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Fostering Psychological Safety in Global Virtual Teams: The Role of Team-Based Interventions and Digital Reminder Nudges

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Abstract
Psychological safety (PS), the feeling of being comfortable to express one's ideas or opinions in teams, is a key determinant of successful global virtual teams (GVT). Even though considerable knowledge exists about its antecedents, it is unknown how team-based interventions (TBI) and technology-based interventions (digital reminder nudges, DRN) foster PS among team members. Based on a survey involving 235 participants, our data show that TBI and DRN foster psychological safety in GVT. However, only the effect of TBI on psychological safety can be explained with a higher-quality coordination process. It remains unclear what causal mechanism explains the effect of DRN. These findings contribute to the literature on PS by showing that TBI facilitate effective coordination processes and to the literature on digital nudges by demonstrating that technology-based reminders drive PS.

Keywords Collaboration · Digital nudging · Psychological safety · Team intervention · Global virtual teams

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1 Introduction

Global virtual teams (GVT) are defined by two characteristics: team members are geographically dispersed across countries, and teams interact in a technology-mediated environment (Gibson and Cohen 2003). The Covid-19 pandemic challenged virtual teamwork as interaction among team members became more asynchronous, static, siloed, and less synchronous (Yang et al. 2021). In GVT, multiple perspectives, cultures, language barriers, and time zone differences exist, which can result in miscommunication, a lack of trust, anxiety, and coordination issues (Morrison-Smith and Ruiz 2020; Powell et al. 2004). Dispersed teams must rely on technology-mediated, often asynchronous communication, which can strain collaboration because nonverbal cues are missing (Nunamaker et al. 2009). Without active interventions to foster team exchanges and feedback, GVT lose their capability to perform (Peñarroja et al. 2015). Psychological safety (PS), which describes a team climate in which team members feel comfortable expressing themselves and overcoming interpersonal fear (Edmondson 2018), is a key ingredient of successful high-performing teams and a driver of individual and team learning (Newman et al. 2017). It is thus not surprising that PS has received much attention (e.g., Frazier et al., (2017)'s meta-analysis) because of its significance to GVT performance (Glikson and Erez 2020).

Team members can actively intervene into their team processes and interpersonal relationships (Kahn 1990) to create a supportive work context and foster PS (Frazier et al. 2017). Also, the digital collaboration environment is an enabler (Griffith et al. 2003) and facilitates the building of PS. When these team-based and technology-based interventions are targeted at establishing role clarity or clarifying task goals, they improve group processes and help overcome coordination issues (Espinosa et al. 2007). Thus, we consider, on the one hand, team-based interventions (TBI), which refer to team members' communicative actions to create a supportive work context and provide guidance to team members. An example of a TBI is when one team member reminds another team member of an upcoming deadline. On the other hand, we also explore the perceived effectiveness of digital reminder nudges (DRN) as an antecedent of PS, which refer to the perceived effectiveness of deliberate notice interventions provided by a digital choice environment to guide behavior (Schneider et al. 2018).

Some empirical evidence links TBI to PS (Frazier et al. 2017), but whether and how DRNs affect PS is unclear. Recent research emerged that digital tools can nudge team members to have the ability to work together on a variety of collaborative tasks, but with positive and negative effects (Gupta et al. 2024). In fact, research on the effectiveness of digital nudging shows that the magnitude of the effect varies (Hummel and Maedche 2019) and depends on individuals' abilities and motivation (Caraban et al. 2019). The effectiveness of DRN in a team context is unclear (Gupta et al. 2019), and their effect on facilitating PS is unknown. Thus, TBI and DNR could be highly effective for some team members but ineffective for others in establishing PS. It could also be that one form of intervention is more effective than the other. If they are effective, TBI as internal, team-based

interventions and DRN as external, task-based interventions help teams form informal mutual adjustments and team structure, which should benefit the team by having better coordination processes. However, it is unknown if TBI and DRN are antecedents of high-quality coordination. Moreover, empirical evidence is scarce that investigates the effects of DRN in a team setting. Consequently, not all team members may react equally to team interventions and nudges, so that team members may perceive their effectiveness differently. Understanding the effectiveness of TBI and DRN and how they work is crucial because it allows for the setting of informed interventions to foster PS. Our study aims to understand whether the perceived effectiveness of TBI and DRN facilitate PS and if higher coordination quality can explain these effects. Thus, we state the following research question: *How do team-based interventions and digital reminder nudges affect psychological safety?*

We surveyed 235 respondents who worked in GVT in a controlled setting for seven weeks to answer this research question. Our research contributes to the fields of digital nudging and PS. First, we expand the knowledge on digital nudging in a team environment and provide empirical evidence that DRN foster PS directly. Second, we provide additional nuances to the body of knowledge on PS by showing that the quality of team coordination is a causal mechanism explaining the effects of TBI. These research contributions can also help practitioners manage their GVT better and use DRN as cost-effective interventions to foster a safe team environment for team members.

2 Theoretical Foundation and Hypotheses Development

2.1 Team Effectiveness Framework for GVT

Much team research builds on McGrath's (1964) Input-Process-Outcome (I-P-O) model, which has evolved into Input-Mediator-Outcome models (Ilgen et al. 2005) to explain the critical team inputs and mediators (i.e. team processes and emergent states) that drive team outcomes. Team inputs comprise the individual team members and the team and organizational context they are in (Mathieu et al. 2008). This study focuses on team- and technology-based interventions, that is *TBI* and *DRN*, as inputs, which can either be exerted by a team member or come from the task environment.

Teams engage in several team processes. Marks et al. (2001) distinguish between transition, action, and interpersonal processes. Transition processes are planning, strategy formulation, and evaluation phases that guide the team's path to task accomplishment. Action processes include the actual taskwork, i.e., the processes directly related to the team's task. This includes coordinating the interdependent actions of team members toward the shared goal. While transition and action phases will alternate, interpersonal processes are constantly ongoing. This study focuses on *coordination processes* as one type of process that converts inputs into an outcome (Mathieu et al. 2008).

Moreover, team processes must be separated from emergent states (Gibson and Gibbs 2006). Emergent states, such as PS, are characteristics of a team and develop over time based on inputs, team processes, and previous outputs (Marks et al. 2001). As such, PS can be both an emergent state and outcome of team interaction, influencing team processes in future collaboration episodes. In this research, we consider *PS* as an outcome and present the theoretical underpinnings of all focal variables in the following.

2.2 Psychological Safety in GVT

Psychological safety refers to the "shared belief held by members of a team that the team is safe for interpersonal risk-taking" (Edmondson 1999, p. 354). It includes an assessment of the team environment as to how others will react to seeking feedback, pointing out mistakes, or pitching ideas (Edmondson 1999). A person will feel psychologically safe if the team environment is perceived as non-threatening and no negative consequences are expected when expressing oneself (Zhang et al. 2010). While PS was originally used in a group context, it is often a matter of individual perception. Thus, it has also been established as an individual-level construct (Edmondson and Lei 2014).

PS has received widespread attention because it is one of the top predictors of team performance, team resilience, and team member well-being (Cardon et al. 2022; Kim et al. 2020; Newman et al. 2017). The concept became even more relevant during the Covid-19 pandemic when all teams transitioned to collaborate virtually, and the emotional states of team members shifted due to a global health crisis (Lee 2021). Particularly in the context of GVT, PS can mitigate the negative effects of virtuality (Clark 2022; Gibson and Gibbs 2006; Hao et al. 2022).

Past research on PS, as an outcome of team interaction, has placed significant emphasis on its antecedents. These encompass a range of factors, such as interpersonal relationships, group dynamics, leadership style, organizational norms, work design, and personality (Edmondson 1999; Kahn 1990; Newman et al. 2017). A meta-analysis by Frazier et al. (2017) has found large support for these antecedents and found that certain personality traits, positive leader relations, work design characteristics (autonomy, interdependence, role clarity), and supportive work context (peer support) are the most defining drivers of PS.

While there is a considerable amount of research on the antecedents of PS in teams, little research exists on concrete interventions that can facilitate PS (Donovan and McAuliffe 2020). The few existing studies lack a clear pathway toward a successful intervention. Some evidence suggests that team-based games can increase PS (Parker and du Plooy 2021). Other studies found that training as an invention has little to no significant impact on PS (Dusenberry and Robinson 2020). Educational interventions, such as simulations or video trainings show mixed results in effectiveness. Moreover, it is unclear if the findings can be generalized to the GVT context, as most existing studies were conducted in the healthcare context (Donovan and McAuliffe 2020). After all, GVT, are often characterized by high task autonomy and a lack of formal leadership, differing vastly from medical teams.

We specifically move away from education-based interventions. Instead, we build on the work of Frazier et al. (2017) and investigate if TBI and DRN aimed at fostering a supportive work context can facilitate PS in GVT. Such team-based and task-based interventions could help teams build better coordination, which drive PS. Figure 1 summarizes our research framework and the hypotheses are developed in the following.

2.3 Team-Based Interventions and Digital Reminder Nudges

2.3.1 Team-Based Interventions

We conceptualize TBI as communicative actions set by team members to create a supportive work context as defined by Frazier et al. (2017). In this vein, team members exert social influence on the team, provide peer support and mutual support as well as engage in (bi-lateral) team caring and organizational citizenship behavior to facilitate accomplishing team tasks.

TBI serve both task and relationship goals. We distinguish task- and relationship-oriented communication, sometimes called taskwork and teamwork (Salas et al. 2015), both of which are part of TBI. On the task-oriented side, TBI are, e.g., temporal reminders where team members remind each other of deadlines and task completion that initiate team action processes (Siddiquei et al. 2022). TBI are particularly important for self-managing teams that have a lot of agency over their task accomplishment and lack an external party to provide these interventions. Team members require interpredictability; i.e., they need to rely on their teammates to complete tasks as arranged (Mastrogiacomo et al. 2014) and to check in on their teammates whether tasks are being completed. In the relationship-oriented context, social psychology research offers insights that explicit actions of peers and mere reminders of social attention influence people's behaviors and performance. This suggests that TBI also includes subtle cues that evoke a sense of being observed and accountable (Steinmetz and Pfattheicher 2017).

TBI was studied in domains such as psychology, information systems, health care, and organizational behavior. In information systems, peer information interventions to reduce procrastination have only been studied at the individual level

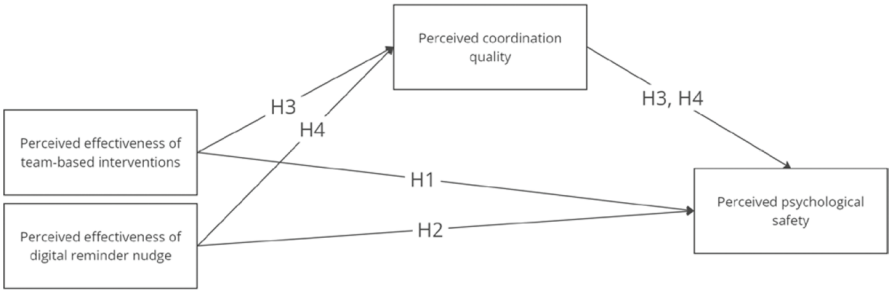


Fig. 1 Research model

(e.g., Li et al. 2021). In mental health and higher education research, these concepts have been researched on the team and interpersonal level and found to have positive effects on success (Khan et al. 2023; Repper and Carter 2011). One of the insights from this literature stream in the context of work teams is the impact that TBI have on PS (Frazier et al. 2017). The supportive work context that TBI create becomes vital in GVT where the physical distance can exacerbate feelings of isolation and uncertainty. GVT often suffer from process losses due to cultural miscommunication and virtuality (Adler and Gundersen 2001). It is, therefore, more difficult to establish PS as an outcome of team processes. In these environments, TBI are expected to be even more relevant for establishing PS because they will mitigate process losses. GVT teams can intervene by clarifying deadlines, deliverables, and expectations. When team members discuss, remind each other proactively, and ask each other questions to clarify expectations, they build social relationships. These types of interventions have shown to improve team climate (Miles and Kivlighan 2008), facilitate trust (Cheng et al. 2021), and PS (Frazier et al. 2017). This reciprocal nature of peer support not only influences individual well-being but also contributes to the collective ability of teams to cope, adapt, and ultimately thrive in the face of adversity. Thus, it is clear that TBI, rooted in peer support and mutual encouragement, play a pivotal role in shaping the PS of GVT.

Hypothesis 1 Higher perceived effectiveness of team-based interventions results in higher perceived psychological safety.

2.3.2 Digital Reminder Nudges

Interventions into teams can also occur from outside a team and nudge team members to perform certain behaviors. A nudge describes any deliberate change in a choice environment by a choice architect to influence a decision maker's behavior without forbidding any decision options (Thaler and Sunstein 2009). When nudges occur in an online environment, such as user interface elements (e.g., buttons, pictures, or different font sizes and colors), they are called digital nudges (Weinmann et al. 2016). A (digital) nudge focuses the attention of decision-makers in a particular direction with the aim of a beneficial outcome (Thaler and Sunstein 2009). Nudges influence how decision-makers process decision attributes by utilizing heuristics and biases (Hansen 2016; Thaler and Sunstein 2009). Several types of nudges exist, e.g., default rules, simplification, disclosure, warnings, and reminders (Sunstein 2014).

This work focuses on reminder nudges, which are notification tactics that provide relevant information and make certain information salient to a decision-maker (Hansen 2016). Past research studied reminder nudges in different contexts. Smith et al. (2018) investigated homework reminder nudges in the context of higher education and found that simple e-mail reminders about homework deadlines can increase grades. Zavaleta Bernuy et al. (2022) studied the effects of email-based reminder nudges to reduce students' tendency to procrastinate. They showed that students who received reminders started their homework earlier in the week and also performed

better. In the context of charity giving, Sonntag and Zizzo (2015) found that participants donate more when they receive monthly reminders.

Nudging individuals to adopt a certain behavior (e.g., less procrastination, higher security, more donations) with simple reminders in the form of e-mails has shown to be effective. However, their effect size varies from non-existing to large (Hummel and Maedche 2019). It is likely that the effectiveness of nudging depends on the recipients' perception of performing the nudged behavior (Van Gestel et al. 2021). Specifically, "a person must have sufficient motivation, sufficient ability, and an effective trigger" (Caraban et al. 2019, p. 503). Reminder nudges are effective triggers but do not motivate people as much as social comparison nudges, or make choices easier as do default nudges. Therefore, the effectiveness of reminder nudges can vary depending on perception. Gaining insights into the peoples' perceived effectiveness of reminder nudges is particularly interesting in team-based settings, where the nudge aims to affect all team members. Even though research on moral nudges shows that those nudges can be effective at the team level (Dunaiev and Khadjavi 2021), it is unknown if reminder nudges are effective interventions in a team setting, particularly when other interventions are present at the same time.

In the context of GVT teams, reminder nudges may guide the attention towards the expectations that exist around team outcomes, such as team deliverables (Gupta et al. 2019; Haki et al. 2023). Reminder nudges make task expectations transparent, which helps team members clarify team roles and what others can expect from their work. When reminder nudges are sent from an external source, the reminder nudge also uses the messenger effect, giving the information more credibility and making it more likely to be accepted by the team members. Weekly reminder nudges help team members to keep the latest deadlines and expectations at the top of their mind, thus fostering the availability heuristic (Caraban et al. 2019). These nudges preservefreedom of choice (Thaler and Sunstein 2009), which gives team members the autonomy to decide whether to accept the guidance. Literature on PS has established that task design characteristics, such as autonomy and role clarity, facilitate the emergence of PS (Frazier et al. 2017). As established, reminder nudges signal team members' tasks and role expectations, thus facilitating goal clarity while leaving the decision-making power with the individual team members. However, even if reminder nudges make roles and expectations transparent, they are not necessarily perceived as such. Team members may still perceive reminders as unclear and ambiguous and may still feel unsure of how to engage in the team and contribute effectively. In such cases, DRN are perceived to be little effective, which should result in lower PS. Thus, we hypothesize,

Hypothesis 2 Higher perceived effectiveness of digital reminder nudges results in higher perceived psychological safety.

2.3.3 Coordination in GVT

When teams collaborate, they engage in processes of communication, cooperation, and coordination (Fuks et al. 2008; Salas et al. 2015). Coordination is defined as the integration and management of interdependent activities towards a common

goal (Berntzen and Wong 2021; Espinosa et al. 2007; Ji and Yan 2020; Malone and Crowston 1994). Effective coordination is a cornerstone of successful teams (Espinosa et al. 2012; Gimpel et al. 2023). It helps teams overcome technical, temporal, and process-related coordination problems (Espinosa et al. 2007). When a task needs to be completed by a group of people or relies on an activity or information from someone else, coordination is needed.

Coordination in GVT requires even more deliberate effort from team members than in co-located teams. International, virtual collaboration challenges communication due to culturally specific forms of communication and the lack of informal and face-to-face communication (Kiely et al. 2022). While digital communication benefits coordination in the sense that it is always available and immediate and allows for communication across geographical and temporal boundaries, it also hinders coordination because it is often asynchronous, lacks social cues, and team members communicate less, particularly on an informal, relationship- and trust-building level (Cheng et al. 2021; Kiely et al. 2022). Moreover, virtual, self-managed teams are characterized by many degrees of freedom in how to approach their tasks (Berntzen and Wong 2021). This autonomy requires coordination within the team itself, such as managing the team's progress. The geographical dispersion, time zones, language and cultural differences, as well as lower trust, impact coordination quality negatively (Espinosa et al. 2007; Kiely et al. 2022; Lee et al. 2013). To overcome these challenges, teams can include pre-defined work processes such as methodologies, codes of conduct, guidelines, templates, schedules, or project plans (Berntzen and Wong 2021; Kiely et al. 2022). They can also manage shared resources, including task assignments, oversee producer/consumer relationships, handle prerequisites and constraints, and address task and subtask dependencies (Malone and Crowston 1994). Therefore, GVTs rely on coordination mechanisms like standards, plans, and both formal and informal mutual adjustments to coordinate effectively.

We argue that TBI and DRN are forms of informal mutual adjustments. More specifically, (in)formal mutual adjustments refer to relational, knowledge-based coordination, which is characterized by a high degree of interaction and communication (Berntzen and Wong 2021; Kiely et al. 2022). This could either happen in informal communication that has not been planned for (Berntzen and Wong 2021; Kiely et al. 2022), and thus TBI, or through planned meetings and email updates (Berntzen and Wong 2021; Kiely et al. 2022), and thus DRN. TBI and DRN are also interventions to form team structure consisting of a clear division of labor, clear roles, and defined rules and processes, which fosters effective coordination (Ji and Yan 2020). This team structure can be defined by outsiders to the team, such as management or the organization, but also by internal team members. TBI and DRN represent this dichotomy of structuring approaches (Bresman and Zellmer-Bruhn 2013). TBI are communication statements internal to the team that help structure collaboration, while DRN are an external way to structure teamwork. Both support the team's ability to self-manage and coordinate. Consequently, TBI and DRN are likely antecedents of effective coordination, but this relationship has not been established empirically thus far.

When teams can establish interpersonal relations with TBI, they can increase the quality of their teamwork processes and effectively support each other

(Donovan and McAuliffe 2020). The presence of caring and supportive relationships among team members increases the team's capacity to adapt to environmental challenges and coordinate difficulties effectively (Carmeli et al. 2014). TBI can offset the negative effects of virtuality in dispersed teams (Espinosa et al. 2007) when teams find ways to share knowledge effectively (Carmeli et al. 2014). TBI can foster coordination in GVT meetings because it helps team members build trust and facilitates the sharing of information that helps solve task conflict, develop a shared understanding of the project goal, create transparency, and provide role clarity (Cheng et al. 2021). All of these lead to a safe and predictable environment, thus PS (Bresman and Zellmer-Bruhn 2013; Frazier et al. 2017). With good coordination, team members can provide open feedback and voice concerns over team members, processes, and task completion (Jarzabkowski et al. 2012). The ability to speak without fearing repercussions is a central aspect of PS.

Hypothesis 3 Perceived coordination quality mediates the relationships between team-based interventions and psychological safety.

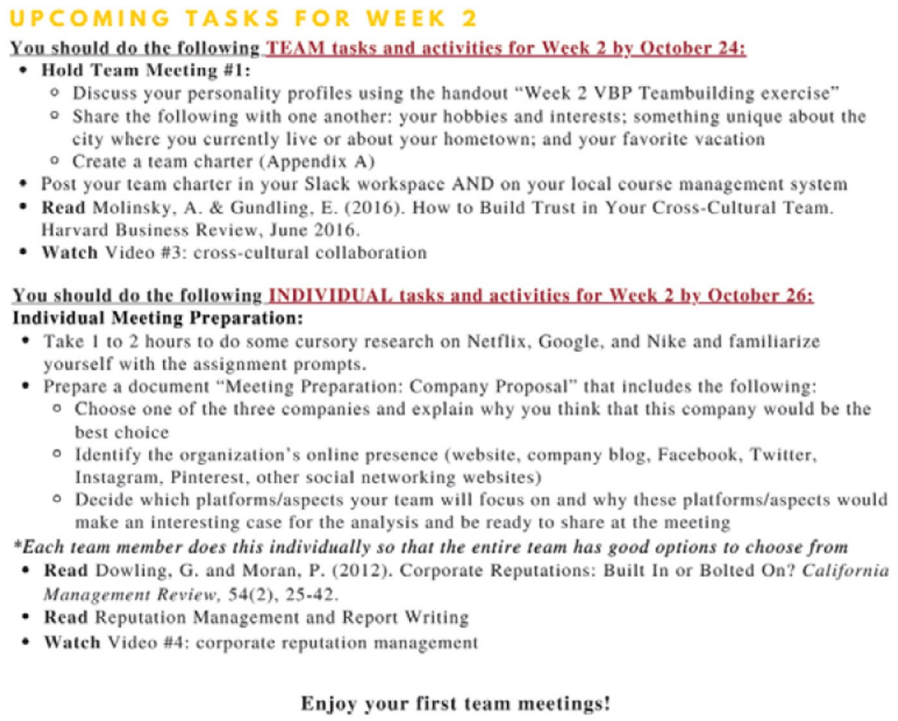
As an external way of structuring teamwork, DRN push deadlines and task details to the attention of the team members and serve as a common artifact that functions as external memory to decrease ambiguity and mitigate task-related misunderstandings. DRN introduce an element of formal authority to the otherwise non-hierarchical, self-managed team. Such a hierarchy has been found to increase certainty and coordination in teams (Halevy et al. 2012). The better coordination that formal authority fosters mitigates task conflicts, reduces distrust, and balances out an uneven distribution of tasks. Hence, DRN are a digital facilitation technique that may increase performance in high-coordination teams (Gimpel et al. 2023). The encoded information within reminder emails allows team members to revisit the team goals, expected deliverables, and deadlines so that it should become easier to build shared understanding of the goals and plan accordingly. Team members should have more clarity about their task goals, which should facilitate their task coordination. When GVT struggle with agreeing on a joint work goal, role, and task distributions, they have more difficulties trusting their team members that everyone will deliver their assigned tasks in the agreed timeframe and quality (Cheng et al. 2021). Yet, process standardization mitigates the negative effects of global team dispersion on coordination (Lee et al. 2013). In summary, DRN provide role, task, and time clarity to team members. As such, DRN standardize team processes and can mitigate some of the difficulties of GVT for coordination. When team members have a hard time estimating their virtual teammates' competencies, working styles, and environmental restraints, DRN can provide guidance on how to manage and coordinate the work towards a common goal. Thus, we hypothesize.

Hypothesis 4 Perceived coordination quality mediates the relationships between digital reminder nudges and PS.

3 Methods

3.1 Sample and Data Collection

Our study consists of survey data from GVT in which participants interacted in a real-world setting. The task, study environment, and methods of data collection were adapted from (Fleischmann et al., 2023). The study environment was controlled in the sense that teams had similar tasks, worked in similar-sized groups, and had identical instructions and project conditions. All teams completed a consulting project for a large multinational organization in the technology industry. Teammates were dispersed around the globe, never met in person during their 7-week project and did not know each other nor had worked together before the project. Teams produced a report of their analysis, findings, and recommendations for a client. Instructions for the project, including goals, tasks, deliverables, and deadlines, were communicated at the beginning of the project. Additionally, weekly email reminders were sent to participants each Monday morning. These DRN included a reminder of upcoming tasks and deliverables, and a recommendation and the sender's signature in accordance with Zavaleta Bernuy et al., (2022). Figure 2 visualizes a DRN, which was sent in the second week. It makes the tasks and roles transparent that the GVT members



UPCOMING TASKS FOR WEEK 2

You should do the following TEAM tasks and activities for Week 2 by October 24:

- **Hold Team Meeting #1:**
  - Discuss your personality profiles using the handout "Week 2 VBP Teambuilding exercise"
  - Share the following with one another: your hobbies and interests; something unique about the city where you currently live or about your hometown; and your favorite vacation
  - Create a team charter (Appendix A)
- Post your team charter in your Slack workspace AND on your local course management system
- **Read** Molinsky, A. & Gundling, E. (2016). How to Build Trust in Your Cross-Cultural Team. Harvard Business Review, June 2016.
- **Watch** Video #3: cross-cultural collaboration

You should do the following INDIVIDUAL tasks and activities for Week 2 by October 26:

Individual Meeting Preparation:

- Take 1 to 2 hours to do some cursory research on Netflix, Google, and Nike and familiarize yourself with the assignment prompts.
- Prepare a document "Meeting Preparation: Company Proposal" that includes the following:
  - Choose one of the three companies and explain why you think that this company would be the best choice
  - Identify the organization's online presence (website, company blog, Facebook, Twitter, Instagram, Pinterest, other social networking websites)
  - Decide which platforms/aspects your team will focus on and why these platforms/aspects would make an interesting case for the analysis and be ready to share at the meeting

**Each team member does this individually so that the entire team has good options to choose from*

- **Read** Dowling, G. and Moran, P. (2012). Corporate Reputations: Built In or Bolted On? *California Management Review,* 54(2), 25-42.
- **Read** Reputation Management and Report Writing
- **Watch** Video #4: corporate reputation management

Enjoy your first team meetings!

Fig. 2 Screenshot of DRN in week 2

need to accomplish and utilizes the availability heuristic (Caraban et al. 2019) to help team members keep tasks fresh in mind.

A total of 235 individuals in 96 teams participated in the project. All teams had 5 or 6 team members and were composed to reflect similar levels of diversity. Each team consisted of 2 or 3 US-based team members and team members from at least two other countries. The three most represented countries in the sample are USA, India, and Germany. Participants were mostly Gen Zers (from birth year 1997) with some Millennials (born between 1981 and 1996) that were enrolled in an undergraduate or an MBA program at one of 13 participating institutions in 7 countries on 3 continents. In total, participants in the study come from 23 different countries originally. Participants were mostly female, aged 21 to 25, had high English proficiency, and had never used Slack, the collaboration platform, before.

Data was collected via quantitative surveys before the teams began working together, at the beginning of October 2022, and after the project had ended in late November 2022. Pre- and post-project survey responses were matched using person-specific identifiers. The response rate was at 58% for the pre-project survey and 53% for the post-project survey. Of the 532 participants in the project, 235 participants completed both the pre- and the post-survey.

3.2 Measures

PS was adapted from Edmondson's (1999) scale and measured on the individual level using a 6-item version (Fleischmann et al. 2021). Items included "It is safe to take a risk on this team." and "People on this team sometimes rejected others for being different." (reverse-coded). The answer scale ranged from 1 (strongly disagree) to 7 (strongly agree). Perceived coordination quality was measured with four items and adopted from Hoegl, Weinkauf, and Gemünden (2004). Perceived effectiveness of TBI was measured with four self-developed items, which asked how well team members helped to stay on top of temporal milestones, time task achievement, check each other's' task progress or stick to agreements. Perceived effectiveness of DRN was assessed with self-developed items, which covered the notion that reminder e-mails helped to stay focused on deadlines, provided relevant information, made information salient, and to remember information.

We also controlled for a participant's belonging to a team (teamID) as better performing teams are likely to experience less conflict, which may potentially affect PS. Moreover, cultural differences in GVT can lead to miscommunication (Adler and Gundersen 2001) and coordination issues (Espinosa et al. 2007; Kiely et al. 2022). Many of these issues stem from differences in the communication style of a culture, which is covered by the concept of context orientation and describes the extent to which team members communicate implicitly and indirectly (Hall 1989). We tracked participants' country of origin as a proxy for high or low-context orientation (Van Everdingen and Waarts 2003). 130 participants were from low-context orientation cultures, which included the U.S.A and Germany. 30 participants were from high-context orientation cultures such as Taiwan, China, and India. The other 48 participants were from countries that are considered to have medium context orientation.

The variables TBI, DRN, COO, and PS were collected as part of the post-survey, while the country of origin was collected in the pre-survey. All items were measured on the individual level. We ran an ANOVA analysis to assess if there exist significant differences between teams, which would warrant a group-level analysis. However, the findings did not support a group-level study, so that we proceeded with our analysis. We also assessed a potential presence of common method bias (CMB). We conducted Harman's test, which revealed that the first factor of the unrotated exploratory factor solution accounts for 46.6% and thus suggests that CMB is not an issue in the study (Tehseen et al. 2017).

4 Findings

4.1 Measurement Model

In a first step, we performed confirmatory factor analysis in R 2023.03.0 using the lavaan package (Rosseel 2012) to assess validity and reliability (see Table 4 and 5 in the appendix) of the instruments and model fit. The constructs PS, TBI, DRN, and coordination were operationalized as latent constructs with reflective indicators. All results were bootstrapped with 5000 iterations.

We assessed reliability of all reflective constructs with standardized factor loadings and composite reliability. We dropped three items from the PS scale due to low factor loadings affecting reliability. After deletion, standardized factor loadings were between 0.769 and 0.937; thus beyond the conventional threshold of 0.708 (Hair et al. 2011). Composite reliability was between 0.827 and 0.946, which is higher than the conventional threshold of 0.7 (Hair et al. 2011). Convergent validity of all reflective constructs was measured with Average Variance Extracted (AVE) and the AVE of all latent variables was beyond the recommended threshold of 0.5 (Hair et al. 2011). Finally, discriminant validity for all reflective constructs was assessed using the Fornell-Larcker criterion, which suggests that the AVE of each latent construct should be higher than its squared correlation with other latent constructs (Hair et al. 2011). All reliability and validity tests (see Table 4 and 5 in the appendix) were deemed satisfactory, which is why we proceeded to assess the model fit.

We ran two models to gradually assess how the mediator variable can explain the effects of DRN and TBI on PS. We ran one model to measure the main effect of the two independent variables on PS. The second model measured the mediating role of coordination. Model fit was assessed with the fit indices root mean square error of approximation (RMSEA < 0.08), comparative fit index (CFI > 0.9), and Tucker-Lewis Index (TLI > 0.9). All fit indices reached the conventional thresholds (Gefen et al. 2011), which can also be taken from Table 1.

4.2 Structural Model

The hypotheses were tested using structural equation modelling (SEM) using the Lavaan package in R (version 1.3.073), and the regression results are provided in

Table 1 Model fit indices

Model	N	RMSEA	CFI	TLI
Model 1: main effects	235	0.068	0.973	0.964
Model 2 + 3: mediation effects	235	0.067	0.965	0.956

Table 2. Hypothesis 1 suggested that more effective TBI lead to higher PS, which is consistently supported throughout our tested models. Hypothesis 2 suggested that more effective DRN result in higher PS. This relationship could only be supported in our main effects model, which disregarded coordination as covariate. Hypothesis 3 tested the quality of coordination in the team as a mediator for TBI. The results in Table 3 show that coordination quality fully mediates the relationship between TBI and PS (Ind. Eff. = 0.718 [0.464, 1.051], Dir. Eff. = 0.318 [0.034, 0.172]). We also tested Hypothesis 4, which suggested that coordination quality mediates the path between the perceived effectiveness of DRN and PS. Since the confidence intervals cross zero, the indirect effect is not significant so that H4 was not supported. Thus far, the findings suggest that coordination mediates the effects of TBI on PS, but DRN foster PS directly and not via coordination.

We also assessed the impact of the control variables. Whereas the participants' belonging to a team did not affect coordination quality or psychological safety, the analysis revealed a significant moderation effect of context orientation (CO). The moderated mediation analysis showed that the moderation effect did not moderate the indirect path (Ind. Eff. = 0.684 [0.450, 1.001]). But, the direct paths between TBI as well as DRN and psychological safety were moderated by context orientation. PS was significantly lower when team members considered their TBI to be highly effective and were high-context communicators compared to low-context communicators. In turn, PS was significantly higher for team members who considered their DRN highly effective and were high-context communicators compared to low-context communicators.

5 Discussion and Implications

GVT heavily rely on collaboration technology to execute their tasks. However, the nature of virtual collaboration introduces numerous challenges, underscoring the crucial need for teams to cultivate a high level of PS. Research has consistently demonstrated that PS is a pivotal predictor of a team's ultimate success (Edmondson 2018; Frazier et al. 2017; Newman et al. 2017), but understanding the effects of specific interventions is unclear. This study addresses this critical knowledge gap by investigating how the implementation of TBI and DRN influences PS.

Our findings provide several valuable insights for research and practice. First, the perceived effectiveness of TBI and DRN contribute to an increase in PS in GVT. Second, we discovered that the impact of TBI on PS is fully mediated by the perceived quality of the team's coordination process. However, our study did not find that coordination quality mediates the effect of DRN on PS. This result leaves open

Table 2 Results of structural equation modeling

	Main effect model	Mediation model		Moderated mediation	
	DV: Psychological safety Model 1	DV: Coordination quality Model 2	DV: Psychological safety Model 3	DV: Coordination quality Model 4	DV: Psychological safety Model 5
	Estimate (St.Dev) [lower CI, upper CI]	Estimate (St.Dev) [lower CI, upper CI]	Estimate (St.Dev) [lower CI upper CI]	Estimate (St.Dev)[lower CI upper CI]	Estimate (St.Dev) [lower CI, upper CI]
Digital reminder nudge	**0.156 (0.078)*** [−0.005, 0.306]	0.137 (0.074) [−0.005, 0.296]	0.040 (0.067) [−0.087, 0.172]	0.158 (0.117) [−0.053, 0.405]	0.127 (0.096) [−0.028, 0.377]
Team-based intervention	**1.066 (1.165)***** [0.761, 1.403]	**1.038 (0.145)***** [0.769, 1.343]	**0.318 (0.169)** [0.034, 0.172]	**1.020 (0.154)** [0.731, 1.323]	**0.293 (0.166)** [0.008, 0.650]
Coordination quality	–	–	**0.685 (0.118)** [0.451, 0.920]	–	**0.671 (0.119)** [0.449, 0.911]
Team ID	−0.022 (0.003) [−0.007, 0.003]	0.001 (0.003) [−0.004, 0.006]	−0.002 (0.002) [−0.007, 0.002]	0.002 (0.003) [−0.003, 0.007]	−0.002 (0.002) [−0.006, 0.003]
Context orientation	**0.177 (0.070)** [0.049, 0.322]	0.033 (0.064) [−0.089, 0.160]	**0.162 (0.056)**** [0.061, 0.281]	0.016 (0.074)	
[−0.145, 0.152]	0.166 (0.060) [−0.006, 0.230]				
DRN x Context orientation				0.044 (0.139)	
[−0.156, 0.427]	**0.157 (0.101)** [0.015, 0.449]				
TBI x Context orientation				−0.083 (0.128) [−0.423, 0.113]	**−0.156 (0.097)** [−0.401, −0.001)]

Bolded values show significant effects according to bootstrapping with 5000 samples

* $p<0.5$, ** $p<0.01$, *** $p<0.001$

Table 3 Results of mediation and moderated-mediation analysis

Path	Indirect effects	Total effects	Type of mediation
DRN→COO→PSY	0.098 [−0.003, 0.242]	0.170 [0.014, 0.330]	No mediation
TBI→COO→PSY	0.718 [0.464, 1.051]	1.042 [0.734, 1.378]	Full mediation
DRN × CUL→FCOO→PSY	0.029 [−0.096, 0.316]	0.156 [−0.031, 0.457]	No moderated-mediation
TBI × CUL→COO→PSY	−0.056 [−0.325, 0.071]	0.237 [−0.153, 0.649]	No moderated-mediation

the question of how DRN foster and enhance PS within GVT. We initially hypothesized an information processing-based explanation as the DRN makes information on roles and responsibilities more salient, which allows leveraging the availability heuristic, framing bias, or the messenger effect (Haki et al. 2023). This should have assisted teams in surmounting coordination challenges. However, our data does not confirm this mediation path. We offer two alternate explanations. First, DRN affect PS through an emotional route. Related research has shown that DRN provide a motivational boost, but could also lead to frustration and panic (Weintraub et al. 2021; Zavaleta Bernuy et al. 2022). Second, DRN could foster PS through other collaboration processes. Gupta et al. (2024) found that nudges that structure complex choices, which applies to our DRN, fostered skill use processes that resulted in better team outcomes. Further research is warranted to delve deeper into the possibility of a serial mediation route via TBI, considering either an emotional route or alternative collaboration processes to foster PS. This will provide a more comprehensive understanding of the mechanisms at play.

Third, we offer empirical evidence that team members' context orientation and their perceived effectiveness of TBI or DRN matter for boosting PS. High-context communication cultures prefer to communicate more indirectly and implicitly instead of codifying information (Hall 1989). Following this, high-context communicators should benefit from effective TBI and low-context communicators should benefit from effective DRN, which codify team tasks and deadlines to boost their PS (Fleischmann et al., 2023). Interestingly, the anticipated moderation effect is supported by our data but in opposite directions. One explanation is that the cultural backgrounds of participants in this study differed from (Fleischmann et al., 2023). Whereas high-context communicators in (Fleischmann et al., 2023) were mainly from China and Taiwan, a large proportion of the high-context communicators in this study were from India. While both cultures are considered high-context communicators, they differ in many regards, such as punctuality (Ursu and Ciortescu 2021). The transparency that DRNs gave to time-sensitive issues, such as deadlines, might have helped high-context communicators with tendencies to flexible scheduling (such as Indians) to align better with expectations that are important in low-context cultures.

Additionally, many of the low-context communicators are from the United States and native English speakers. They rely less on specific, written DRN and hence, perceived them as less effective in establishing PS than non-native speakers (Klitmøller and Lauring 2013). Large cross-cultural studies such as the work by Hofstede

(2001) and the (House et al., 2004) have found cultural differences in ICT adoption, attitudes and usage. Many of the high-context cultures in our sample have high rates of ICT adoption in their countries and may be more inclined to view DRN positively than team members from cultures with lower ICT adoption (Erumban and de Jong 2006; Krishnan and AlSudiary 2016) and having low context orientation. These relationships will need further investigation.

Our findings have implications for the literature stream on PS (Edmondson 2018; Frazier et al. 2017; Newman et al. 2017). Our results show that successful interventions of TBI and DRN foster PS. Related literature established that personality traits (Frazier et al. 2017), effective learning behaviors, and leaders (Edmondson and Bransby 2023) are likewise influencing factors for establishing psychologically safe teams. The findings of this study provide nuance to this knowledge base as we show that TBI, which are reflective of a supportive work context (Frazier et al. 2017), foster this effect by influencing the quality of the coordination processes in the team.

Our findings also advance literature on digital nudging (Schneider et al. 2018; Thaler and Sunstein 2009) and particularly on nudging in the team context (Gupta et al. 2019, 2024; Haki et al. 2023). Our findings show that DRN foster PS in teams directly by focusing the attention of team members on deadlines, expectations, and upcoming tasks. Thus, also digital nudges, such as DRN can be considered digital intervention tools driving collaboration in GVT as has been recently suggested (Gupta et al. 2024). DRN drive PS and thus foster good team performance (Cardon et al. 2022) independently of a team member's context orientation. Thus, DRN can be effective, culture-independent team interventions even though their magnitude of effect is smaller than those of TBI. A striking non-finding is that DRN do not influence teams' coordination processes. The underlying mechanism through which these nudges foster PS remains unknown; therefore, we call for future research in this area.

Finally, the results of this study have implications for practitioners and particularly managers of GVT. We provide evidence that TBI is an important form of group intervention that fosters PS (Frazier et al. 2017). Given the cultural effects at play, it is recommended that managers train their teams in intercultural communication to acknowledge each others' potential work communication preferences to avoid team conflict, which could harm PS. Moreover, DRN can be a low-cost intervention tool (Gupta et al. 2024) for managers to foster PS in GVT.

6 Limitations and Future Research

This study has a few limitations. This research was exploratory and observational in nature, which comes with some shortcomings (e.g., no control group, confounding, no randomization or treatment), but allows investigating the relationship between exposures and outcomes, as well as causal mechanisms (Rijnhart et al. 2021). To mitigate confounding effects, we observed teams in a highly controlled setting by controlling team size, composition of teams, age, and background. Future research could devise an experimental design to

manipulate the effectiveness of TBI and DRN. Additionally, PS and the effectiveness of interventions were self-reported on the individual level (Shuffler et al. 2018). Future research could employ team-level measures, rely on other measurements, and study team in an organizational environment.

Another limitation concerns the design of the DRN. Weekly reminders were sent via e-mail from the professor, who can be considered an external authority. This way, e-mail as a communication channel was different from the communication channel where team members accomplished their work. Integrating the reminder nudge into the collaboration environment could have made its information more salient and available to team members. Thus, it is recommended to test different implementations of a DRN to see if the magnitude of effect on PS can be enhanced.

DRN and TBI were measured using self-developed scales. We developed the scale based on observations made in previous experimental rounds. Even though reliability, convergent, and discriminant validity reached the conventional thresholds, establishing content validity did not follow a systematic approach. Therefore, we call for future research to test content and construct validity.

The present study considered TBI and DRN as independent interventions to foster a supportive work environment, which has shown to facilitate PS (Frazier et al. 2017). It is conceivable that external interventions in the form of DRNs moderate the effect of TBI on PS or that TBI mediates the effect of DRNs on PS. However, more empirical evidence needs to be collected to theoretically argue for such an interdependency of external and internal team interventions.

This study also opens avenues for future research. Human-AI teams are becoming more prevalent in organizations. Teamwork structuring, coordination, and PS may differ in such teams compared with all-human teams. Initial research suggests that, for example, human-AI teams are rigid in their coordination and have difficulties to flexibly adapt to changing circumstances (Demir et al. 2019). It remains to be explored how this effect plays out in relation to PS. Autonomous agents may be used in several roles in teams (Siemon 2022), e.g. to aid coordination by providing real-time feedback on coordination to adjust to the team's needs (Wiltshire et al. 2022).

Appendix

See Tables 4 and 5.

Table 4 Items, validity, and reliability

Latent variable	ID	Item	F.L	C.R	AVE
Perceived effectiveness of digital reminder nudges	DRN1	The VBP weekly e-mail reminders helped me stay focused on the deadlines for my deliverables	0.878	0.946	0.815
Digital reminder nudges	DRN2	The VBP weekly e-mail reminders provided relevant information for my taskwork	0.913		
	DRN3	The VBP weekly e-mail reminders made information for my taskwork salient	0.937		
	DRN4	The VBP weekly e-mail reminders helped me remember information	0.881		
Team-based interventions	TBI1	In my group, we have reminded each other of important temporal milestones	0.838	0.840	0.710
	TBI2	In my group, we have urged one another to finish subtasks on time	0.829		
	TBI3	In my group, we have prompted each other to stick to agreements	0.861		
	TBI4	In my group, we have checked on each other about task progress	0.842		
Psychological safety	PSY1	People on this team sometimes rejected others for being different. (reversed)			
	dropped	0.827	0.614		
	PSY2	I was afraid of making mistakes. (reversed)	dropped		
	PSY3	I felt at ease to speak up about problems and tough issues	dropped		
	PSY4	It was easy to ask for help from my team members	0.795		
	PSY5	I felt appreciated as a member of my team	0.786		
	PSY6	It is safe to take a risk on this team	0.769		
Coordination	COO1	Processes and activities are well coordinated within our team	0.862	0.910	0.717
	COO2	Duplicated and overlapping activities are avoided	0.813		
	COO3	Discussions within the team are conducted constructively	0.849		
	COO4	Conflicts with team members are settled quickly	0.815		

F.L. Standardized factor loadings, *C.R.* Composite reliability

Table 5 Discriminant validity

	PSY	DRN	TBI	COO
PSY	*0.783*			
DRN	0.348	*0.903*		
TBI	0.690	0.346	*0.843*	
COO	0.777	0.344	0.701	*0.847*

The values on the diagonal represent the square root of the AVE; the other values are correlation coefficients

PSY Psychological safety, *DRN* Digital reminder nudge, *TBI* Team-based interventions, *COO* Coordination quality

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Declarations

Conflict of interest The authors declare that they have no conflict of interest

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