Smarter Tech ↔ Better Teams

Citation for published version (APA):
Gevers, J. M. P. (2024). *Smarter Tech ↔ Better Teams: A Dual Imperative*. Technische Universiteit Eindhoven.

Document status and date:
Published: 16/05/2024

Document Version:
Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

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Download date: 17. May. 2024

Prof.dr. Josette Gevers
May 16, 2024

INAUGURAL LECTURE

Smarter Tech ↔ Better Teams: A Dual Imperative

EINDHOVEN
UNIVERSITY OF
TECHNOLOGY

DEPARTMENT OF INDUSTRIAL ENGINEERING & INNOVATION SCIENCES

INAUGURAL LECTURE PROF.DR. JOSETTE GEVERS

Smarter Tech ↔ Better Teams: A Dual Imperative

May 16, 2024
Eindhoven University of Technology

Introduction

Dear family, friends, and colleagues,

Welcome, and thank you for coming to my inaugural lecture. My lecture is about teams; more specifically, work teams. Work teams are groups of people collaborating to achieve organizational goals (for further details, see textbox 1: What is a team?). They are the backbone of our working society. Whether in industry, healthcare, or science, teams are a central building block of organizations, an important source of competitive advantage and a crucial means for organizational productivity and innovation (Grote & Kozlowski, 2024). Teams provide many benefits, especially for tackling complex problems. They bring extra resources and flexibility in using them. They facilitate the integration of diverse perspectives and allow for heightened creativity and better decision-making. Teams create the potential for team members to realize ambitions that none of them could accomplish alone (Hackman, 1998).

What is a team?
A team is "a distinguishable set of two or more people who interact, dynamically, interactively, and adaptively toward a common and valued goal/objective/mission" (Salas, Dickinson, Converse, & Tannenbaum, 1992, p.4.). In work teams, people collaborate to attain organizational goals. There are at least six different types of work teams: project teams, production teams, service teams, management teams, action teams such as surgical teams and fire fighter crews, and parallel teams such as quality circles and continuous improvement teams (Sundstrom, 1999). The common denominator across all teams is that members have at least one shared goal and depend upon one another to reach that goal. A group of people waiting on a bus is not a team. They happen to want to get on the same bus, but they each have their own destination, and are not dependent on each other for getting there. Only once people need each other for information, resources, knowledge, skills, and collaborative efforts to accomplish tasks and meet objectives, does a group of people become a team.

Textbox 1.

Teams can do amazing things. Consider the remarkable speed at which the first vaccines were developed following the onset of the COVID-19 pandemic. Thanks to the collaborative efforts of scientists and researchers across the globe, COVID-19 vaccines were developed and brought to market in record time. Similarly, teamwork has played a pivotal role in developing transformative technologies like smartphones and the internet, which – for better or worse – have now come to dominate our contemporary society. Tech giants like Google claim that teamwork is core to their success and, when asked, ChatGPT itself confirms that teamwork was central to its development, as well as that of other sophisticated artificial intelligence (AI) applications.

Indeed, teams can do amazing things, but success is not a given. All too often, teams just aren't cutting it. They simply fail to live up to their promise and the benefits of collaboration are diminished due to problems with coordination and motivation. Progress gets stifled by a lack of direction, there's conflict and confusion about strategies and responsibilities, and people may start to feel drained and unhappy. These matters are not trivial; countless examples demonstrate that poor teamwork can lead to disasters, from mild industrial accidents to catastrophic nuclear powerplant meltdowns, causing loss of life, environmental damage, and substantial financial costs.

One of the primary reasons why teamwork is challenging stems from the fact that teams are diverse. Work teams increasingly consist of people from different cultural, organizational, and disciplinary backgrounds. The members of these teams may not only speak a different language – both in terms of mother tongue and disciplinary language – but may also have very different objectives, expectations, and ways of working and decision-making. These differences can easily lead to misunderstandings and conflicts, even more so when team members are dispersed across offices and time zones, relying on digital tools and platforms to shape their collaboration. Diversity, distance, and digitization make teams prone to communication mishaps and 'us versus them' thinking, making working together effectively and harmoniously inherently difficult (Haas & Morteson, 2016).

But that's not all. Rising levels of workplace volatility force teams to be ever more flexible and adaptive to cope with dynamic work conditions (Maynard et al., 2015). Every day, teams meet unforeseen events, shifting demands, and changing circumstances. A teammate calls in sick, a machine breaks down, a client puts in a last-minute request, or – considerably more dramatic – severe postpartum bleeding leads to the rapid deterioration of a mother's condition after giving birth.

Evidence shows that teams are not necessarily very good at responding to such unexpected (crisis) events (Driskell et al., 2018; Stakowski et al., 2009). At least in part, this is because the stress induced by crises tends to narrow people's attentional focus from a broad team perspective to a more individualistic self-focus (Driskell et al., 1999; Karau & Kelly, 2004). As a consequence, team members lose sight of what others are doing, leading to a lack of coordination in their individual actions. This may have far-reaching consequences, especially in high-stakes environments such as emergency medicine.

So, in order for modern work teams to be effective, they must not only bridge individual differences and develop a common mindset to accomplish shared objectives but also need to carefully coordinate their interdependent actions to adapt to changing conditions. How do teams do that? Exactly this question is what my field of research is all about.

The science of team effectiveness

Ever since I started my career at TU/e almost 25 years ago, my work has been dedicated to studying team effectiveness in complex and dynamic organizational settings. I started out, in 1999, as a doctoral candidate under the supervision of Christel Rutte and Wendelien van Eerde on a project about the role of time in organizations, more specifically on the question of why so many teams so often fail to meet their deadlines. At the dawn of the Y2K, as tech companies were fiercely trying to outsmart the Millennium Bug, there couldn't have been a timelier topic. The salience of that worldwide deadline suddenly made understanding and managing time within organizations of pivotal importance.

At the time of application, there were two projects: one focused on how individual employees meet deadlines and the other on how teams accomplish this.
During the job interview, Christel asked me which project I preferred. In a bit of a knee-jerk decision, I chose the one on teams. I motivated my answer by saying it resonated with my background in social psychology. In hindsight, that response may have been somewhat misplaced considering that the job involved longitudinal field-based team research, studying real teams in real organizations over extended periods of time (in some cases, up to two years). Quite a labor-intensive and time-consuming way of doing research and one that stood in stark contrast to the prevailing trend in social psychology at the time. Despite once being the cradle of small group research, social psychology had largely abandoned field studies in favor of the much less time-consuming lab-based examination of individual responses to the simulated or imagined rather than the actual presence of others. This shift was met with great dismay by scholars interested in real groups and teams, so much so that in the late eighties, Ivan Steiner (1986), a respected social psychologist and prominent group researcher, went so far as to declare that team research was dead. He found his words refuted a couple of years later by John Levine and Dick Moreland (1990), two potentially even more prominent team researchers, arguing that team research was, in fact, "alive and well, but living elsewhere" (p. 620). Team research had moved in with work and organizational psychology. Inspired by the success of the Japanese manufacturing industry, which had started to strategically structure work around teams rather than individual jobs, the torch of team research was picked up by work and

organizational psychologists who were eager to understand the effectiveness of teams in organizations (Ilgen, 1999). So, in a somewhat ironic twist, the response that apparently convinced Christel that I was the right person for the job ended up leading me to switch from social psychology to work and organizational psychology.

So, by the time I entered the team research arena, work teams were the center of attention. I joined the force of scholars trying to unravel how teams get to work together effectively and how desirable team processes can be leveraged to maximize corporate success. Being a team researcher at TU/e had considerable advantages. The prestige of the technical university served as the proverbial foot in the door, granting me access to companies in the region that generously welcomed me to study their teams. Armed mainly with surveys administered at strategic time points – notably at the beginning, midpoint, and near the end of a project team's life cycle – I studied how team members planned and executed their work toward timely completion despite differences in how they viewed, used, and valued time. Later, I expanded my horizon to a wider range of processes and outcomes, including team cognition, team leadership, team learning, team creativity, team innovativeness, team adaptation, and team member well-being, also because of their relevance to our master's programs in Operations Management and Logistics and Innovation Management. Focusing mostly on cognitive aspects of team functioning, I consistently found that team effectiveness relies on a shared understanding of collaborative goals, roles, and processes that enhance synergistic, innovative, and adaptive performance.

Today, after more than half a century of team research, the field is said to have accumulated solid evidence of a 'Science of Team Effectiveness' (Kozlwoski & Ilgen, 2006; Kozlowski, 2018). There's an impressive body of evidence-based knowledge that outlines core team process factors that are crucial for team effectiveness, as well as actions and interventions in team design, composition, training, and leadership that can be used to enhance those processes (Kozlowski, 2018; Salas et al, 2015). But there are two ways in which our current knowledge falls short: a) we actually don't know how teams really work, and b) we don't know to what extent the current knowledge base is future-proof.

Let me explain.

UNDERSTANDING TEAM DYNAMICS

Most team research has been conducted within the realms of famous team effectiveness models, such as the input-process-output (IPO) model (McGrath, 1964), and its successor, the input-mediator-output-input (IMOI) model (Ilgen et al., 2005), as shown in Figures 1 and 2 respectively. The essence of these models is that inputs such as team composition, task characteristics, and organizational context (e.g., structure, resources, information, and rewards) influence the cognitive, behavioral, and attitudinal processes through which teams transform input into outputs.
The processes are what we – in everyday language – call teamwork, as distinct from taskwork (Marks et a., 2001). While taskwork represents what it is that teams are doing, teamwork describes how they are doing it with each other. It includes a wide range of processes such as team communication, coordination, cooperation, and conflict management (Salas et al., 2015). Over time, these processes give rise to 'emergent states' (Marks et al., 2001) that describe team properties like trust, cohesion, and shared cognition, that influence how teamwork further unfolds.
Outputs represent the outcomes of team members' efforts, not only in terms of quantity, quality, and timeliness of products and services, but also in terms of team member satisfaction and team viability (i.e., a team's willingness to work together in the future). Together, these are the three core dimensions of team effectiveness (Hackman, 1987).

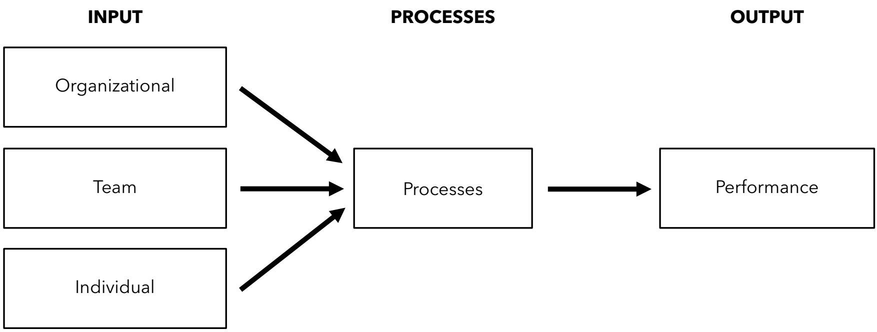

Figure 1. Input-Process-Output (IPO) Model (based on Mathieu et al., 2008).

Although these frameworks provide a useful overview of the factors that contribute to team effectiveness, they are criticized for providing little insight into how teams really work (Cronin et al., 2011; Kozlowski, 2015). The IMOI model includes recursive relationships and feedback loops to indicate that the relationships go both ways, but, in essence, the processes and states remain trapped in a static box. But teams are not static; they change and evolve. A team that you start a project with is not the same as the one you end it with. Team processes and states are subject to continuous change. Therefore, an increasing number of team scholars have come to adopt a more contemporary perspective, approaching teams as multilevel, dynamic systems embedded within a broader organizational and task context requiring continuous adaptation to changing conditions and demands (Cronin et al., 2011; Klein & Kozlowski, 2000). According to this perspective, it is at the intersection of the broader organizational and task context and members' individual characteristics that team members get to interact and produce team processes and states that will change and evolve over the entire team's life cycle (Kozlowski, 2015). But how these dynamics emerge and unfold has largely remained unaddressed. How does trust come about? Or shared cognition? How long does it take for teams to develop such properties and how do they change over time? What do these trajectories look like and why? Research investigating these dynamics is gaining momentum but poses significant challenges as it requires intense longitudinal designs and sophisticated measurement tools (Kozlowski & Chao, 2012). The traditional survey-based approaches that I mentioned earlier are absolutely inadequate for this purpose.

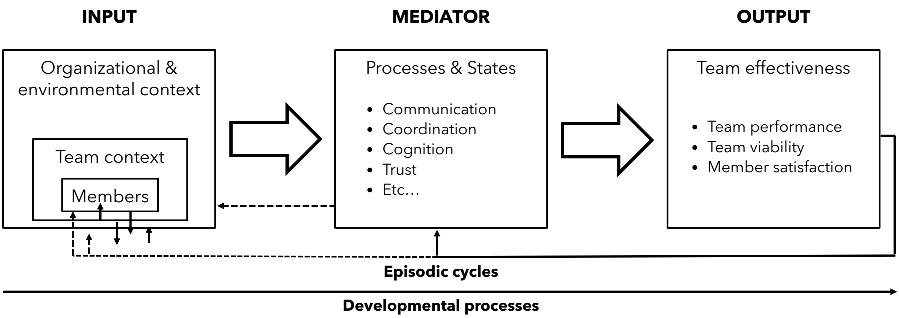

Figure 2. Input-Mediator-Output-Input (IMOI) Model Team Effectiveness Framework (based on Mathieu et al., 2008).

Fortunately, technological advancements in AI are opening up intriguing opportunities to capture team dynamics, thereby enabling a better understanding of how teams really work, and paving the way to monitoring and supporting team functioning in real-time as it unfolds (Wiltshire et al., 2022). As such, AI-based applications could significantly advance team theory and practice by honing deeper insight into team dynamics and by providing crucial support during crisis events. Paradoxically, artificial intelligence is also the reason why our current knowledge base may not be exactly future-proof.

ONBOARDING ARTIFICIAL INTELLIGENCE IN TEAMS

At the dawn of the Fifth Industrial Revolution, it is important to take stock of the fact that the teamwork landscape is drastically changing. The staggering prominence of artificial intelligence in the workplace can be expected to have major implications for the future of teamwork. Advancements in artificial intelligence have reached the point where intelligent agents, like AI and robots, can make independent, goal-directed decisions, allowing them to work alongside humans not as passive tools but as proactive teammates (Larson & DeChurch, 2020; O'Neill et al., 2022). Many people worry about AI and robots taking their jobs, but it is far more probable that people will work together with these intelligent machines. Technology is not nearly smart enough to fully act on its own, and the benefits are largest when humans and AI closely collaborate, complementing each other's strengths and weaknesses (Centeio Jorge et al., 2022). Hence, the prospects are that, in the future, collaborative work in healthcare, logistics, and manufacturing, as well as other sectors, will be performed in 'human-autonomy teams' (HATs) in which humans collaborate with autonomous intelligent agents on joint tasks toward realizing common objectives (O'Neill et al., 2022).

The onboarding of artificial intelligence in teams can do harm as well as good (Seeber et al., 2020). The visions of Industry 5.0 describe sustainable, resilient, and human-centered designs of sociotechnical systems that allow for smooth collaboration between humans and AI (Kaasinen et al., 2022). When designed according to this vision, such systems could indeed significantly enhance workplace productivity, accuracy, efficiency, and safety and serve as an important means to addressing shortages of skilled workers in various sectors. But, working with artificial teammates will not be sustainable or empowering for humans if these intelligent teammates fail to grasp the essence of teamwork (Begerowski et al., 2023). Any system design that cuts corners in terms of human-centeredness could result in people having to sacrifice their own autonomy, creativity, learning, and well-being to fit machine limitations (Kaasinen et al., 2022; Seeber et al., 2020). To ensure that the balance tips in the right direction, it is essential that we gain a better understanding of what it takes for humans and AI to work together effectively.

THE FUTURE OF TEAMWORK: A DUAL IMPERATIVE

So, on the one hand, AI might contribute significantly to advancing our understanding of team dynamics, while, on the other hand, it has us groping in the dark as to what future teamwork will look like. Therefore, one of the most interesting and urgent issues that team researchers face today is how to ensure that teams actually benefit from the integration of AI. That AI will actually make teams better, not only in terms of performance but also in terms of team member satisfaction and team viability. I will argue that addressing this issue creates a dual imperative. On the one hand, effective human-autonomy teaming relies on smart technology becoming smarter, such that AI and robots understand the essence of teamwork. The second imperative emerges when we invert the title of this lecture, implying that achieving smarter technology relies on better teams, more specifically on research teams mastering the art of cross-discipline collaboration to develop technology from a more holistic perspective. In the remainder of this lecture, I will explain the challenges associated with these imperatives, thereby also discussing some of my own work in these areas. This should then provide us with ample food for thought and a solid foundation for the more important part of today's event: the drinks.

Smarter tech → better teams

Smart technology is a popular term for a wide variety of devices, systems, and products that incorporate advanced technology to enhance their functionality, connectivity, and automation (Alter, 2020). There are various dimensions of smartness, but to keep it simple we can generally consider technology as 'smart' when it can perform tasks, make decisions, and adapt to user preferences without constant human intervention. At the lower end of the 'smartness' spectrum, we find technology like smartphones, wearable fitness trackers, and voice-activated home appliances. These devices can automate specific tasks and adapt to user preferences, but their level of autonomy is limited. Their behavior is fully programmed and they do not act on their own. At the other end of the 'smartness' spectrum are machines that, powered by AI, can autonomously make complex decisions using real-time data and adjust their actions without direct human intervention. These machines have a high level of autonomy, although they may still be overruled or vetoed by a human if necessary. I will refer to this category as autonomous intelligent agents.

TECHNOLOGY AS TEAMMATE

Over the last decade, the idea that AI could become an integral part of teams has developed from a promising vision into a reality. This can take many forms. AI can be largely invisible when embedded in a larger tool, like in autonomously driving cars; it can be virtual and displayed as text, like ChatGPT, or it can be embodied in a physical robot, such as a logistic or medical robot (Glikson & Woolley, 2020). AI can assist human workers in tasks ranging from assembly in manufacturing to diagnostics in healthcare to idea generation in research and development and crop and cattle management in agriculture.

Of course, humans working with technology is nothing new; robots have been part of our work processes for decades. So, why should we all of a sudden call them teammates? The designation of autonomous agents as teammates hinges on two factors: agency and interdependence (Murray et al., 2021; O'Neill et al., 2022). As agents get smarter, they go from just being tools used by humans to machines that can make decisions, take action, and exert influence on their own. This enables them to take on their own unique roles and responsibilities in task execution. With humans and agents each taking on part of a job, they become dependent on one another to complete it, which captures the essence of being teammates.

While this in itself would already be enough to qualify as a teammate, research indicates that agency and interdependence also prompt individuals to perceive autonomous agents as teammates (O'Neill et al., 2022). Studies show that as the level of agency and interdependence increases, people are more inclined to use notions of 'self' and 'other' and start showing politeness and gratitude toward agents (Nass et al., 1996; Walliser et al., 2017; Wynne & Lyons, 2018). People start to trust and rely on the agent and feel a stronger emotional bond, similar to the dynamics we see in teams that work with animals, like search and rescue dogs (Begerowski et al., 2023).

Given their technological qualities, the potential of artificial teammates is huge: they can process information much faster than we can, they are capable of much more precise and accurate execution of tasks, they can be deployed to work in hazardous environments, and they never get tired or bored. Combined with people's abilities for cognitive flexibility, creativity, social skills, emotional intelligence, and ethical and moral judgment, this should make a great team. Unfortunately, it is the teaming bit where issues arise. I will illustrate this with a couple of examples.

CHALLENGES IN HUMAN-AUTONOMY TEAMING

The first example involves the Da Vinci Xi Surgical System, a highly sophisticated medical robot that is used to perform minimally invasive surgery in, for example, urology and gynecology. The robot has multiple arms with surgical instruments, which are controlled by the surgeon with a pair of funny-looking joysticks. Working with the robot allows the surgeon to perform procedures with very high precision through a few tiny incisions. This results in less pain, less scarring, less risk of infection, and faster recovery, all of which are notable and commendable achievements.

I wonder if you notice anything peculiar about this surgical setup? In traditional surgery, medical professionals gather closely around the patient, exchanging instruments and instructions and often relying on physical contact to coordinate their actions. Here, the surgeon sits at the far end of the operation room, their head tucked away in the console, secluded from the patient and other medical staff. Nothing in this configuration even slightly suggests that conducting surgery is a collaborative effort in which the surgeon, surgical assistant, and anesthetist must work together closely to ensure the operation's success and the patient's safety. How could they take a crucial member of the team, typically the one leading the operation, and isolate them from the rest of the team? From a teamwork perspective, that just doesn't make sense.

Ethnographic analyses of the work processes involved in Da Vinci surgery, conducted in the Netherlands and the United States (Pelikan et al., 2018; Sergeeva et al., 2020), indicate that the surgeon's posture, vision, and manual dexterity are greatly enhanced but that the teamwork is considerably compromised by the robot design. Communication and coordination within the team are seriously hampered by the fact that the surgeon is 'cut off' from the rest of the OR. Also, staff report that it is difficult to maintain a good overview of what is going on (i.e., situation awareness) and also more difficult to stay in tune with each others' moods and feelings during the surgery. And although some other teamwork aspects, like the power dynamics within the team, changed in a positive way, team members – the anesthetist and operating assistant in particular – had to come up with several workarounds to allow them to do their jobs and maintain the proper functioning of the team as a whole. Hence, a clear example of the team having to adjust to the robot rather than the other way around.

Turns out Da Vinci was initially developed for remote surgery purposes, such that surgeons could perform operations in military situations without being physically present. This explains the "not-very-social" surgical setup, as one doctor characterized it (Sergeeva et al., p.1264). But the point I want to make is that working with a robot has important implications for teamwork; the design of a robot impacts not only how team members work with and relate to the robot but also how they work and relate to one another.

Now, Da Vinci isn't even an autonomous robot. It operates under full human control. It doesn't make decisions on its own and couldn't be expected to coordinate its behavior with others in the team. But autonomous robots should possess these abilities. Yet, as it stands, they lack the necessary skill for such coordination. Robots are typically designed for taskwork, not for teamwork. Even collaborative robots, designed to work alongside humans in a shared workspace such as in manufacturing and warehouses, have limited ability to detect social cues and to interpret and respond to social situations between humans and between humans and robots (Kragic et al., 2018; Lorson et al., 2023). They lack the kind of social awareness and responsiveness that is required for effective collaboration (Fiore et al., 2023), making it hard for them to engage in the most fundamental teamwork processes, such as communication and coordination (Kaasinen et al., 2022). In fact, what they have been made to be really good at is avoiding humans.

Humans, on the other hand, have difficulty reading, accepting, and trusting the collaborative qualities of their robotic counterparts. Trust is considered one of the most essential mechanisms for effective human-autonomy teaming (Ulfert et al., 2023). Consider the following example of a closed-loop ventilation system that is used in intensive care units (ICUs) to support critically ill patients with breathing problems. A common risk associated with ventilation is that the patient's lungs get damaged by a lack of synchrony between the ventilator and the patient's natural breathing rhythm. Closed-loop ventilators are intelligent in that they autonomously adjust the airflow based on continuous streams of patient-specific data to avoid ventilation asynchrony. The system significantly contributes to patient comfort and safety and may also reduce the workload of nursing staff as their role shifts from actively handling the ventilator to simply monitoring it. However, an eye-tracking study revealed that many nurses faced challenges in trusting the system (Buehler et al., 2021). This led them to check on patients more frequently than strictly necessary, thereby – interestingly enough – predominantly using the information provided by traditional control and monitoring panels to allow them a sense of reassurance. Inexperienced nurses reported higher anxiety when using the closed-loop ventilation system. But, paradoxically, many of them relied on the system too much, causing them to not check on patients frequently enough, showing that both under- and overreliance may hinder optimal human-autonomy teaming. Trust also emerged as a major issue in a recent study by Begerowski and colleagues (2023) on worker experiences with autonomous robots in the manufacturing and construction industries. The workers in this study emphasized the importance of trust in their collaboration with the robot, but they nevertheless adopted a 'trust-but-verify' mindset, remaining skeptical of the robot's capabilities. This may seem innocent at first, but such skepticism may seriously undermine team effectiveness as people have been found to reciprocate the level of cooperation they perceive in robots. For example, in one study participants intentionally withheld information from their robotic teammate when they felt the robot wasn't attentive enough to their needs, resulting in less cooperation and resource sharing in the team as a whole (Chiou & Lee, 2016; McNeese et al., 2019).

These are only a few examples of potential challenges associated with human-autonomy teaming. Regrettably, organizational scholarship has not kept pace with technology's impact on teamwork (Kellogg et al., 2019), despite early calls to integrate teamwork considerations into human-technology research and design (Bell & Kozlowski, 2012; Kozlowski et al., 2015). There is, of course, an abundance of research on the relationship between humans and technology from the field of human-robot interaction, but much of it focuses on short-term encounters between a single human and a single robot (Wolf & Stock-Homburg, 2022). The assumption that phenomena in dyadic (i.e., one-on-one) relationships will generalize to teams of three or more is problematic. Although dyads can demonstrate collaboration, mutual dependence, and shared goals, there are several complexities characterizing teams that simply cannot occur in dyads, such as in-group/out-group dynamics, majority/minority influence, and coalition formation (Moreland, 1990). Hence, relying solely on insights about dyadic interactions between humans and robots may lead to misunderstandings about dynamics in larger collectives, also because the team composition has been shown to make a big difference. For example, identification with the team is stronger with a higher proportion of human co-workers on the team (You & Robert Jr., 2022), and people trust autonomous agents more when other human teammates show trust in them (Schelbe et al., 2022).

We are only scratching the surface of the complexities in human-autonomy teaming and there is still much work to be done. In fact, a recent report from the National Academies of Sciences, Engineering, and Medicine outlined no less than 57 research objectives for the upcoming 15 years to address the many challenges in human-autonomy teaming (National Academies of Sciences, Engineering, and Medicine, 2022). Without going into detail, key research topic areas include: the development of models and metrics for studying human-AI teaming, the development of approaches for human-AI interaction, the improvement of shared situation awareness through AI transparency and explainability, better understanding of contributors to trust, and the importance of more holistic approaches for designing effective human-AI teams. These objectives are considered fundamental to the safe and reliable introduction of AI into work teams.

One final issue that may seriously hamper effective human-autonomy teams in real-world settings is a lack of responsiveness of autonomous robots to dynamic work environments. Industry 5.0 advocates that human-robot systems of the future should not only be human-centric and sustainable but also resilient in the face of complexity (Kaasinen, 2022). This implies that robotic systems should continue to work effectively when faced with unexpected events or disturbances. This is widely identified as a problematic issue, as illustrated by this last example, again from a healthcare domain.

Not too long ago, we visited a medical center in the middle of the country. They had opened an innovative sterilization department in which robots collect and transport medical equipment between the operating rooms and the sterilization room located in the basement of the facilities. The equipment is gathered in large crates that are quite heavy. Having the robots do the carrying significantly reduces the physical burden on the employees. The robots prioritize and perform tasks autonomously based on information obtained from the patient registration system. Initially, everyone was really excited about the new system. However, in practice, the robots turned out to be too rigid and too slow for the dynamic hospital environment. During critical moments, such as when a patient required emergency surgery, the robots would be stuck in slow and rigid routines and medical staff would have to rush down to the basement to retrieve the necessary equipment. Obviously, this creates a hazard to patient safety and seriously hampers the team's ability to do their work well. As a consequence, the system has now been shut down to be reassessed and improved.

Although comparable technology may work well in other settings, the hospital's dynamic environment obviously requires a more adaptable and responsive system that can handle dynamic demands. In other domains too, demand for more flexible and adaptive systems is increasing. For example, foreseeable future scenarios picture multiple humans working together with multiple robots in collaborative order picking (Srinivas & Yu, 2022), where neither humans nor robots follow strictly controlled, pre-defined plans; instead, they must dynamically and collaboratively coordinate optimal protocols for task execution.

Based on an extensive review of literature across multiple disciplines, Tilman, one of my PhD students whom I supervise together with Anna-Sophie Ulfert-Blank, has formulated four principles that would support such adaptive coordination in human-autonomy teams in stable as well as unstable contexts. Focusing on knowledge sharing, the framework outlines how adaptive coordination in human-autonomy teaming relies on observability, predictability, plannability, and directability. Together, these principles prescribe how humans and artificial teammates need to interact and share information to allow for an effective response to changing situations. This entails mutual awareness among humans and agents of each others' goals, roles, status, and actions (i.e., observability), such that they can anticipate each others' future actions (i.e., predictability).

This then enables them to share relevant procedural ('know-how') and strategic ('know-why') information and decide what needs to be done and how and why (i.e., plannability), upon which basis the team can establish (and adapt) work plans, task distributions, and decision control as needed (i.e., directability). In the continuation of his project (and possible subsequent projects), we will test the framework with the aim of establishing actionable guidelines for optimizing adaptive coordination in human-autonomy teams. With limited real-world opportunities to study advanced teaming setups, investigations will initially rely on lab experiments with mock setups but should eventually allow for iteratively developing and testing increasingly advanced robot capabilities and human-robot teaming technology in practice.

I will now shift focus to another set of projects in which we use smart technology as a means to assess team dynamics and to monitor and support teamwork during crisis events.

WEARABLE TECHNOLOGY FOR MONITORING AND SUPPORTING TEAMWORK DURING CRISIS EVENTS

Chances are that at least some of you are regular users of smartwatches or other tracking devices. The popularity of 'the quantified self' movement has witnessed significant growth in recent years (Lupton, 2013). This movement refers to the practice of individuals using technology, such as smartwatches, to collect, track, and analyze data about various aspects of their daily lives, such as physical activity, sleep patterns, and stress levels. In work settings, self-tracking devices are increasingly used to optimize work habits and manage stress and to improve performance (Lomborg, 2022). Team research has not remained unaffected by this trend. An increasing number of scholars are using wearable technology as a means of continuous assessment of team dynamics, using team-based metrics rather than individual ones (Delice et al., 2019; Halgas, 2023; Kazi et al., 2021). Wearable technology, like smartwatches, enables instant objective assessment of physiological and behavioral data from multiple team members without being subject to (self-)report bias and without disrupting team processes. When considered at the individual level, such data can provide valuable insight into a person's physical or mental state. For example, an elevated heart rate might signal cognitive overload (Ahmad et al., 2020), whereas increased skin conductance (i.e., how sweaty your skin gets) may indicate that a person is stressed

(Christopoulos et al., 2019). When considered in concert, data obtained from interacting team members can provide important information about the state of a team as a whole (Gorman et al., 2020; Halgas et al., 2023; Kazi et al., 2021; Palumbo et al., 2017).

To explain the rationale behind this claim, I call to mind the notion that teams are dynamic systems consisting of multiple components – the team members – interacting across time and conditions to achieve one or more common goals (Kozlowski & Ilgen, 2006). The state of a system cannot be grasped by looking at the individual components in isolation, only by considering how individual components change over time in relation to one another, becoming more, less, or differently coordinated. Consistently, the state of a team can be assessed by observing changes in coordination between team members over time, as captured in 'team coordination dynamics' (e.g., Gorman et al., 2010; see also Amazeen, 2018; Nalepka et al., 2017). These coordination dynamics are reflected at various levels, such as at the behavioral level, with team members showing coordinated limb movement, and at the physiological level, with team members showing coordination in heart rate or skin conductance. Coordination may involve synchrony when signals consistently rise and fall across individuals, but also other forms of coordination, like regularity, when a certain pattern repeats over time, such as with turn-taking in conversation (Butner et al., 2014). Importantly, changes in signals at one level of the system can be reflective of changes at other levels of the system. So, coordination in low-level markers (e.g., heart rate, movement) may reflect unique high-level team phenomenon, like team mood or cognitive processes (see Halgas et al., 2022; Kazi et al., 2021; Palumbo et al., 2017). This means that we could use these low-level markers, as assessed with wearable technology, to objectively and unobtrusively monitor how high-level team processes and states change over time and across circumstances (Wiltshire et al., 2022). As mentioned, this not only opens up opportunities for better understanding team dynamics, but also for supporting team funding as it unfolds.

Based on funding obtained with two consortia, Kyana, Elwira, and Jingwen, three PhD students that I supervise together with Travis Wiltshire, have been working on this topic. Kyana and Elwira were appointed in 2020, right in the middle of the COVID-19 pandemic, on a NWO fund together with Tilburg University, Philips, three hospitals (Rijnstate Ziekenhuis, Spaarne Gasthuis, and Maxima Medisch Centrum), and Grendel Games, a developer of serious games. After an initial literature review (Halgas et al., 2023), they collected data from student teams playing a stressful collaborative game in a lab setting and from professional healthcare teams engaging in simulation-based team training at the partnering hospitals. In the lab study, teams played several levels of the game before we staged a system malfunction across half of the teams, causing the loss of a team member so that the teams had to reconsider their game strategy. During the team training in the hospitals, doctors and nurses operated in realistic task scenarios with actors and high-tech patient simulators involving life-threatening complications, such as a patient with sepsis in the emergency room and the delivery of a baby in breech at the maternity ward. In both settings, we used smart watches to collect data on team members' heart rate, skin conductance, and arm movements.

Using the lab data, Elwira looked at the level of coordination in heart rate and skin conductance across different stages of gameplay to see if they could predict or reflect how well teams adapted to the loss of their teammate. Her findings showed that we could indeed distinguish between teams that adapted more or less effectively from the physiological data after the crisis, not from before the crisis. Prior to the crisis, there were no differences, but while adapting to the crisis, the more effective teams showed higher regularity in heart rate and lower regularity in skin conductance. This suggests these may be important indicators to track adaptive performance of teams in real time. The fact that the heart rate and skin conductance signals showed opposing effects seems to suggest different high-level processes at play. Based on prior literature showing that heart rate reflects cognition and skin conductance reflects affect (stress), these findings may suggest that more consistent cognitive patterns and more flexible affective patterns are ingredients for more effective adaptive performance.

Kyana, in the meantime, has been using heart rate, skin conductance, and movement data from both studies to evaluate various approaches to computationally detect team coordination breakdowns. Coordination breakdowns are episodes during which team functioning becomes ineffective due to misunderstandings or disagreements in a team (Bearman et al., 2010). With a detection rate of 96%, the software is currently very good at identifying coordination breakdowns based on physiological and movement data, but it is not yet precise enough (van Eijndhoven et al., 2023). A considerable proportion of the incidents identified by the software are not breakdowns but other phenomena happening in the team. Kyana is now exploring specific data features to improve the precision of the computational breakdown detection. Moreover, both Elwira and Kyana are currently analyzing the hospital data to see if coordination in physiological signals can be linked to (transitions between) specific modes of coordination (i.e., implicit vs explicit) in team adaptation to see if we can detect more favorable patterns of implicit and explicit coordination in team adaptation to crises.

Jingwen, who joined the team last year as part of the European-funded Tools4Teams project, has started investigating methods for providing direct feedback during crisis events based on wearable data. This is not at all straightforward considering that teams are already under high pressure. This means that the feedback must be impactful enough for team members to notice and respond to, yet subtle enough to avoid disrupting ongoing team activities. She will be evaluating different feedback mechanisms, such as a light indicator or vibrations, and different target recipients for the feedback as providing feedback to all team members might add to the coordination burden and therefore be less effective than targeting one person who can then communicate corrective actions to the rest of the team. Although our research is at an early stage and requires further development, our initial insights hold promise for advancing team dynamics research and for monitoring and supporting teams with (near) real-time feedback during stressful events. These insights might not only be relevant for teams in acute care but also for other action teams, including firefighter crews and police squads. Additionally, we see potential for similar methods to enhance coordination in human-autonomy teams, allowing humans and autonomous agents to better understand what is going on with their collaborative counterparts (Wiltshire et al., 2017). Evidently, we recognize that our research is not without ethical implications, raising important concerns about personal privacy, data security, and employee autonomy. We are regularly reviewing the ethical implications and ensuring alignment with evolving ethical standards and employee expectations, which are also included in our current research program.

Better teams → smarter tech

Up to this point, I have highlighted that artificial intelligence has immense potential for enhancing future teamwork but that significant research efforts are needed to ensure that the technology truly delivers on its promise. This brings me to the second imperative and the final part of this lecture. In a recent publication, Steve Fiore and colleagues (2023) warn of how "rapidly changing technology too often outpaces our ability to study its impact, thus limiting our ability to understand its implications as well as appropriately develop applications" (p. 419). This is certainly an issue with the integration of artificial intelligence into teams. Applications are quickly developed and implemented without a good grasp of their impact. In the meantime, research on technology integration in the workplace has increased tremendously, but efforts have been fragmented across disciplines. To ensure an adequate integration of artificial technology in the workplace, it's essential that researchers from diverse fields, such as mechanical engineering, computer science, social science, management, ethics, and design, start integrating their research efforts. By joining forces, they can develop integrated insights and solutions that truly harness the best of technology while upholding core human values. This calls for interdisciplinary research or, ideally, transdisciplinary research (OECD, 2020). Both seek to integrate disciplinary insights, with transdisciplinary research going one step further and also incorporating input from non-academic stakeholders, such as industrial partners and policymakers (Stokols et al., 2008). Fiore et al. (2023) argue that transdisciplinary research, in particular, offers a solid foundation for gaining insight into how teams are affected by the integration of artificial intelligence and for the proactive shaping of human-autonomy teamwork to avoid having to address undesirable effects afterward.

The Brainport region is up for this challenge. The success of the region is said to be built on a collaborative mindset across companies in the area, as well as in partnerships with local knowledge institutes and governmental bodies such as the province and municipalities. On campus, this has materialized in institutes such as Innovation Space, Eindhoven Engine, the Eindhoven Institute for Renewable Energy Systems (EIRES), and the Eindhoven Artificial Intelligence Systems Institute (EAISI) – which carries a wonderfully optimistic name for such a complex undertaking.
The region has proven fruitful soil for spearheading collaborative innovations and I consider myself fortunate to work in this vibrant and inspiring environment.

In the last couple of years in particular, I've had the chance to collaborate with scientists and practitioners from diverse fields, driven by shared interests and committed to jointly creating knowledge and solutions. While they have been immensely fulfilling, I would be the last to claim that such collaborations are easy. It is evident that interdisciplinary and transdisciplinary research comes with many challenges and poses significant dilemmas for the researchers involved (Newig et al., 2019; see also Ulfert et al., 2024). Integrating diverse perspectives and overcoming methodological differences and language barriers takes a lot of time, coffee, and sometimes highly confusing conversations (e.g., do you have any idea how many different meanings the word 'model' has across different scientific disciplines?) Consequently, inter- and transdisciplinary research is often slow and risky. Also, researchers report difficulties in finding a journal to publish their research results. And although engaging non-academic partners in projects has been shown to improve the societal impact of research, it is also known to negatively impact academic publication outputs and citations, as well as PhD completion rates (Newig et al., 2019). This makes it difficult to live up to academic standards and makes it hard for young scientists to build a career upon this type of research.

These effects need to be addressed with system- and institutional-level measures aimed at transforming academic culture, such as with the national Recognition & Rewards program (VSNU, NFU, KNAW, NOW, and ZonMW, 2019), and can further be mitigated through effective project design and management (Newig et al., 2019). In recent years, a new research field has emerged known as 'The Science of Team Science (SciTS)' (National Science Council, 2015), alongside initiatives like the Global Alliance for Inter- and Transdisciplinarity (ITD Alliance), aimed at advancing our understanding of interdisciplinary and transdisciplinary research. Besides valuable insights, these initiatives offer practical tools for establishing and guiding successful science teams, with an emphasis on shared goals and vision, an open and inclusive culture that fosters mutual respect and trust, interdisciplinary training programs, and effective management of roles, responsibilities, and decision-making processes (see Vogel et al., 2013).

These tools are helpful when establishing inter- and transdisciplinary research teams, but also when preparing future generations for transdisciplinarity with integrative learning approaches, such as challenge-based learning. Integrative learning requires students to discuss and negotiate their disciplinary values, perspectives, and insights to deliver integrated solutions. However, students often resort to a quick division of tasks and distribution of responsibilities to bolster project efficiency, thereby inadvertently limiting opportunities to truly integrate perspectives toward more comprehensive solutions. Recognizing this as quite a persistent issue, my colleague Sonja Rispens and I have introduced team charters in our course on team dynamics and team performance. At the start of their project, team members discuss expectations and establish an agreement for how they will work toward achieving shared ambitions. This encourages students to embrace their individual differences and promotes more integrative teamwork. It is a very small measure, but many students have indicated that they found these and other practices encouraging and helpful in improving their collaborative skills.

What I mean to say is that as the need for transdisciplinary research increases, so does the need for evidence-based strategies and policies that can effectively promote and support such initiatives. It is naïve to assume that effective inter- and transdisciplinary collaborations will just happen (Grote & Kozlowski, 2024); this requires intentional effort and systematic approaches and support. Additional research is still needed to provide a more robust theoretical and empirical understanding, but utilizing the knowledge already available in the social sciences, especially in the field of team science, can offer valuable insights for enhancing the effectiveness of science teams in tackling the world's most pertinent problems.

Conclusion

I've come to the conclusion of my talk. I will keep it short. The rapid advancements in AI are undeniable and its increasing integration within work teams is evident. We won't be able to call these advancements to a halt nor should we, given their potential. However, it is crucial to recognize that insights from team science and other disciplines will be essential to ensuring that future applications fully harness the integration of human and technological capabilities. In addition to providing substantive contributions, team science is uniquely positioned to guide cross-disciplinary collaborations toward the development and integration of smarter technology. It is up to us to shape the future. The future of teamwork is in our hands.

Words of gratitude

I opened this lecture by emphasizing that teams can *do* amazing things. I will close it by highlighting that teams can also *be* amazing, being a great source of inspiration and support. This is certainly true for many teams I've been a part of, each of which has contributed to shaping me and enabling me to be where I am today. I wish to express my deepest appreciation to the members of those teams.

Let me start by thanking the university board and department board, both former and current, for entrusting me with the position and duties of a full professor. I've been a member of the TU/e team for almost 25 years now, and with immense pleasure and pride. When I first joined the university, I could never have imagined that I would be standing here today. Thank you for providing me the opportunity to grow into this role.

I want to thank Christel Rutte and Wendelien van Eerde for introducing me to the academic world and providing me with the confidence to pursue an academic career. I am grateful to Jan de Jonge, Evangelia Demerouti, and Pascale Le Blanc for recognizing and nurturing my talents and for teaching me the ropes. A special word of appreciation goes to Ingrid Heynderickx, our former dean, for encouraging me to believe in myself and persevere in ambitions that I wasn't even so sure I should have.

I hope my talk effectively conveyed that science nowadays is a collaborative effort. I owe gratitude to many colleagues, co-authors, and students for our collaborations. First and foremost, I want to thank my PhD students. Boudewijn, Irene, Jef, Christian, Luuk, Michael, Ruobing, Kyana, Elwira, Jasper, Tilman, and Jingwen, working with you all has been an immense pleasure and the part of my job that I love the most. You help me to stay young – well, at least in spirit. It has been great to see you grow and I want to thank you for allowing me on your journeys.

I want to express my gratitude to Arjan van Weele, Travis Wiltshire, Joyce Westerink, Anna Wieczorek, Anna-Sophie Ulfert-Blank, and all others with whom I had the pleasure of supervising these PhD students. I have learned so much from each and every one of you and I am truly thankful for our collaborations.

A big salute to all my colleagues in the HPM group. You are a truly magnificent group of people and a wonderful team to be part of. A special word of thanks goes to Sonja Rispens, with whom I not only share a fascination for teams but with whom I've also shared truly every aspect of academic life, from teaching and research to grant writing and PhD supervision up to sharing an office in Atlas and hotel rooms during conference visits. Thanks also to Nathalie van de Kamp for being a wonderful secretary and for serving as the social glue that binds our group together.

Thank you to colleagues from the Coordination and Complexity consortium, the Tools4Teams consortium, and the Gravitation grant consortium. It is through collaborations with you that I get to enjoy science at its best. Thank you for sharing your knowledge and perspectives, which have enriched my understanding of the world both inside and outside of academia. A special word of thanks to Kristina Lauche for her guidance with respect to today's lecture and equally to Susan Mohammed, Mara Waller, Birgit Schneidmueller, Matt Cronin, Franciska Tschan, and Norbert Semmer for the encouragements and inspiration provided during my sabbatical last year.

And then there is life outside of academia. Of course, my first ever team was the family I was born into. Although my parents are no longer with us, I am sure they would have been damn proud to see one of their kids become a professor. Had they been here, I would have thanked them for raising me with a balanced sense of independence and belonging, granting me the freedom to find my way in the world, always respecting and supporting the choices I made. Luckily, I can share this day with my brother and sisters, Marian, Ad, Anneke, and Ellen. Als jongste heb ik altijd veel van jullie mogen leren en jullie hebben paden voor mij geëffend zonder dat ik er ooit om hoefde te vragen. Door de jaren heen is onze band alleen maar sterker geworden. Familie kun je niet kiezen, maar ook als ik de keuze had gehad, zou ik jullie hebben gekozen.

Then I have an equally loving family that I married into. Frans en Anne, Maria en Frans. Ik was nog een tiener toen ik jullie leerde kennen en jullie hebben mij mijn hele volwassen leven zien opgroeien. Jullie zijn een bron van liefde en steun geweest, zeker nadat onze kinderen werden geboren en jullie liefdevolle grootouders werden. Hetzelfde geldt ook voor jou, Walther. Bedankt voor jullie liefde en steun.

A big shout out to my running team, Cindy, Sabine en Ruud, al jaren mijn vaste loopmaatjes en daardoor inmiddels veel meer dan dat. Jullie houden me fit, zowel mentaal als fysiek. Motivationele quotes zijn zelden nodig, alleen als er echt heel slecht weer is voorspeld.

En dan, het meest belangrijke, mijn thuisfront. Met jullie deel ik grote gebeurtenissen, zoals vandaag, maar ook de alledaagse kleine dingen die het leven zo mooi en zo de moeite waard maken. Nona en Vern, jullie zijn altijd fantastische kinderen geweest, creatief, eigenzinnig en altijd lief voor elkaar. En nu zijn jullie fantastische jongvolwassenen met wie ik graag de koffiehuisjes van Eindhoven afstruin op zoek naar goede koffie en een goed gesprek. Ik kan niet wachten om te zien wat voor moois het leven nog voor jullie in petto heeft en ik hoop ook dat we daarin nog lang samen kunnen optrekken. In de woorden van Emma Stone: I love you bigger than the sky.

En tot slot, Joeri, mijn steun en toeverlaat en de liefde van mijn leven. Met jou deel ik lief en leed. Werk is daarin maar bijzaak. Ik houd van je eerlijkheid en je humor en van hoe je van mij houdt. Ik houd zeker zo veel van jou.

Ik heb gezegd.

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Curriculum Vitae

Prof.dr. Josette Gevers was appointed full-time professor of Team Effectiveness and Workplace Collaboration at the Department of Industrial Engineering & Innovation Sciences at Eindhoven University of Technology (TU/e) on February 1, 2023.

Josette Gevers (1970) graduated in Social Psychology at Tilburg University. She completed her PhD at TU/e in 2004 on the topic of team time management. She focuses on investigating the drivers of team effectiveness in dynamic, time-critical organizational contexts, and developing (technology-based) workplace interventions to enhance synergistic and adaptive team performance. Her recent research explores the potential of smart technology (AI, robots and wearables) for team augmentation. Josette's work is funded by various national and EU grants and is published in prestigious international journals in the fields of applied psychology, organizational behavior and management. She currently (co-) chairs the Human Performance Management group and the Interdepartmental Committee HTMD and serves as an associate editor for Small Group Research.

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