that in addition, as the number of self-turns increases, the individual’s perception of psychological safety also increases. Therefore, even if an individual does not get a response from their team members right away, they still feel confident and psychologically safe enough to speak again without instant feedback. To note, the relationship between turn length and psychological safety was also tested, but the result was non-significant. As turn length was not the focus of this paper, we are not including the details here.

Once again, these findings are reflected in the qualitative post-discussion surveys. Participant 257 who had the lowest perception of psychological safety in the study (4.29 out of 7) wrote, “sometimes I’m really afraid to speak up because I’m worry about my English-speaking skills.” On the other end of the spectrum, 10 participants had a perfect psychological safety score of 7 and mostly wrote about only their positive interactions and did not cite any negative interactions. Participant 210 in Team 54 wrote, “We came up with plenty of meaningful ideas and have very productive conversations regarding our problem.” Communication is a key factor of psychological safety as mirrored in both the turn-taking and survey data. Since psychological safety is often studied at the team level, we also examined if these findings would stay consistent or change at this level.

RQ3: Does the number of turns between team members and self turns a <u>team</u> takes affect the team's psychological safety?

While RQ2 focused on individual perceptions of psychological safety, RQ3 turns the focus to team psychological safety. Specifically, if the number of turns between team members and self-turns a team takes affects their psychological safety level during concept generation. Similarly to RQ2, we hypothesized that the number of turns between team members and self turns would have a positive relationship with the team psychological safety, since prior research depicted that increased communication results in higher psychological safety [72]. To analyze psychological safety at the team-level, it was justifiable to aggregate to the team level, as demonstrated by an acceptable level of agreement ($r_{wg} = 0.87$, ICC(1) = 0.17, and ICC(2) = 0.44) [68].

Before running the linear regression, all assumptions were checked and met. Specifically, there was homoscedasticity and normality of residuals as well as linearity by visually inspecting the scatterplots of self turns and turns between team members against psychological safety. After running a linear regression, there was not a significant relationship between self-turns and psychological safety at the team level during concept generation, $F(1,13) = 2.286$, $p = .154$. A similar nonsignificant relationship was found between member turns and psychological safety, $F(1,13) = 0.029$, $p = .867$. Therefore, unlike the individual level, the number of self-turns or turns a participant takes with their team members does not affect their team's psychological safety score.

To further explore what was happening at the team level, we graphed the communication patterns for all teams separated by team size and ranked by psychological safety score (see Figure 1). From a visual examination of the pattern charts for both 3 and 4 person teams, there does seem to be a general trend of low number of turns aligning with low psychological safety and a high number of turns aligning with high psychological safety. For both team sizes though, there are

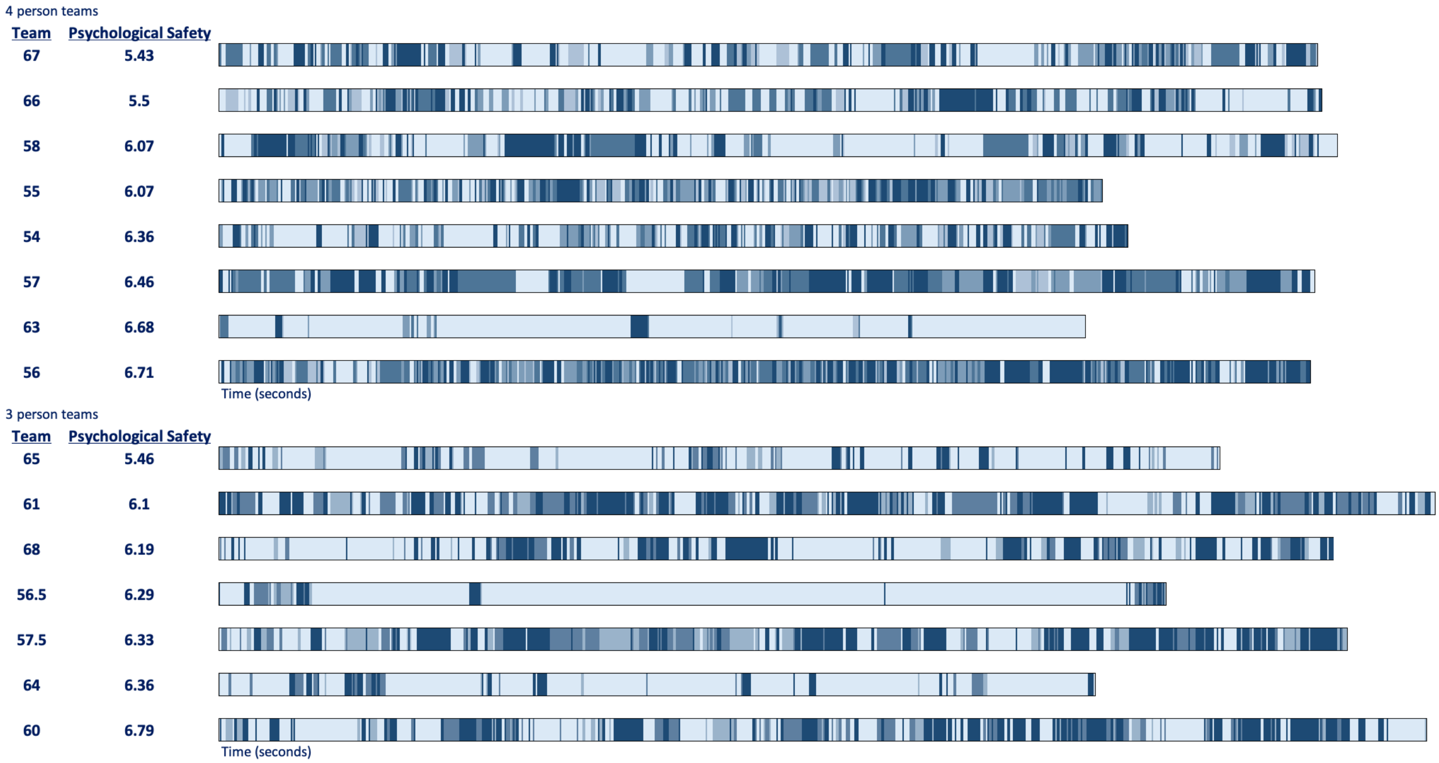

Figure 2: Communication pattern charts categorized by team size and psychological safety score. Colors represent individual participant speaking time and silent time as the lightest color. Silent time in the team is shown by the lightest color and the individual who spoke the most is represented by the darkest color. The other 2 or 3 students in the team are represented by the color range in between.

outliers that affected the analysis. For a 4-person team, Team 63 seems to be an outlier with a high psychological safety score of 6.68, but a high amount of silent time, and low number of turns. In addition, Team 63's psychological safety survey responses contradict their survey responses as none of their team members spoke about negative interactions in the discussion. In contrast, they spoke positively about their experience and one member wrote, "We were able to brainstorm many good ideas and build off each other," which intuitively would reflect a high level of participation.

The 3-person team charts show a similar pattern as the 4 person charts with low psychological safety teams such as Team 65 (PS score of 5.46) having low participation and turns and high psychological safety teams such as Team 60 (PS score of 6.79) having the reverse. There are a few outliers that can be seen visually in the pattern charts for 3 person teams. Team 64 has the second highest level of psychological safety, 6.36, but a low amount of participation and turns. Two of the team members wrote that they did not experience any negative interactions, whereas, one member wrote, “Some of the ideas that I proposed were met with "I don't know" and no further discussion occurred.” As for Team 56.5, although their psychological safety score of 6.29 is higher than three of the teams, their participation and number of turns are lower. One of the team members wrote, “Maybe we did not talk as much as I would have liked to but we’re getting there,” showing a positive outlook of the future.

Both the pattern chart and the qualitative responses explain that there are other factors that must be taken into consideration when analyzing psychological safety at the team level. Further research is needed to understand how additional factors such as the mix of personality types among members could moderate the relationship between the frequency of turns and psychological safety at the team level.

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Chapter 6

Limitations, Conclusions, and Future Work

This study confirmed the importance of communication in facilitating psychological safety [5, 8, 9], but looked at it through a new lens of turn-taking. We can conclude that not only is the inclusivity of turns important in teams [3, 11], but also the frequency of turns each individual takes. Our findings related to self-turns and psychological safety aligned with previous research, which stated that a higher number of self-turns signals an individual's higher level or confidence or comfortability within the team [33]. When the data was analyzed at the team level though, the relationship between turns and psychological safety was not significant as there are more factors such as personality types within the team that could come into play. Also, past research stated that female team members usually take more turns than their male counterparts [46], but this was not the case in our research. We can conclude though, that male team members have a higher perception of their psychological safety. This confirms past research that found that males often overrate themselves, while females underrate themselves [61, 63, 64].

While this study presented findings on the effects of gender and turn-taking on psychological safety at the individual and team levels, there are some limitations to take into consideration. The sample size of this study was quite small with only 15 teams. A larger sample is needed to further examine team level data. Also at the team level, other factors such as personality type must be studied in conjunction with turn-taking to better understand the full picture of team communication. The participants in this study were engineering students, so it is unknown whether these findings will replicate in team conversations outside of the classroom. In addition, the individual and team psychological safety scores were determined from survey results. Although students were assured that their responses would not affect their success in the class, sometimes students are not completely honest with the difficulties they might face in the team. Moving forward, it would be interesting to study the effects of gender on turn-taking specifically with an increased sample size and strategically formed teams to understand same gender communication compared to opposite gender communication. Also, future studies should analyze audio transcriptions, if possible, to further understand team interactions. In conclusion, the following conclusions were made from our analysis:

- Male team members had a higher perception of psychological safety in the team than females.
- Self-turns and turns between team members positively predicted individuals' perceptions of psychological safety.
- Self-turns and turns between team members did not significantly predict team psychological safety.

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WORK EXPERIENCE

L'OREAL | Operations Intern **June 2021-Aug 2021**
- Communicated with 10 different electric vehicle charging station companies to plan implementation, saving the company 35% of the total cost of purchasing and installation.
- Renewed the utilities' maintenance management system by adding 96 new assets and transferring 84 preventative maintenance schedules to improve the efficiency of the utilities department
- Identified 24 risks associated with a high speed CeraVe packaging line and suggested a plan to mitigate these risks.

L'OREAL | Operations Extern **June 2020-Aug 2020**
- Collaborated on a cross-functional team of four externs to create an innovative packaging solution that eliminated plastic through the use of bamboo and water-soluble pods.
- Proposed "Easy-Tear Packaging," which helped to decrease carbon emissions by increasing the number of uses per product and transitioning the packaging to a recyclable alternative.

Ingersoll Rand | Operational Excellence Intern **May 2019-Aug 2019**
- Performed time studies and developed before and after bar charts for the electrical department to create a new layout that reduces up to 22% of waste.
- Utilized data analysis to categorize the on-time shipment misses weekly and created a plan to eliminate the highest Pareto by 90%.
- Improved inventory accuracy and material shortages by 50% through a reorganization of the coil shop by checking the physical location of parts and matching it to the system location.

BRITELAB | Research Assistant **Sept 2018-Present**
- Analyzed data from content analysis using SPSS to determine what factors contribute to the building or waning of psychological safety in engineering design teams.
- Coded interviews to categorize how risk and creativity affect businesses in the problem-solving process.

AURORA: Penn State Outdoor Orientation Programs | Backpacking Leader **Jan 2018-Aug 2019**
- Practiced risk management, empathy, conflict resolution and decision-making while leading backpacking trips

CLASS PROJECTS

Service Systems Engineering Projects (IE 460) **Jan 2021-May 2021**
- Utilized Excel Solver to determine optimal hospital locations in Pennsylvania for installing aerial CT machines to minimize cost while reaching stroke victims in a timely manner.
- Estimated demand and created a queueing model to vaccinate approximately 450 people per day at Penn State with an average process time of 20.72 minutes

Optimization of Building Cleaning during COVID-19 Pandemic **Aug 2020-Dec 2020**
- Utilized AMPL to determine the optimal cleaning labor schedule for 11 Penn State buildings that would save $1,200 on worker costs daily.

Entrepreneurship Class Projects **Aug 2019-Dec 2019**
- Earned $3,044 in a 3-week competition to make the most money by selling koozies at Penn State football games.
- Placed 1st place in a 13-team class project by creating a 10-year marketing, operations, and financial plan for a new purse with added components to help women feel safe while walking home.

Water Pollution Project **Jan 2019-May 2019**
- Traveled to South Africa to present a solar powered system that tracks water pollution
- Managed and delegated the virtual collaboration for a team of 12 students from Penn State, South Africa, and Australia as the Team Coordinator.

Baobab Project (PSU designed machine to process Baobab plants) **Aug 2018-Dec 2018**
- Led team while communicating with multiple international vendors to assess the design, cost, and capability to produce machine availability and market demand of the baobab machine in Africa.

INVOLVEMENT AND SKILLS
- Technical Skills: Microsoft Office, SolidWorks, NVivo, SPSS
- Icebreaker Chair: Society of Women Engineers, Member: IISE, Member: Dancer Relations committee (THON)