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# Teaming up with robots: Analysing potential and challenges with healthcare workers and defining teamwork☆

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ABSTRACT

In interviews with healthcare workers, we explore the potential and challenges of future deployment of robotic assistance systems in healthcare. We focus on individual expectations, wishes and fears. We especially emphasize the potential role of robotic systems in team dynamics. Will robots be coworkers in the future or are they expected to be tools? Irrespective of that, are they anticipated to change coworking within a team? Following a grounded theoretical approach, we aim to generate new theories and research questions on robotic assistance systems from the perspective of healthcare workers. We find that healthcare workers are generally optimistic about the implementation of technology in their workplace and not all have pressing concerns. Paradoxically, we further find that reasoning for why a robot could be part of a team are similar among participants who are opposed to robots in teams and those who are in favour. While participants only focused on work- and task-related criteria when arguing why a robot could be a future colleague, they presented work-and task-unrelated criteria for why a robot could not be one. We discuss the expected impact of robotic assistance systems on work teams in healthcare and pose resulting questions to inspire future hypothetico-inferential research on human-robot teams. We conclude with arguing why current team definitions do not fit human-robot teams and propose a new theoretical model for teams that include humans and robots.

## 1. Introduction

Qualified healthcare staff shortage is a challenge faced by many countries. The so-called "nursing crisis" became more salient during the Covid-19 pandemic, but is caused by many factors. While some reasons for the crisis are unique to some countries, many others are shared, e.g., demographic change, low job satisfaction, physical strains, high stress, low wages (Wada, 2020). Many tasks that are carried out by healthcare workers, such as lifting patients or getting medical supplies, lead to physical health problems, e.g., back pain. In Germany, staff in the healthcare sector had 45,5% more absent days from work due to musculoskeletal impairments when compared to a matched group of all professions in 2018 (Gesundheitsreport, 2019). These circumstances reduce the number of deployable professionals on top of a general shortage.

Robots can be a means to meet the increasing demand for healthcare workers. Especially, to prevent physical strains, lifting or carrying tasks could be supported or completely carried out by robots in the future. This solution sounds only consequent and logical. Technical constraints aside, how easy is the introduction of robotic help in healthcare?

In this paper, we qualitatively explore the potential deployment of robotic assistance systems (RAS) in healthcare teams by utilizing interview data from 14 healthcare workers. We adopt a grounded theoretical approach to understand co-working with RAS in healthcare from the perspective of caretakers. Our focus is on the individual level, emphasizing the emotions and expectations of our respondents rather than an institutional perspective that considers healthcare organizations and management.

We highlight individual emotions, expectations, and anticipatory sensemaking, which have been shown to play a crucial role in facilitating the acceptance of robotic helpers in healthcare (SIINO & HINDS, 2004). Our findings aim to provide insights into emotional and physical workloads as well as perceived opportunities and challenges associated with technology integration within healthcare teams. It is important to note that our research does not constitute a requirements analysis for new technology; instead, we seek to identify both utopian and dystopian scenarios envisioned by healthcare workers, regardless of their familiarity with technological advancements.

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Our goal is to offer a fresh perspective on collaboration with robots in healthcare, intending to generate theoretical frameworks and raise new research questions that will guide future empirical investigations on this topic. Specifically, our interviews concentrate on participants' perceptions of robots as potential colleagues and team members. We inquire whether healthcare workers anticipate teaming up with robots as partners or viewing them merely as technical tools. Additionally, we explore their expectations regarding how RAS might influence team dynamics and emotional experiences, as well as their visions for an ideal future workplace.

In the following section, we will review prior research on RAS in healthcare. We focus on studies on trust, emotions, hopes and wishes towards RAS in healthcare, and RAS as team members. We will then outline the interview structure, methodology, analysis, and results. Finally, we discuss our results with reference to the nursing crisis, propose research questions on RAS as potential team members and theoretically reflect and discuss definitions of all-human teams and their applicability to human-robot teams. We conclude our paper with the proposal for a new theoretical model on human-robot teams.

## 2. Theoretical background on RAS in healthcare

In healthcare, two viewpoints play an important role when discussing the deployment of RAS in care: the patient's perspective and the caretaker's perspective. Many studies have addressed the first viewpoint and researched whether patients accept different kinds of robots as care support or entertainment systems. Several studies show which expectations patients have, the factors that lead to acceptance and usability of robotic systems by patients (e.g. (Hendrich et al., 2015; Portugal et al., 2019),) and how robotics can enhance mood and well-being (Alemi et al., 2014; Bennett et al., 2017), general health, e.g., in dementia patients (Tamura et al., 2004; Wada, 2020), and quality of life (Chen et al., 2020). All of these results show the benefits of RAS for patients and how they can assist to provide good care.

Fewer studies have adopted the caretaker's perspective. These studies mainly focus on the direct human-robot interaction, e.g., on usability and technology acceptance (e.g. (Riek, 2017; Vichitkraivin & Naenna, 2021),), and less on the caretaker's feelings and expectations towards integrating robots in healthcare teams.

Moreover, among healthcare staff and different hierarchies within the hospital or nursing home, conflicts of interest might arise that affect deployment of RAS. We cannot assume that "the caretaker's perspective" as referred to above is a unified perspective. As Mutlu and Forlizzi conclude after their ethnographic study in 2008: "Designers of most organizational technologies might assume that a collective goal is sought by all members of the organization and overlook conflicts of interest that might occur" (Mutlu & Forlizzi, 2008, p. 292). In their study, caretakers were interviewed who worked with a fetch-and-carry robotic system. The authors discuss their results on an organizational level: how does this RAS impact workflow in different healthcare units? They found that "differences in the goal and interests of two types of units within the hospital led to differences in the perception of the robot" (p. 288). In post-partum units, the robot was generally accepted and positively evaluated, while in medical units, the robot was perceived as a burden rather than a help. Their results show how careful we have to consider the diversity in caretaking tasks and the different expectations and needs that come along with it. Authors conclude with "when technologies such as service robots are adopted by organizations, they have an impact on social dynamics and work practices of many groups" (p. 293). We deem this aspect - the impact on social dynamics - very relevant for successful integration of RAS in healthcare.

Different groups in a study on healthcare robotics perceived the potential benefits differently, with anticipation of robotic deployment triggering sensemaking processes (SIINO & HINDS, 2004). This sensemaking helps integrate robots into the workplace, highlighting its importance even without prior experience with the technology. We conclude that understanding social dynamics and personal opinions of healthcare workers is crucial before deploying robotics.

Other key factors for adoption of robotics in healthcare include: safety and reliability, usability and acceptability, capability and function, clinical effectiveness, and cost effectiveness (Riek, 2017). While prior research has shown that these factors are essential, we propose to include social dynamics to the list, which have received less attention. Group dynamics, generally defined as the interactions within and between groups (Forsyth, 2014), can significantly impact coworking of healthcare professionals. The introduction of a RAS (independent of how it looks, what it does or what its capabilities are) into such a dynamic results in change that goes beyond questions of usability, technology acceptance, safety and so forth. The introduction of a robotic system can alter social dynamics, potentially introducing challenges like conflicts and fears or creating opportunities for cohesion and optimism. Currently, there is limited research on how robotic systems affect these dynamics, prompting us to explore these questions qualitatively.

With the current study, we would like to theoretically contribute research questions that we develop by analysing our qualitative interview data and combine the newly gained knowledge with a reflection of prior research. We aim to inspire further empirical work by proposing research questions on RAS in healthcare teams from the perspective of healthcare workers. In the following sub chapters, we introduce our research agenda in more detail.

### 2.1. *Trust and emotions towards RAS*

In the healthcare sector, trust towards used automation is considered crucial, both for healthcare providers and for patients. Trust is a multidimensional construct, built up upon experience and interaction, that can be defined as an attitude or cognitive state where a human believes that a robot will perform according to the expectation, and can be relied upon to achieve its intended goals (Lewis et al., 2018). Described as high-risk medical environment, the healthcare sector is considered to be a field where trust is more vital than in other areas (Marinaccio et al., 2015). In general, trusting and accepting a robot affects the intention to actually use or engage with it (e.g. (Freedy et al., 2007; Ogreten et al., 2010; Plaks et al., 2022),). A robot's task and healthcare context was shown to be important for people's perception of privacy risk (Jayaraman et al., 2024). Perception of a robot's expertise impacted trust. Participants in a study on healthcare advice by a robot trusted the robot with advice when it had low-risk consequences (Giorgi et al., 2023). Most of the studies on trust in healthcare focus on social robotics and, more importantly for the current study, on trust by patients. Not only patients need to trust a RAS, but healthcare staff too. Opposition of healthcare staff to the implementation of technology, trust issues and perceived threats are described to be major barriers in the implementation of technology in the healthcare sector (Silvera-Tawil, 2024).

In this research study, we pose the following questions concerning trust.

1. Does healthcare staff expect to trust a robot in their work environment?If they do, why would they trust a RAS? If they do not, why not?
2. And what would they need to gain trust?
3. When and under what circumstances do they perceive a RAS as trustworthy?

With respect to emotions towards RAS in the healthcare sector, prior research demonstrates that staff members showed psychological closeness towards an implemented robot. Perceptions of robots have been shown to be indirectly influenced by prior emotions (Spekman et al., 2018). In a study by Engelberger et al. (1998) the staff talked to the robot in a humanlike manner, greeted and thanked it and even dressed it up for Halloween. Others report, talking to the robot made them feel happy when the robot talked "cheerfully" to them (Sabelli et al., 2011). These examples indicate the human–robot interaction that took place was accompanied by positive emotions. However, it sometimes turned into disappointment or disinterest because the robot had limited functions or output options as well as occasional dysfunctions. Employees stated to get annoyed by the robot's vocal repetitions and its inability to participate in a real conversation (Hebesberger et al., 2017). Some staff members in the same study claimed they were unwilling to share their work environment with robotic systems. They argued that robots should not be allowed to do any care tasks and expressed fears that RAS would take away the jobs of human staff members (Hebesberger et al., 2017). All of these results represent anecdotal evidence from studies that mainly focused on: usability and task performance. In the current study, we would like to systematically explore staff member's anticipatory emotions, irrespective of a certain system's functionality and usability.

Hence, we pose the following questions concerning emotions.

4. Are healthcare workers generally optimistic or pessimistic when considering the introduction of robotic helpers in their field? Why?
5. What are they looking forward to? What do they fear?

### 2.2. Hopes, wishes and perceived challenges of RAS

Robotics in healthcare can help healthcare workers in two ways: directly in either taking over tasks or assisting in tasks, or in providing support to patients, e.g., by improving patient's mood and alleviate their pain (Pu et al., 2020), which can lead to better interaction between caretaker and patient. When taking over more and more tasks, participants in studies have addressed fears. Fear about losing one's job after the introduction of RAS have been recognized and studied early on and Engelberger described in 1998 that it might be problematic but all the more important to get all staff members onto the same page when considering the implementation of a robot. This requires a good preparation before even bringing in a robot (Engelberger, 1998). Deployment of a robot can then become even more complicated and frustrating for staff when the robot is not designed in a way that is wished for by healthcare workers. A study by Graf et al. revealed that staff members were unhappy with the implemented robot's size and screen placement, as it was too heavy to manoeuvre and the screen blocked their view. Another critical factor in robot acceptance and general content with a robot is that it alleviates work (Graf et al., 2004). In a study, the robot's voice was hard to understand by elderly people, staff members had to frequently help the residents with the robot, which resulted in more work for the working staff (Sabelli et al., 2011). Logically, more work leads to more stress and frustration for the staff. Understanding healthcare workers' hopes and wishes towards the functionality of a system and considering perceived challenges from their perspective is essential knowledge for successfully researching and implementing RAS for healthcare.

Based on these considerations, we ask:

6. What hopes and wishes do healthcare workers have concerning RAS?
7. Why do they hope for a better or worse future involving RAS?
8. What do they wish a RAS can do?
9. Do they expect a RAS to alleviate their workload, both mentally and physically?
10. What are challenges that they perceive in their specific work environment?

### 2.3. RAS as team members

When Robots take over tasks formerly done by caretakers and hospital staff, they might also be considered as team members. So far, few results from research reports or surveys show opinions of employees with regard to the role of robots for currently existing work teams. The study by Sabelli et al. revealed that staff viewed the implemented robot as a family member or friend while others reported that the staff perceived the robot as childlike and treated it accordingly (Sabelli et al., 2011). Since a very intimate relationship with the robotic assistance is already evident here, it is important to investigate what role a robot could take on in a work team and if it will also be seen as co-worker and member of the staff's team. This includes, for example, if it would be regarded as equal or whether a hierarchy between the staff and the robotic assistance is desired.

Research on human-robot mixed groups is a relatively new area, emerging over the past 15 years. This is largely due to the overall youth of the humanrobot interaction field (Weiss and Yanco, 2012), which initially focused on one-on-one studies. However, applying findings from dyadic interactions to mixed groups has limited validity; because adding one to a dyad significantly alters dynamics (Forsyth, 2014). So, several researchers have highlighted the need for group interaction studies, as robots are expected to operate in group settings (Jung et al., 2017; Abrams & der Pütten, 2020; Strohkorb et al., 2020; Fraune et al., 2017, pp. 205–213).

While we have some knowledge on effects of type and number of robots on groupness perception (e.g., (Fraune et al., 2015; Fraune et al., 2017, pp. 205–213), social categorization and intergroup bias with robots (e.g. Häring et al., 2014; Kuchenbrandt et al., 2011; Kuchenbrandt et al., 2013; Deligianis et al., 2017), robots' impact on group dynamics (e.g. Jung & Hinds, 2018; Martelaro et al., 2015; Shen et al., 2018; Tennent et al., 2019) and effects of constellation of groups encountering robots (e.g. Fraune et al., 2019; Sabanovic et al., 2006), almost no studies consider human-robot group interaction in the context of healthcare. Results from ethnographic research in healthcare (e.g. Mutlu & Forlizzi, 2008), requirements analysis (e.g. Riek, 2017) and usability studies in a healthcare setting (e.g. Freedy et al., 2007; Ogreten et al., 2010) mostly focus on specific robotic systems, on the organizational level and on aspects of functionality and handling of robotic systems.

We conclude that we lack empirical results from group studies involving robots in healthcare, especially from the staff perspective. Even more fundamental is the lack of theories and hypotheses on human-robot mixed groups and teams, which is essential for advancing this emerging research area. Therefore, we aim to find answers to the following questions by means of qualitative analysis of interviews with healthcare personnel and discussion of prior research on human-robot teams.

11. Do healthcare workers expect a robot to change coworking within theteam?
12. Do they expect a robot to be part of the team or do they expect toperceive it as a tool?
13. Could a RAS become a team member over time? What factors mightplay a role from their perspective?
14. Where do they think it stands in the staff hierarchy?
15. Is a RAS perceived differently from other technical devices?

## 3. Method

### 3.1. Participants

14 participants were recruited via email to suitable institutions in the area (local hospitals and elderly care homes). Participant characteristics can be found in Table 1. The age in this sample ranged from 31 to 64 years ($M$ = 43; $SD$ = 11.31). Of those, nine participants indicated working positions where they are in direct contact with patients. One participant worked in a quality management position and four participants worked in the sterilization for medical instruments. Their work experience ranged from 1 to 36 years ($M$ = 17.57; $SD$ = 12.82). Prior to their participation, all participants gave informed consent to taking part in this study as well as consent for the interview recording via video and voice. Participants received 15€ as compensation.

**Table 1**
Participant characteristics.

| Participant Code | Age | Gender | Profession | Care sec-tion | Experience |
|---|---|---|---|---|---|
| P1 | 52 | f | Nurse and Deputy Ward Manager | Nursing | 30 years |
| P2 | 40 | f | Nurse | Elderly care | 22 years |
| P3 | 50 | f | Nurse | Nursing | 25 years |
| P4 | 34 | f | Geriatric nurse | Elderly care | 14 years |
| P5 | 32 | m | Quality Management | Elderly care | 1 years |
| P6 | 58 | f | Nurse | Operating room | 25 years |
| P7 | 31 | f | Nurse | Intensive medical care | 7 years |
| P8 | 64 | m | Nurse and technical sterilization assistant | Central sterilization | 45 years |
| P9 | 31 | f | Technical sterilization assistant | Central sterilization | 5 years |
| P10 | 38 | m | Facility and instrument management | Central sterilization | 5 years |
| P11 | 34 | m | Operating room nurse | Operating room | 11 years |
| P12 | 31 | m | Shift management for medical device reprocessing | Central sterilization | 5 years |
| P13 | 57 | f | Operating room nurse | Operating room | 36 years |
| P14 | 50 | f | Geriatric nurse | Elderly care | 15 years |

### *3.2. Additional information on participants' education and prior experience with RAS*

To become a nurse in Germany, students can either decide for studies at university (which is newly introduced) or vocational training. This 3-year practical vocational training is completed partly in companies or institutions in the private or public sector and partly through accompanying courses at a vocational school.

Currently, the curriculum for becoming a nurse in Germany includes no specific technology-related courses. In the context of this paper, we refer to healthcare workers, not nurses, because our sample includes some who have not underwent the traditional vocational training ($n = 3$) or are in a quality management position ($n = 1$). In the interviews, we asked participants if they would consider themselves to have an affinity for technology or not. Some participants ($n = 5$) described themselves as having no affinity for technology. They argued that they had little experience or contact with technology ($n = 5$), or that they would rather describe themselves as having a talent for crafting and manual skills ($n = 1$). Nine participants did indicate to have an affinity for technology. They stated that their job as operating room nurse includes handling complex technology ($n = 2$), or that there is a general interest in technology ($n = 5$), that they own assistance robotics at home ($n = 2$), or that they are fascinated with what technology can achieve in the healthcare sector ($n = 1$). Most participants ($n = 11$) stated to have an interest in technological developments in general, and also for the healthcare sector. Almost none of the participants ($n = 13$) had personal experience with robotics in healthcare. Most participants ($n = 10$) could name examples of real RAS that they knew from media reports and documentaries (e.g., service robots in restaurants, socially assistive robots in elderly care, exoskeletons, lawn mowers and vacuumers, or assistance systems in cars). One participant (*P11*) frequently worked with the Da Vinci surgical system (a surgical robot, that does not fall in the category of healthcare robotics).

### *3.3. Procedure*

After participants indicated interest in taking part in the interview study via email, they received the necessary forms of consent and were scheduled for an online interview appointment. The interview started with the interviewer welcoming the interviewee, shortly explaining the purpose and topics which would be addressed in the interview and answering any potential questions. The interviewer also informed the participant that they may or may not answer to the posed interview questions, that there are no wrong answers and the participant can speak freely and honestly. Before recording, the interviewee was again asked for consent verbally. Upon agreement, recording and the interview started. The interview was conducted following a semistructured interview guide. Specific topics were discussed in greater depth depending on the individual answers and in different orders depending on the flow of conversation. Some interview topics were added to the guideline for later interviews, when they were brought up by participants in previous interviews. This was done to monitor and reach thematic saturation (Naeem et al., 2024).

### *3.4. Interview guideline*

The semi-structured interview guideline included different question hierarchies. This means that questions started on a general level and became more specific over the course of the interview. An overview of the concepts and exemplary questions can be seen in Table 2. At the outset of the interviews, the interviewer aimed to engage deeply with the interviewees' imaginative capacities. Participants were prompted to share their prior experiences with robotic assistance systems and articulate their interpretations of the term. Our interviews sought to empower participants to envision and conceptualize assistive technologies that would create an ideal work environment, independent of current technological developments and constraints. Our focus was not on the feasibility of constructing such imagined robotic systems but rather on understanding the tasks these systems might perform, how they would impact participants' feelings, and whether they could envision collaborating with such envisioned technology. This approach was crucial for gaining insights into healthcare workers' perceptions of robotic systems, as well as the emotions and expectations they associate with their visions of a future integrated with such technology. We then continued with the questions on hopes, wishes, challenges and team-related questions.

During the interview, participants either adapted terminology of the interviewer ("robotic assistance systems") or continued with other terminologies.

Over the course of the interview, the interviewer aligned with the wording the participant used (mostly "robot", but also "it", "he" "the thing", "the system", "the tool", "the device"). In doing so, we intended

**Table 2**
Constructs and exemplary questions from the interview guideline.

| Construct | Exemplary Questions |
|---|---|
| Welcome and Consent | *Welcome to …* |
| Occupation-related Questions | e.g., *What is your occupational title? What are the three core tasks in your job?* |
| Personal Questions | e.g., *What is your age?* |
| **Prior Experience** with RAS | e.g., *When I say "RAS", what do you think about?, Do you know any RAS in care?* |
| Expectations on RAS -**General** | *Scenario-based inquiry: Imagine a RAS is introduced in your workplace* [ …] e.g., *What would you expect from it?* |
| Expectations on RAS -**Hopes and Wishes** | e.g., *Is there anything that you would whish for specifically?* |
| Expectations on RAS -**Challenges** | e.g., *What are potential challenges?* |
| Expectations on RAS -**Emotion and Trust** | e.g., *Would you consider yourself as a person with technology affinity? How do you feel when new technology is introduced? Would you trust a robotic system at your workplace?* |
| Expectations on RAS -**Team** | e.g., *How important is teamwork in your job? What constitutes a good team for you? Do you think a RAS would have an impact on your teamwork?* |

to stay in the participants' imagination and perception of a RAS. In a second part of the interview, we asked system-specific questions where a specific robotic system was presented to the participants. Analysis of these results are out of scope for the current paper.

### 3.5. Analysis procedure

First, all interviews were transcribed. In order to rule out possible problems in understanding the content due to participants' accents, dialects or internet connection problems, the transcripts were then proofread by two independent persons, including the interviewer. Data was coded and analysed with MAXQDA, a software for qualitative content analyses. We adopted an iterative approach in our coding: (1) using the pre-defined categories from the interview guideline as a starting point for coding, (2) coding of one interview by two independent coders, (3) discussion of the coding scheme and adoption of new codes, (4) coding of the rest of the interviews independently by both coders using the agreed upon coding scheme, (5) analysis of intercoder reliability (more details below), and (6) discussion of reliability and specific disagreements, and (7) final agreement on coding and categories for analysis. A list of all codes is in the supplementary material.

Intercoder reliability was calculated for each interview with Cohen's Kappa. We counted the consensus of assigned codes and considered any code that was not used by both coders for one participant an agreement as well. Reliability ranged from $k = .72$ to $k = .86$. For 9 interviews, reliability was $k > .75$ which indicated excellent intercoder reliability. The remaining 5 interviews reached $k = .72$ to $k = .74$ which indicates good reliability. As basis for the analysis, we used a merged version of both coders' work. This resulted in a lot of redundant information (because in most cases coders agreed upon coding), but it ensured that in the few cases of disagreement (e.g., when one coder identified a relevant statement that the other coder missed) no information got lost.

The analysis follows a grounded theoretical approach: interview data is used to build theory and identify relevant questions for further research. In accordance with the PRICE model (Naeem et al., 2024), we use the processes of recapitualization (transforming data into codes and themes), integration (connecting and making sense of codes) and crystallization (structuring codes and themes in the form of tables and figures) which we present in the results section. In the discussion section, we follow the principle of edification from PRICE model where information is clustered in a theoretical framework.

In the following sections, we will only rarely report numerical values. The analysis is focused on WHAT was said and WHY, rather than how many participants said it. For the current analysis and the posed research questions, the latter has no meaning.

All citations from participants were translated from German to English by the first author with the help of DeepL.com (free version).

## 4. Results

### 4.1. What is the prior experience with RAS?

Questions about prior experience are supposed to give a better insight into the participant's background and knowledge about RAS. This is important for the interpretation and discussion of further interview questions. All participants expressed individual ideas of what RAS could or should look like: e.g., *"I can imagine a robot that drives in our hallway. It looks a little bit like a human, but at the same time, it looks like, yes, like these cleaning robots." (P4)* or *"[It looks] Normal. Just like a human with hands [laughs]. And feet, or rather with wheels. Emm. Not easy to imagine. I think about iRobot, a robot with hands and feet, just like us." (P11)*. A humanoid appearance seemed to be a frequent image in participants' heads. Some participants talked about famous robotic characters from films (e.g., Number 5, R2D2).

Participants' spontaneous judgment/evaluation of RAS for healthcare were mixed. All participants expressed interest for the topic, which is also implicitly evident in their voluntary participation in the interviews. But some participants were ambiguous in their current impression of such systems. Overall, most participants had the tendency to evaluate technological advancements and robotics in the field positively, but some also expressed doubts within the first minutes of the interview, e.g., *"yes, it is exciting, I think. Well, it is, I mean, first of all it is a bit strange, but, probably this will be our future." (P4)*. One participant's first impression was negative and they provided the following reasoning: *"A negative connotation, probably because of science fiction films." (P10)*.

### 4.2. What are general expectations for RAS?

Participants were asked what general expectations they had for RAS. From the interviews, the following eight categories could be derived for general expectations towards RAS (sorted from broad categories to more specific expectations for tasks or interaction with the robot).

1. reduction of workload/facilitation of work (*"I expect a great relief and easing of the whole personnel situation." (P3)*)
2. saving of time (*"It is so frustrating and we lose so much time every day. It's unbelievable. Because employees are lacking [ …]. And we could replace them with robots. (P13)*)
3. reduction of repetitive tasks (e.g., disinfection, carrying goods)
4. physical requirements for the robot (e.g., the robot should have arms, robot adapted to workspace/environment)
5. functional requirements for the robot (e.g., basic working tasks should be pre-programmed, robot should be able to carry out tasks spontaneously)
6. fetch and carry tasks (more details below)
7. high quality of task performance/expectation-conform task performance (e.g., *"the robot should do what I say" (P1), "that I don't want to take care of the system, (…) that the system works in it's area, in which it is deployed completely flawless and we can trust it" (P5)*
8. robot should learn from human (e.g., through observation or explanation, *"it should be similar to a human who is a first-time intern in an elderly home. I would take him along and show him around, how everything works and what I usually do" (P2)*)

Concerning fetch and carry tasks, all interviewees considered this an area for robot deployment. Ideas ranged from collecting linen and towels to getting shampoo or medicine for a patient. We considered fetch and carry a representative task for supporting healthcare, but not healthcare itself. Consequently, we coded participants' answers for what they would expect a robot to work in along the following three dimensions.

- tasks that do not necessarily include patient contact (e.g., fetch and carry, sorting medication, disinfection),
- tasks that involve interaction with patients (e.g., taking orders, delivering food, explaining hospital policies, entertainment),
- and tasks that involve caretaking of patients (e.g., transferring patients, taking patients' temperature, carrying the patient, washing the patient).

Considering the above listed dimensions, we could identify two main types among our participants: some could imagine a robotic system deployed in all of the three working dimensions (type 1) and some would only use the robot for supporting tasks, not so much for interaction with patients, but definitely not for taking care of patients (type 2).

On the one hand, one participant (type 1) said *"I can imagine very well that in some years or in the near future, healthcare will be completely replaced by robots. I can imagine that it is possible." (P11)*. Another participant imagines the robot replacing a colleague fully: *"What I would like him to do, for example, is to conduct some conversations himself or make appointments or help me at certain times with certain residents. So that's how*

*I imagine it, that I could give them a handover in the morning, which I usually pass on to my colleague" (P14)*. On the other hand, another participant (type 2) expresses concerns: *"well, I definitely think that the sideshow can be replaced. [ …] For me, it's very hard to imagine that caretaking and guidance could be taken over completely. [ …] I say, that the interpersonal aspect can't be replaced by a robot." (P2)* The interpersonal aspect is mentioned frequently by participants that we identify as type 2: *"I think I would be reluctant to leave interventions close to the body, such as personal hygiene and so on, to a robot, because then the observation would not be there. Well, I have to observe the skin, the behaviour, the movements and [pauses …] Wait. I think that would also be something for the robot, wouldn't it? Movement sequences like that? But not when it comes to personal hygiene; I would quite like to do that myself, things that actually require an interpersonal relationship" (P3)*.

In conclusion of this section, we would like to state the two identified types within our sample. These types are based on the tasks that participants expected a RAS to take over and the general attitude towards RAS:

**Type 1: generally accepting technology, expecting technology to gradually take over more and more tasks in healthcare, eventually taking over all tasks**.

**Type 2: conditionally accepting of technology, demanding technology to take over only certain tasks in healthcare**.

During this stage of the interview, many participants (classified as type 2) expressed doubts and scepticism along with their expectations. Although mentioned in the context of expectations, we report and analyse these comments together with perceived challenges and fears in sections 4.4 and 4.5.

### 4.3. Which hopes and wishes for RAS did healthcare workers have?

After the general expectations that humans had towards a RAS, we asked for more specific wishes. We can cluster our participants' hopes and wishes along two dimensions: (1) wishes towards the technical system and its functionalities, and (2) hopes towards better working conditions. An overview of the wishes can be found in Table 3 on general wishes and Table 4 on exemplary statements on interaction and design.

Some wishes listed in Table 3 are contradictory. Some participants wished for constant feedback by the RAS to be able to monitor closely what it does, and others expressed the opposite. So, we can identify two clusters concerning the level of autonomy.

**Table 3**
Wishes towards a RAS.

| Participants' Wishes | Further Explanation and Examples by Participants |
|---|---|
| Right to have a say in the purchase of the RAS | involvement in the acquisition, statements on failed implementation of technology that were due to miscommunication in the purchase process |
| Spatial fit | robotic size appropriateness, e.g., for disinfection of small objects and corners of a room or for tidying up storage areas |
| Technical assistance external from support | support service for emergencies that is reachable at any times; communication of repair cycles, updates and new features; permanently employed technician; step-by-step technical introduction |
| Reliability | reliable and flawless execution of work (outside of periods of maintenance and battery charging), independently working without adding workload |
| Usability | easy to use, intuitive interface, operation without much thought |
| Reliable error display | quick notification in the event of an error, especially involving patients; communication about upcoming maintenance; no notifications under normal work circumstances |
| General feedback by the RAS | traceability of all work assignments; for approval and confirmation of work orders for RAS |
| Working independently | generally working independently under normal conditions without any feedback and necessity of human approval or involvement |

**Table 4**
Wishes towards a RAS on interaction and Design.

| Participants' Wishes | Exemplary Citations from the Interviews |
|---|---|
| Technical commmunication | *"A display on it where you can read: what is it currently doing, what job it has, perhaps battery capacity." (P10)* |
| Human-like communication | *"Or that he can sing, that you can really use him when you don't have time to sing with the residents" (P4), "Voice control or something like that would be nice, of course. Erm, yes, that would be the most convenient. It's the quickest and doesn't take long." (P10)* |
| Multimodal communication | *"All patients would have to be addressed. One can see better, the other can hear better" (P1)* |
| Human-like appearance | *"Making the robot a bit cute" (P7), "I think for the inhabitants it's more like a human being. Not driving around like R2D2. I think that would be very frightening for the inhabitants. It would be more like a human - what a human looks like" (P4).* |
| Appealing design | *"It doesn't necessarily have to have the human features [ …] I think that's quite good for acceptance from all sides and otherwise I think just bright, good colours."* (P6) |

- participants with a wish to monitor closely and
- participants with a wish to monitor as little as possible.

Type A argues that technology is not good enough to be left alone, that patients might be endangered and that healthcare workers are the ones who know how it is done well. Type B's arguments are: technology has to be good to be able to be deployed, too much monitoring means too many added tasks which results in less time for important tasks.

Concerning hopes, participants mostly named **reduction of workload** and **reduction of repetitive tasks**, as has been described in the previous section. We asked for further explanation why participants had these hopes. Participants explained that they hoped for a reduction of workload because the RAS would take on tasks that they had to perform themselves previously. In addition, some participants hoped for better conditions because a RAS cannot get sick: *"And above all, the best thing is that he's always there when he's loaded. He's never ill." (P13)* Another participant *(P14)* mentions: *"Yes, I think that in many areas you can use them for the whole time, for example, where you have to expect people to take a break or give them a break."* Another participant also explained that they hoped for RAS to make a position in healthcare more attractive to younger people: *"So that's the hope, also getting young people excited about it again. They're all growing up with digital things these days." (P6)*. Here, the argument is that RAS might not only reduce workload through its own presence and task completion, but through attraction of possible new employees who fill vacant positions.

We can conclude that the hope for reduction of workload and less repetitive work is expected to result from the RAS (1) taking on tasks, (2) working

continuously without breaks, (3) and making the workplace more attractive for young people and technology enthusiasts.

### 4.4. Which challenges did healthcare workers expect with deployment of RAS?

In our interviews, we did not ask specifically what participants' opinions were on general challenges in healthcare. However, participants frequently talked about it. They especially mentioned nursing crisis and staff shortage. Mostly, these general shortcomings in the healthcare system were used to justify the introduction of RAS, e.g.: *"But in view of our care shortage, this [RAS] can only be helpful if no one wants to do this work any more, then we have to react. We wouldn't even have the idea [of introducing RAS] if we had enough people." (P13)* From this exemplary and multiple other statements, the opinion becomes clear: If there were enough people, RAS would not be considered.

Statements about technical implementation included worries about charging, maintenance, handling and level of autonomy. An exemplary comment was: *"Hmm, and I'm just worried about these failures. It's dependent on electricity, it's dependent on battery power and things like that. And that's, that's already associated with a lot of maintenance that someone would have to do. And let me just say, we also have monitors that are never charged because nobody takes care. And that's the point. So the best thing is for it to drive itself into the socket." (P3)* With this exemplary comment, we can see that expected challenges sometimes followed a certain hierarchy. This participant talked about maintenance of a robotic systems. The underlying identified challenge, however, is (the fear of) additional work that comes along with it. The expected result is non-usage, as it seems to have happened with other technology in the past.

All identified challenges that healthcare workers expected for RAS are summarised and explained in Table 5.

### *4.5. How do healthcare workers feel towards RAS? Do they expect to trust a RAS?*

Participants' trust and emotional remarks concerning RAS were coded separately from hopes and challenges, even though there was some overlap in how participants responded emotionally towards what they hoped for in a RAS or expressed trust issues or fears in challenges to be expected. The

coded emotional responses are summarised and explained in Table 7 and remarks on trust in Table 6.

When asked about trust in RAS directly, participants that indicated to have no trust in RAS, stated that trust could be build up. One participant (P9) explained that as long as the RAS was not known to them, there would be no trust. Another participant stated that *"because it's a robot that takes over my work. It's a bit, yes, unfamiliar, new" (P4)*. Unfamiliarity and novelty were the most mentioned arguments for lack of trust. For building up trust, participants mentioned to expect prior experience with robotics, explanation of functions, and interaction with the specific RAS to play a role (e.g., *"Hmm, it [the RAS] would have to earn that [trust] first" (P3)*.)

Some participants generally expected to trust a RAS that would be introduced in their workplace. Upon being asked if they could trust a RAS, one participant responded: *"Er, yes, why not?" (P8)*. One participants drew a comparison with trusting another human who is unknown but employed because of their qualification for the job. Therefore, there

**Table 5**
Expected challenges.

| Expected Chal-lenges | Further Explanation and Examples by Participants |
|---|---|
| Healthcare in general | Challenges because of nursing crisis, general lack of staff and short- term lack of staff (many sick leaves) |
| Technical implementation | Concerns about maintenance, charging, handling and level of autonomy |
| hygiene of the system | RAS should clean according to legal regulations, RAS should be easy to clean, surface should be resistant against disinfectant |
| Maintaining boundaries | RAS should maintain physical and psychological boundaries of patients, staff should maintain emotional boundaries/should not get attached too much to RAS, and concerns about over reliance on the system |
| Communication problems | Language barriers between RAS and staff or RAS and patients and problems because of multilingualism (languages, accents, dialects) |
| Operation of the robot | Missing professional requirements/technical know-how among staff, training and further education by staff needed, worries to be overwhelmed with the technical requirements and non- user friendliness |
| Additional work/strain due to robotic system | Concerns about high need for monitoring, error-prone programming/performance and the need to find solutions for it, disturbances in the workflow through the presence of the robot (spatial, auditory) and necessity to spend time for further training and education |
| Rejection/concerns of colleagues | No affinity for technology among staff, no willingness to learn/spend time with technology, fear of technology taking away the work, and concerns about convincing people that technology potentially alleviates work strain |
| Risk of injury/endangerment of patients | Worries about injuring patients in any caretaking task (e.g., transfer, feeding), RAS colliding with or running over patients, concerns about patients' privacy rights (e.g., RAS being present when patient is undressed), RAS carrying out inappropriate actions (something against the patient's will) |
| Fear by patients | Concerns about patients feeling uncomfortable or afraid of RAS and patients' potential (un) willingness to be helped/cared for by a RAS; especially mentioned with regard to older patients and seniors in nursing homes |

**Table 6**
Trust towards a RAS.

| Coded Remarks about Trust | Further Explanation and Examples by Participants |
|---|---|
| Generally trusting | General trust in (process of developing) technology, mostly in accordance with statements on having no fears |
| Not trusting | Unfamiliarity and insecurities with handling technology; confidence that this might change over time |
| No loss of trust after errors | Expressed understanding that technology is sometimes flawed and errors happen; understanding of origin of error and resolution leads to no loss of trust |
| Loss of trust after errors | Errors leading to loss of trust include endangerment of staff or patients, loss of trust because RAS does not keep up with its advertisement |
| Forgivable errors | Minor deficiencies in the disinfection of rooms |
| Building trust through reports from others | Learning about success stories from others, documentation from other teams in other healthcare facilities working with RAS, workshops with other healthcare workers on RAS |
| Building trust through interaction | RAS has to earn trust through continuous use, habituation through interaction that leads to trust, comparison with other existing technology that was new once and became normal in everyday practice |
| Building trust through explana-tion of functions | Explanation of all the features and functions, information of usage and handling, time to get acquainted, being supported with implementation period |

**Table 7**
Emotions towards a RAS.

| Coded Emotional Responses | Further Explanation and Examples by Participants |
|---|---|
| Fears about liability | Concerns about liability, repair costs, responsibility |
| Fears about system failure | Concerns about unexpected technical system failures, especially in the event of urgent use; including fears that staff cannot resume work in case of system failure |
| Fears about RAS re-placing people/staff | Technology as a competitor for jobs, technology leading to changed job conditions including different tasks |
| Fears about RAS lacking humanness | Concerns that RAS cannot provide good care as a human caretaker would, worries that patients would not accept a non-human care provider, RAS seen as a potential burden, e.g., lacking human communicative skills |
| No Fears | Participants who expressed to have no fears at all, because of the expectation that (1) technology would not be deployed in all areas or (2) technology would only be deployed when it is save and ready |
| Expected stress relief through technology | Comments on generally high workload, emotional and physical stress that is expected to be relieved by additional help through technology, e.g., through saving time on certain tasks |
| Discomfort/scepticism | Scepticism towards technology readiness; statements on discomfort, especially when RAS is in direct contact with patients, e.g., when assisting with washing patients |

is also fundamental trust in *"that the machine can do what is advertised" (P2)*. Another participant (P5) expressed that confidence and trust in RAS will be part of their future work, no matter what. This participant stated that most technology is in its infancy but that they are confident that this will change and technology will be soon developed that is deployable in healthcare.

When asked directly how they really felt with the outlook of a more technologised working environment, some participants addressed fears (Table 7.) One fear that some participants mentioned is the fear of being replaced. One participant (P3) states *"He's not supposed to take over my work, he's just supposed to make it easier"*. Another participant (P4) is afraid that tasks could be taken away that are enjoyful: *"Well, when I started my training, we used to do a lot of, um, things to accompany the residents in their daily lives, for example we really spent a lot of time with them, sang and so on, and that has now been replaced to some extent, thank goodness, by the care assistants, who take over that. We used to complain and say, 'well, now the nice things are being taken away from us too', because we simply have to take on a lot more, um, responsibility for medical care, because it's becoming more and more time-consuming and documentation and so on. That's why the day-today accompaniment has meant that we no longer have so much time for it. Yes, that would be the - the concerns I would have."* This participant describes how her job has become different when tasks were distributed differently and new positions were made for so-called "everyday helpers". The job

description changed meaning that less socio-emotional support and more medical caretaking were part of the job. This participant expects a similar change in job description when new positions are created for RAS and is afraid that this change might be in their disadvantage. However, not all participants expressed fears of losing jobs or favorite tasks, e.g., *"I see this very, very positive, I don't view them as competitors" (P13)*.

Another participant (P13) addressed the challenge to keep up with an ever changing technological environment at work, given her age: *"I'm also one of the older ones, the older generation, and of course it's difficult to keep up with new things. [ …] I'm not that tech-savvy. But I don't shy away from it."* The last sentence is the key information on their emotional state. They do see potential challenges coming their way but confidently state that they are willing to take them on.

### *4.6. Do healthcare workers expect the RAS to become a team member?*

All participants considered a "team" to be essential for their job, also more essential and important compared to other professions. We coded and summarised all reasons for what a "good team" constituted (alphabetically ordered).

- Clear task division and performance
- Cohesion
- Common goals
- Communication
- Good/feel-good atmosphere
- Mutual respect
- Mutual understanding
- Openness
- Reliability
- Support amongst each other
- Trust

One participant clearly stated: *"In my profession, a good team performs twice as good as a bad team" (P12)*. After general questions on teams and reflection on importance of teams, we questioned if participants expected robots to impact teamwork. While answers on the general team questions were very uniform, the answers to robot-related questions were mixed and ambiguous.

#### *4.6.1. Does a RAS change coworking within the team?*

Some interviewees indicated that a RAS would change coworking within the team. Among those, some evaluated the expected changes positively and some expressed doubts at first. *"First of all, everybody would be offended. What? A robot? It takes away our jobs. The team would team up more, because everyone is afraid" (P12)*. This participant expected a common negative emotion shared by the whole team towards robotic deployment to lead to feeling more cohesive within the team. A negative aspect of robotic deployment thus impacts the team positively. P12 further states that *"But after one year, or two, everybody would get used to it and then it would be good. Everybody would say, earlier, we had to get it done ourselves. Nowadays, the robot takes care of it. That is very pleasant."* From these statements, we can see that the initial scepticism is turned into an optimistic future outlook. This view was prominent among our participants. Another participant (P10) explains: *"He [the robot] equalises and de-stresses our work routine. Annoying work is taken over. There wouldn't be as many conflicts within the team, the humans in the team. In that way it would be a relief and positive, yes."* The robot taking over work is expected to have such a positive impact on teamwork, that other doubts get overruled. Less workload and stress is expected to reduce conflicts within a team. Other participants neutrally stated that teamwork would change because tasks would be differently divided, because the robot would take over tasks that certain staff members were responsible for previously.

Some other interviewees stated that they expect no impact of a RAS on the teamwork. In these cases, the robot was partially positively and partially neutrally evaluated. *"It is not a problem if the robot comes into teams. As long as the same people stay, the same employees, it wouldn't be a change or a problem" (P9)*. Another participant compared the RAS with a pet. *"It is as if a puppy comes into the family. Everybody finds the puppy cute and it becomes a common goal, a common object. And a common task. I think that this can unify us, to a certain extent." (P3)* Even though this participant expected no change in teamwork, they did state that a RAS might lead to a more cohesive team. We consider this to be a change. However, the statements are inherently different from the statements above, where participants explicitly articulated that they expect a change in teamwork. The comparison with a pet indicates that there is no real integration of the RAS within the team. We can compare the "pet statement" with the citation above in which P12 expressed concerns about job security. Both participants indicate that the robot is expected to lead to more unified teams which can be considered positively. A more unified team results from a common fear in one statement, which is an essential and serious concern. The other statement can be considered rather playful: the robot as a pet, a puppy even. The underlying emotions and expectations of both statements could not be more different, but both conclude with "a more unified team".

#### *4.6.2. Will a RAS be part of the team?*

In an earlier citation by P10, a side remark is important to highlight: "there wouldn't be as many conflicts in the team, **the humans in the team**". From these sub-clauses, we learn how our participants view humanrobotic teamwork. By specifically referring to "humans in the team", this participant implies that there could also be "non-humans in the team".

At a later stage in the interview, we directly asked participants this question. Do participants understand a RAS as team member? And if so, why? In our interviews, we identified three different categories: (1) participants who spontaneously answered, "yes, the robot would be part of the team", (2) participants who were indecisive and indicated that the robot under certain circumstances could become a team member, and (3) participants who denied that a RAS can be a team member. The first group of participants provided different reasons for the team membership: *"when the robot has a name, yes [laughs]" (P1)*, *"when you are used to the presence of such things, and the tasks it takes over, then it would be part of the team. And it would probably be missed when it would be gone" (P3)*, *"I can't imagine him NOT being part of the team. Maybe not when it comes to* *private things of work colleagues, that you talk about, but otherwise, when it comes to professional stuff, it has to be part of the team" (P14)*. The second group of people were more hesitant in calling a RAS a team member: one participant explains that, on the one hand, they see the RAS in many aspects similar to a human colleague, e.g., the participant would cross the RAS' path multiple times a day as they do with other colleagues, while everyone is completing their assigned tasks. On the other hand, the participant struggles in explaining the difference: *"and I don't know, I don't see the robot, no idea [pause] … How can I explain? It is just there and I use it every day" (P11)*. In this citation, we see a remarkable difference between participants who would consider the robot a team member and those who do not: participants who view the robot rather as a technical tool tend to describe the robot with "usage" terminology. Two other examples of that would be: *"It is a tool, with which I work. And it stays a tool" (P8)* and *"Basically, I would say it's work material" (P8)*. In addition, we see one very common argument: a robot misses human attributes. Participants commented on the fact that the RAS would not take coffee breaks with them, that they could not invite the RAS to the annual Christmas dinner (it would not eat), or that it would not share humorous stories outside of its working life and laugh about it together with the rest of the team. Human characteristics seem to be an important factor for team membership.

Let's look at the following two exemplary citations.

A "Well, a robot is not a person to me and one should somehow be a person to be part of a team." (P10)

B "So, he [the robot] should wear the same workwear like us. We wear blue. Then we have a green version. That is the external version. And we have the white area. That is the nursing station. And I think that the robot, depending on where he is deployed, should wear the respective colour. Because he belongs to the team. And I do think that a robot, even though he has no emotions, he has to belong to the team." (P13)

Both persons acknowledge that the robot does not belong to humanity. Statement A (P10) ascertains that this is why the robot cannot be part of the team. A team member can only be a team member when it is a person. Membership to humanity is a necessity. In statement B, P13 explains that, although the robot is not human and misses human attributes (here: emotions), it is an obligation to include it into the team. There is strong emphasis in statement B: the participant does not say that the robot should or would be part of the team, but that "he has to". The robot's morphology is very present in the interviews with our participants. The robot not being a human seems to be important, but does not necessarily seem to be the defining characteristic for team membership, at least not for all of our participants. We reflect more on this controversy in the discussion section.

#### *4.6.3. Could a RAS become part of the team over time?*

Of those, who denied that a RAS would be a team member, we asked (1) if this could change over time and (2) if there are any factors contributing to the gradual integration into the team. P12 argues that a human name would help in perceiving the robotic system as a colleague. This would also help in referring to it in front of patients. But P2 states *"for my sake, we can call the device Paul, but it's still the device Paul"*. Most participants argued that the most relevant aspect would be the tasks that the RAS takes on. The more tasks in general and the more relevant the tasks are, the more it will become a relevant part in the overall team structure and performance. Generally, participants used **task- and work-related** arguments to state why the robot could become part of the team, and **task- and work-unrelated** arguments why the robot could not become part of the team. This is especially evident for participants who generally reject the idea of robotic colleagues in the future, but also participants who are open towards it provide similar argumentation. Missing human attributes, from not being able to drink coffee to not laughing at jokes or crying out of empathy, is the major argument against team membership of a RAS. All of which are completely unrelated to tasks at work.

#### *4.6.4. Is a RAS an equal partner? Where does it stand in the hierarchy of workers?*

Independent of a RAS's membership in the team, we asked participants if they considered the robot a partner, whether the partnership would be equal or if there would be a certain hierarchy implied. In our sample, we had participants with two positions. Most participants did not expect a RAS to be equal partners. They placed the RAS in a hierarchy under any human working in the team. Some participants expected RAS to be equal partners. No participant imagined RAS in any kind of leading role.

From those who imagined the robot equally, one participant (P6) says that *"I don't see it as hierarchical at all, I see it as synergy"*, another one says (P3) *"You could actually say that he is then also on an equal footing to some extent"* and yet another one (P1) explains that *"Just think, he's equivalent. He does the same thing"*. This participant then continues: *"Well, of course it depends on what he does, if it's just some kind of auxiliary work anyway, warehouse work or pick-up and delivery service, then I would again regard him as, um, not equal"*.

The majority states that the robot would not be an equal partner. From

the last cited statement, we can see the major argument: the tasks that a RAS would fulfill qualifies for equal partnership or not. The RAS is considered *"actually just a* support *and not a full member" (P4)*. Sometimes participants compare the RAS with a human temporary employee who helps with tasks but does not have an independent and responsible role. This explains the hierarchical concept, both for humans and for RAS.

#### *4.6.5. Is the RAS perceived differently from other technical devices?*

The answers to this question were mixed. We have to differentiate between participants who stated that (1) the robot is different from other technology and is therefore automatically more accepted as a team member, (2) the robot is different from other technology, but that does not make it a team member, and (3) the robot is not different from other technology and is therefore also not differently accepted as a team member.

One argument that most participants put forward in the context of difference to other technical devices is the robot's appearance. *"If the robot has a human-like appearance, then you perceive it differently from other devices. I mean, when you package the robot as a human, then you view it more human, that's like a visual deception in the moment" (P14)*. Some participants stated that the more human-like the robot looks, the more it is differentiated from other technology and the more it might be a team member. However, there are other reasons than appearance why different technology is perceived differently. One participant (P1) classified technology in the workplace along importance. She argues that the ventilator that lets patients breathe is a far more important technical tool, not only in keeping the patient alive, but in reference to the task that it carries out. Without it, someone would need to stand beside the patient's bed and constantly provide breathing help manually. In her opinion, this is a much better and more valuable technological help than a robot, e.g., for collecting linen. This is why she would classify a robot lower in the hierarchy than a ventilator. So, different perception of technology does not necessarily mean that far more advanced technology (such as autonomously working robots) or human-like appearance (in a RAS) are automatically perceived better in some way, or automatically perceived as more eligible to be a team member. Another reason provided by participant 11 is the cost of a technological tool. If a technology is more expensive than another one, it is perceived more valuable. A RAS that would include complex technology that is also cost-intensive would be classified higher than other, less complex and cheaper technology. Both reasons, the perceived importance of a technology and the costs, make a robotic system perceived differently from other technology. This does not mean that a robotic system is automatically more integrated as a team member.

Few participants stated that they would not at all differentiate between any used technology, including robotics. One participant jokes *"I also don't say that the coffee machine is a colleague [laughs] No, I couldn't" (P10)*.

## 5. Discussion

In this interview study, we examined healthcare workers' expectations, trust, emotions, wishes, and challenges regarding the deployment of RAS in their workplace. We specifically investigated whether RAS would be seen as team members and the reasons behind this perception.

The discussion will first address healthcare workers' expectations, wishes, challenges, trust, and emotions towards RAS. Then, we will explore the anticipated impact of RAS on teamwork, review relevant literature on all-human teams, and assess its relevance for human-robot teams.

### *5.1. Discussion of expectations, wishes, expected challenges, trust and emotions by healthcare workers*

Some scepticism but overall excitement and optimism towards future deployment of RAS is a common finding in our interviews. We observed this not only for Type 1 interviewees (generally accepting technology, expecting technology to gradually take over more and more tasks in healthcare), but also for Type 2 (conditionally accepting of technology, demanding technology to take over only certain tasks in healthcare). None of our participants generally opposed the idea of robotics in healthcare. This may be due to participants' personal interest in the topic, which reflects the so-called self-selection bias. This would imply that only individuals with a general interest in robotics in healthcare would participate. However, this self-selection bias cannot be circumvented entirely in interview-based research, as voluntary participation is central to ethical good practice (Robinson, 2013). Irrespective of the self-selection bias caused by an interest in the topic, we expected a range of participants from strong supporters to harsh critics. We anticipated both supporters and critics would be interested in the topic, suggesting their presence in our sample. Given our broad promotional efforts through staff superiors, we believe the absence of critics is not due to ineffective advertising. Consequently, we conclude that among healthcare workers in our sample, there are few harsh opponents, mostly enthusiasts or those with indifferent opinions. Some participated in our study, while others may have been too indifferent to engage.

Some participants recognized that RAS might replace parts of the human workforce (type 2), while others, classified as type 1, did not consider negative consequences during the initial open discussion. Type 1 participants expressed expectations that robots could eventually take over most of their work but did not worry about job security or quality of care at that time. When directly asked, some type 1 participants acknowledged potential downsides to introducing technology in healthcare, reflecting similar fears and challenges as type 2 individuals, but only after prompting.

Are these differences related to personality? Do they affect how healthcare personnel will interact with and adapt RAS in their workplace? Further research could clarify the influence of personality on the successful implementation and collaboration with technology for individuals classified as type 1 and type 2. Literature on technology acceptance indicates that personality traits, particularly openness to experience and extraversion, significantly impact usage intentions and expectations (Svendsen et al., 2013). Based on the identified types, we propose the following questions for future research.

- Do we find two clusters of healthcare workers in larger scaled, empirical studies? Will these two clusters reflect the identified types in this study: type 1 (generally accepting technology, expecting technology to gradually take over more and more tasks in healthcare) and type 2 (conditionally accepting of technology, demanding technology to take over only certain tasks in healthcare)?

The general optimism and openness towards the introduction of RAS is suprising given previous research on the matter. Hajiheydari and colleagues cite a Cisco survey from 2017 from which we learn that 75% of IoT (Internet of Things) projects fail because of the "human factor". They expect healthcare provider's scepticism and resistance towards IoMT (internet of medical things) to cause failed implementations. In a review on healthcare robotics from 2024, the author concludes with similar arguments: "Negative attitudes and concerns from the public, patients and healthcare staff can be a significant barrier to implementation. Specifically, healthcare staff might be opposed to the introduction of robots due to lack of familiarity with technology, perceived threats to professional roles (e.g., job losses), absence of an apparent personal benefit, or lack of trust in the technology" (Silvera-Tawil, 2024, p.189). Following our interviews, we cannot entirely confirm this. Lack of familiarity is indeed a concern raised in the interviews, but it is met with constructive ideas on how to overcome this issue (e.g., technical support and explanation of functionalities). We could not detect great fears and negative expectations that came along with it that we consider to hinder implementation of technology. None of our participants had specialized training in technology during their vocational education, yet all felt confident in handling technology or seeking help. One participant noted that healthcare staff in emergency and surgical settings are accustomed to using advanced devices, suggesting that hospitals are not "technology-free zones" and that staff should not be underestimated. The next argument that is refuted in our interviews is the following: absence of an apparent personal benefit. All participants expressed a desire for RAS to physically assist them, highlighting its potential for stress relief both physically and mentally. This represents a significant personal benefit that our participants would readily embrace. The final statement regarding key barriers to implementation was the perceived threat to professional roles, such as potential job losses. We can confirm that most participants classified as type 2 expressed concerns about this issue immediately. In contrast, type 1 participants did not consider these potential negative consequences until prompted directly.

In conclusion, our interviews indicate that concerns about robots replacing staff and the perceived lack of humanness in robots may influence healthcare workers' readiness to accept RAS in their workplace. However, factors such as expectations regarding trust, unfamiliarity with technology, and general opposition are likely **not** significant barriers to working with RAS, as these issues appear to be resolvable over time. We do not observe widespread scepticism or resistance toward technology; rather, we find that healthcare workers are open to technology that enhances their work environment and are willing to invest in their personal development and technological knowledge to adapt to future workplace changes.

However, considering that some prior research suggests healthcare staff are generally more opposed to the implementation of RAS, and our interviews do not reflect this opposition, we would like to propose the following alternative explanation for the participants' overall optimism:

Some statements can be seen as exemplary for what is called "Zweckoptimismus" in German (best translated with calculated optimism, where optimism stems from a specific purpose and does not imply a genuine positive outlook). Even though there might be underlying scepticism, they choose to be trusting and optimistic because there seems to be no other choice. Participants might consciously suppress worries and decide to be optimistic. Partially, we see some evidence of that phenomenon in our interviews.

One participant (P2) expressed that "to care is human," but acknowledged that time constraints hinder the ability to provide quality care. Consequently, RAS are viewed as a means to save time and relieve stress, despite involving non-human elements in caregiving. Our interviews reveal many such contradictions; RAS are primarily considered a valid option in light of the nursing crisis. Without this crisis, some healthcare workers would not regard RAS as a viable alternative. We would like to conclude this with the words of P13: *"This [implementation of RAS] can only be helpful in the current care crisis, if no one wants to do this work, then we have to react. We wouldn't even have the idea [of introducing RAS] if we had enough people."* This is strong evidence for "Zweckoptimismus" to play a role in the observed positivity.

Further research is needed to determine (1) whether healthcare staff are indeed more open and positive about the potential implementation of technology in their workplace than previously assumed, or (2) whether "Zweckoptimismus" serves as a valid explanation for the general positivity observed in our interviews. The second option suggests a forced rather than genuine optimism. Consequently, we need to investigate how these factors may influence healthcare personnel's expectations regarding technology implementation. Given that staff expectations and anticipatory sensemaking of potential benefits play a crucial role in successful implementation (SIINO & HINDS, 2004), it is essential to understand how sincerely anticipated changes are embraced.

- Do healthcare workers who are optimistic and show positive emotions towards the implementation of robotics at their workplace have a genuine positive outlook or is this a sign for so-called "Zweckoptimismus"?

In terms of wishes and hopes, we identified two clusters of participants regarding autonomy: those who wanted to closely monitor RAS and those who preferred an independently functioning system. What factors drive these opposing preferences? Future research could explore how different backgrounds and professions within the healthcare system influence the desired level of autonomy and monitoring needs.

In addition, in further research, the identified types (type 1 and 2) and the need for monitoring could be studied in larger scale studies to make quantified claims and compare identified clusters. Therefore, we would like to conclude this part of the discussion with these resulting questions for further research.

- Concerning the relationship of both identified types (1 and 2) and the need for monitoring: Do healthcare workers who are more skeptical (type 2) than others (type 1) tend towards the need to monitor more closely what a RAS does?
- Concerning the relationship of both identified types (1 and 2) and the wish for an autonomously working RAS: Do healthcare workers who tend to be open towards a RAS working independently also tend to let the RAS work in all of the three identified areas of tasks (tasks that do not include patient contact, tasks that involve interaction with patients, and tasks that involve caretaking of patients)?
- Does the wish for an autonomously working robotic system result from generally higher trust towards technology (or specifically towards RAS) for healthcare workers?

Future research should examine the circumstances and consequences that enable successful RAS deployment in healthcare. Understanding personnel's opinions, thoughts, and fears is crucial. While classifying types may not fully capture individual perspectives, it can guide the tailored introduction of robotic systems to better meet healthcare workers' needs and expectations. Ultimately, as many participants highlighted in our study, society must continually reflect on what constitutes good care and how we wish to provide care to others—and ourselves.

### *5.2. Discussion of teaming up with RAS*

In this section of the discussion, we will first explore the impact of RAS on team dynamics and then consider the potential for RAS to be regarded as team members. Finally, based on our interview findings and theoretical insights, we will propose new definitions for teams that include or exclude RAS.

#### *5.2.1. Discussion of changes to coworking and hierarchies within the team*

In our interviews, we found that participants often shared similar expectations, such as a more cohesive team resulting from the deployment of robotics. However, as noted in section 4.6, the underlying emotions and thoughts can be very different and even contradictory. For instance, one participant anticipated increased team cohesion due to a shared fear of job loss, while another likened a robot to a pet that the team cares for, also expecting it to enhance cohesion. This highlights the value of qualitative research like this interview study, which uncovers individual reasoning and thought processes. In a questionnaire format, we might have recognized both individuals' positive expectations for group cohesiveness without grasping the underlying controversies.

Prior research indicates that cohesive groups enjoy numerous benefits, with multiple studies demonstrating a positive relationship between team cohesiveness and performance (Grossman et al., 2022). From an organizational perspective, using RAS to enhance team cohesion and improve performance is a compelling strategy that future empirical studies could test. However, our participants' statements suggest that the anticipated positive impact on cohesion may stem from underlying fears. To alleviate these fears, RAS deployment should be approached cautiously; otherwise, it may not address issues contributing to the nursing crisis, such as job satisfaction. After all, job satisfaction is unlikely in an environment characterized by fear. Notably, this concern does not apply to all participants—some classified as Type 1 in our analysis may not experience such fears as intensely as those in Type 2. The individuality of these thoughts and emotions cannot be overstated.

In conclusion, we pose the following research questions for further investigation.

- Does the implementation of a RAS positively impact cohesion within the team?
- Do common expectations, especially common fears, towards the implementation of RAS in the workplace strengthen cohesion in a team?

#### *5.2.2. Discussion of potential team membership of a RAS*

Participants expressed diverse opinions on RAS team membership. While there is a spectrum of team quality, they were united in their vision of a "good" team, which not only collaborates effectively but also fosters social interactions and support among members, through social interactions, like coffee breaks and annual parties. Key characteristics identified by participants for "good" teams include mutual understanding, a positive atmosphere, and empathy. However, most participants were skeptical about whether RAS could contribute to these factors. Some believed this lack of human attributes disqualified robots from being considered team members, while others felt that missing these traits does not necessarily exclude RAS from the team; instead, they could play a different role than human partners.

We can see in our findings, that irrelevant of the question whether RAS would be team members or not, the arguments that are used for both positions can be classified into two categories: participants generally used **task- and work-related arguments** to state why the RAS would be part of the team (common goals, shared tasks), and **task- and work-unrelated arguments** why the robot would not be part of the team (coffee breaks, personal conversations). Independent of the participant's personal opinion and position regarding the team membership topic, they always argued along these two dimensions: task-related and task-unrelated criteria.

**So, one of the main learnings from the interviews is**: participants view a RAS as eligible for a team member when it comes to shared tasks, common goals and performance. Even participants who rejected the idea of robotic colleagues at first argued that a RAS could become a team member over time if it successfully takes on tasks that are relevant to the team effort. However, full team membership is hindered because the RAS misses critical human attributes that make a team ”feel” like a team. This controversy is graphically depicted in Fig. 1.

The following questions arise for further research.

- How do the different identified levels of opinion, argumentation and expectation of future RAS team membership impact each other? Where do opinions come from and how is argumentation formed? • Is a humanoid robot more likely to be accepted as a team member than a mechanic looking RAS? Does the robot's ontology play a subordinate role when it has an anthropomorpic design?
- Would a robot that is designed to show certain social qualities (share anecdotes, give collegial advice, go on coffee breaks) be accepted more as a team member?
- Does a robot qualify as part of the team in a subordinate role, i.e., a team assistent, when it works flawlessly?
- When a robot fulfils its work-related tasks flawlessly, is it accepted as a team member, but the team does not qualify as a ”good team”?

From prior theoretical work and empirical studies, researchers have defined what a team is. In what way could a RAS fulfil the requirements? Does a RAS theoretically qualify as a team member or not?

*5.2.3. Discussion of team definitions for Human-RAS teams*

Team research itself originated in the early 1960s. Back then, companies explored the possibility to group employees in smaller units, taking away the emphasis on the individual and give these units more responsibility. Research showed the enhanced productivity of such teams and benefits concerning team decision making (Forsyth, 2014). Most team definitions followed in the 1980s and 1990s, and have been used and adapted until today. We give three exemplary definitions. The first is from a psychology handbook from 2003, in which teams are described as ”dynamic entities of two or more interdependent individuals who work together toward common goals” (Kozlowski & Bell, 2003). From this definition alone, one could argue that a hypothetical RAS could fulfill the requirements. Central to this team definition is the amount of individuals (two or more) and a common purpose (the common goal). Both are easy to apply with a team involving a RAS. Another definition is slightly different and adds more detail: ”A team is a small number of **people** with complementary skills who are committed to a common purpose, performance goals, and approach for which they are mutually accountable” (Katzenbach, 2001). In this definition, we see a conditional aspect: a team consists of people, which excludes any RAS. In the first definition, the wording was ”individual”. A RAS would probably also not classify as such. However, ignoring the aspect of ontology, we could still argue that a robotic system might enrich the team with complimentary skills, that it is programmed to fulfill a common purpose, and it adheres to performance goals. Certainly, the aspect of mutual accountability is controversially discussed in several areas of research. The third definition is from a textbook on group dynamics from 2014: a team is defined as ”a unified and structured group that pursues collective goals through coordinated, interdependent interaction” (Forsyth, 2014), p.399. This definition shares the aspect of a common goal as target factor with both other definitions and the aspect of interdependency with the second definition. In addition, one word stands out in this definition: ”unified”. This word is broadly interpretable. In the context of our interview results, it seems to be the most interesting part of the definition. It might refer to what our participants considered ”the feeling of being a team”, a unity. In the textbook, it is explained by a ”cohesive alliance”, which indicates that ”teams are united in their pursuit of a common goal, so a team's unity usually springs from its task cohesion” (p. 403). Even though, they further argue that social and emotional cohesion are important aspects in team building, the most prominent cohesion factor identified is: task cohesion.

In all of the above definitions, we do not clearly see ”being able to drink coffee during breaks” as a relevant and defining aspect for a team. Commonly, team definitions predominantly integrate dimensions, such as: common goals, shared tasks, performance, and interdependence, meaning that definitions for teams are task-oriented.

This partially aligns with our findings in the interviews. Participants deemed a RAS more eligible for team membership when it carries out tasks that are relevant and when they are performed well, in line with the participant's quality standards. Task-relevant arguments are put forward to justify why a RAS will or could become a team member. Concerning the above mentioned definitions of teams, this would theoretically suffice for the integration into the team. In practical, or at least from our participants' standpoints, this is not enough for the team definition. From our interviews, we learn that the emotional and social

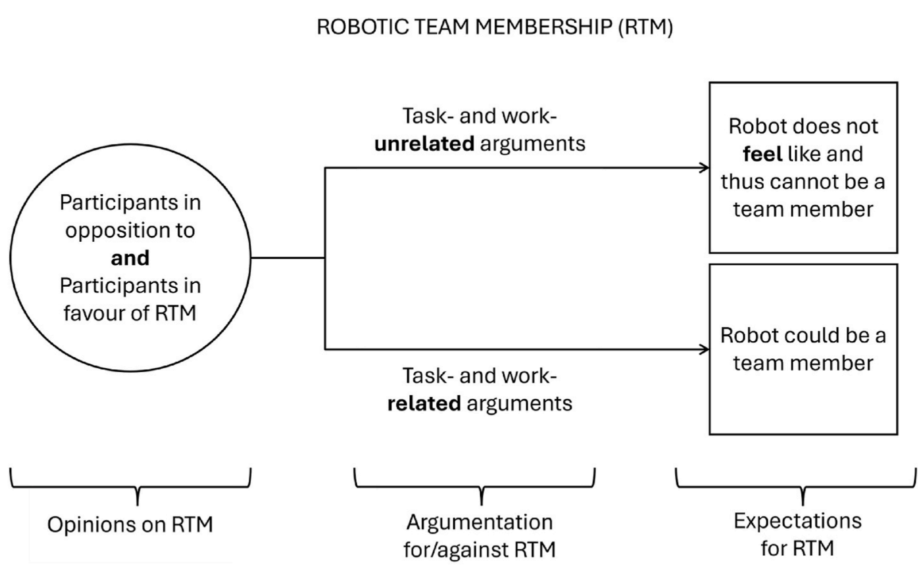


**Fig. 1.** Independent of the participants' opinion (being in favour or in opposition to robotic team membership), participants use the same argumentation strategy to explain their expectation for future robotic team members. So, participants' opinions on robotic team membership do not necessarily predict their expectation of the future. It is the class of arguments, meaning work-related and work-unrelated argumentation, that impacts whether robotic assistance systems are expected to become team members or not.

aspects of human contact are at least as important to the team definition as the task-related aspects. There is no team when these presumptions are not fulfilled.

Certainly, these aspects are also covered in descriptions of teams and covered in research on teams, their evolution and development. As stated above, the importance of cohesion in all its varieties (e.g., emotional and social) are considered (Forsyth, 2014). Research on teams obviously also included other factors, identification with the team, conflict, personality, interrelatedness, and many more facets that impact teams that do not have a task-focus. However, in the standard definitions for what a team is, meaning the one defining sentence, they do not get much attention and for all-human teams, this is justified. For all-human teams, inherently human attributes are assumed. Humans are social and emotional. Humans are obviously able to drink coffee together, share funny stories from their weekend and have a Christmas party. These are not essential factors for the defining sentence that explains a work team. So, for a simple statement of what a team is, these information are not essential for all-human teams. When small work teams were invented in the 1960s, the focus on its task orientation and superior performance was what made a team stand out over individual workers. Logically, research on teams was focused on the explanations how and why teams performed so well on their tasks, and with this the task focus was born.

With RAS entering the work space, the focus has to be shifted. While existing literature demonstrates that teams of humans have successfully collaborated with robots, we wish to emphasize that such successful collaboration does not necessarily equate to the genuine integration of robots into a team. Here, we have to rethink what a team is. Because when entities become potential team members, that are not able to drink coffee and have lunch breaks, these human aspects suddenly become important in the decision if there is a team or not. In consequence, we have to find new definitions. For potentially mixed teams, with human and robotic team members, other factors become more important. Starting with a new theory on what such a team would be, could help in guiding research towards finding an answer to the important question of whether RAS may or may not become team members in work teams in the future.

### 5.3. Defining Human-RAS teams for future research

Prior Literature and our participants propose that good teamwork is more relevant in healthcare than in other disciplines and areas, because it is directly linked to patient safety (e.g. Jeffcott & Mackenzie, 2008). To put it differently, consequences of bad teamwork are more fatal than in many other areas. So, any team should be and feel like a good team - especially in healthcare. If we want to know what a good team is, we have to start with a theory on what a team is.

Especially in healthcare, but also in other areas, we propose to differentiate between three overarching team constellations that need to be further defined.

- all-human teams
- all human teams that work with robotic assistance systems (RAS as tools)
- human-RAS mixed teams (RAS as team partners)

For all-human teams, we have decades of research and theories that we can utilise to understand team development, team dynamics, team performance and other related factors. For the two latter categories, we have little to almost no prior knowledge.

Team researchers should thus choose, which definition and theory they use as a foundation for their research: if all-human, a team is defined as, e.g., dynamic entities of two or more interdependent individuals who work

together toward common goals (Kozlowski & Bell, 2003). So, for the standard definition of a team, we have to include a conditional statement: "if all-human". This implies all the additional human features that are not explicitly mentioned in an allhuman team definition. The following sentence is exemplary for a definition of all-human teams and is derived from the three definitions above (Forsyth et al., 2002; Katzenbach, 2001; Kozlowski & Bell, 2003):

**Definition of all-human teams:** A unified, small group of people is considered a team when all human team members work interdependently, and are committed to a common purpose, performance goals, and approach for which they are mutually accountable.

In a recent review on human-robot team research, authors acknowledge the lack of a fundamental theory for teams that involve RAS and describe it as "unsteady theoretical foundation" for research (Wolf & Stock-Homburg, 2023, p. 1721). Based on the definitions that we have for all-human teams and the knowledge that we have from HRI research (e.g. (Jung et al., 2017; Jung & Hinds, 2018; Strohkorb et al., 2020),), we propose the following definition for all-human teams that work with RAS as tools see the corresponding theoretical model in Fig. 3:

**Definition of all-human teams with RAS as tools**: A unified, small group of people that either shares common tasks with or is otherwise supported by a robotic assistance system is considered a team when all

human team members work interdependently, and are committed to a common purpose, performance goals, and approach for which they are mutually accountable.

For human-RAS mixed teams we also have no defining theory. This is partially due to the fact that we still do not know whether they exist or will ever exist. Is it reasonable to propose a definition for something potentially non-existent?

In theory, a definition for mixed groups could be the following: "A unified, small group of humans and robots is considered a team when all team members work interdependently, and are committed to a common purpose, performance goals, and approach for which they are mutually accountable." From our interviews, consideration of prior research and our discussion above, we know now that this is not a realistically working definition. We will need more research on the "human attributes" that humans seem to deem essential for a proper team. So, at this point, we are unable to propose a definition for human-robot mixed teams. In consequence, for human-robot mixed teams, we do not propose a definition but only the theoretical model for further research to explore the question of robotic team membership. The theoretical model on human-robot teams can be found in Fig. 4, and stands in contrast to the model on all-human teams in Fig. 2.

Both figures depict the discrepancy between definitions that fit all-human teams and definitions that (might) fit teams that include robots. All-human teams include implicit assumptions on humanness, i.e., human traits and characteristics of its human members, that are not explicitly mentioned. **Theoretically, a robotic team member would need to fulfil all of the unmentioned assumptions to qualify as an equal team member within the mixed team.** The long list of implicit assumptions within team definitions has yet to be researched and **the**

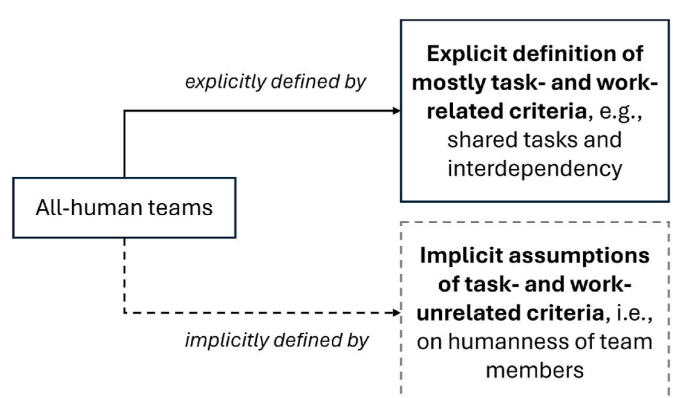


**Fig. 2.** Theoretical model on the explicit definitions and the implicit assumptions for **all-human teams.**

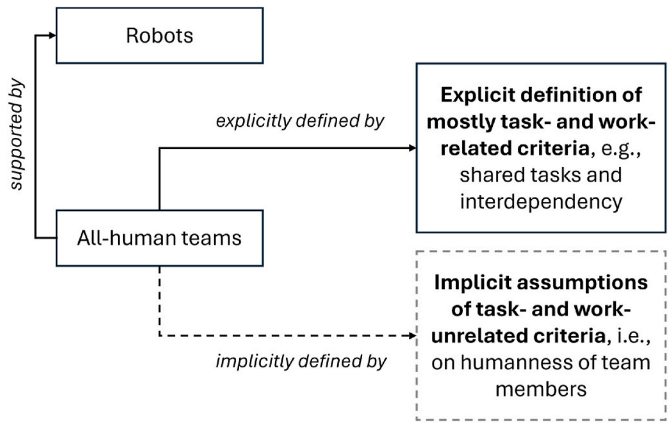


**Fig. 3.** Theoretical model on the explicit definitions and the implicit assumptions for **all-human teams with RAS as tools** (which are not considered part of the team).

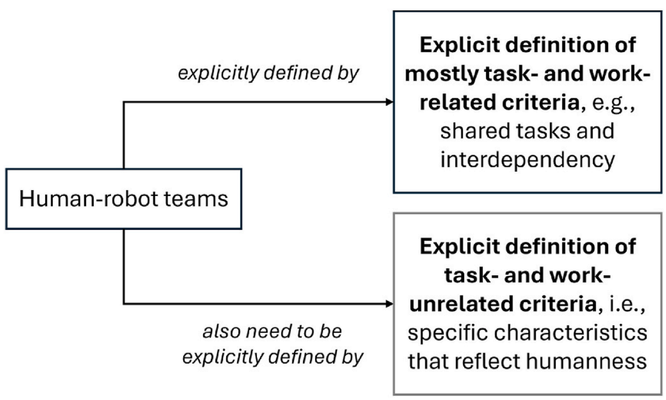


**Fig. 4.** Theoretical model for **human-robot mixed groups** which includes the explicit definition of teams (taken from all-human teams) and the necessity to make the assumptions explicit (that were implicit in all-human team definitions). This includes all the task- and work unrelated criteria that reflect humanness, which seem to be a fundamental necessity to be a team.

**question is open whether fulfilling this list would suffice for robotic team membership or not.**

## 6. Conclusion

In conclusion, our interviews indicate a notable optimism among healthcare workers regarding the deployment of robotic assistance systems (RAS), despite some scepticism. Most participants expressed a willingness to embrace technology, viewing it as a potential solution to staffing challenges, particularly in the face of nursing crisis. While concerns about job displacement were present, they were not predominant, suggesting that readiness to work with RAS is not significantly hindered by fear or distrust. The phenomenon of "Zweckoptimismus" may explain this optimism, indicating a pragmatic acceptance of technology in the face of necessity. Further research is essential to explore this phenomenon and how it may influence successful implementation of robotic systems in healthcare settings. With respect to healthcare teams, many participants saw potential for RAS to enhance teamwork, e.g., through cohesion. However, concerns about the lack of humanness in RAS inhibit expectations of robotic team members. Definitions of teams have evolved, primarily emphasizing task-related aspects, thereby deprioritizing human characteristics. Following our interviews, we understand that these human characteristics are actually fundamental to teams. There is a need to rethink common team definitions with the introduction of RAS at the workplace to account for human attributes. Thus, above we propose new definitions for several team constellations with and without RAS and pose guiding questions for future research, of which the most relevant is: Will robots ever become **true** team members?

## CRediT authorship contribution statement

**Anna M.H. Abrams:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Lena Plum:** Investigation, Data curation. **Astrid M. Rosenthal-von der Pütten:** Writing – review & editing, Supervision, Funding acquisition.

## Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Astrid Rosenthal-von der Puetten reports financial support was provided by Federal Ministry of Education and Research. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chbah.2025.100136.

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