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Table of Contents

Original Manuscript..... 5

Supplementary Files..... 36

0..... 36

CONSORT (or other) checklists..... 37

CONSORT (or other) checklist 0..... 37

CONSORT (or other) checklist 0..... 37

CONSORT (or other) checklist 0..... 37

CONSORT (or other) checklist 0..... 37

CONSORT (or other) checklist 1..... 37

# Exploring attitudes towards AI-based contactless sensors in health – a qualitative study with five stakeholder groups

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## Abstract

**Background:** Contact is a central issue in health and medicine. The rapid rise of AI-based contactless sensors (AI-CS) is expected to significantly transform how patients are measured, monitored, and understood. These technologies offer a versatile, non-invasive approach to data collection and health assessment. Despite increasing implementation in clinical and research settings, there is a lack of empirical research specifically focusing on AI-CS in health. Moreover, existing studies tend to focus on medical or patient perspectives, neglecting other stakeholders such as researchers, political actors or the general public. Both shortcomings – the lack of empirical research on contactless sensor technologies in health and a broad stakeholder perspective – have not yet been addressed in any empirical study.

**Objective:** The study aims providing an in-depth empirical ethical analysis and, through a multi-stakeholder-approach, a uniquely comprehensive overview by addressing the research question: What are attitudes of different stakeholders (patients, healthcare professionals (HCPs), researchers, political stakeholders, and the general public) towards AI-CS and their applications in health?

**Methods:** This cross-sectional study employed stratified sampling, following the concept of an innovation pipeline approach. Interviews used a semi-structured interview guide. Interviews were analyzed using qualitative content analysis with atlas.ti software, applying content-related and scaling structuring techniques. By combining deductive category assignment and inductive category formation, a three-component model of feelings, thoughts, and behavioural aspects was developed as coding scheme. The study followed COREQ (Consolidated Criteria for Reporting Qualitative Research) guidelines.

**Results:** The results of the study provide an in-depth analysis of attitudes towards AI-CS in health of different stakeholders, namely their feelings, their thoughts (focusing on opportunities, challenges and values), as well as behavioural aspects (experiences, formulated implications, and preferred actions). Overall, the results show a high level of openness to AI-CS in health across all stakeholder groups. In terms of feelings and their correlation with behavioral aspects, two key trends emerged: First, greater experience and knowledge correlated with a reduced tendency to react emotionally. Second, participants with positive experiences with technologies were generally more open and positive towards contactless sensors. The combined findings on thoughts and behavioural aspects highlighted three key tensions – around contact(lessness) and the importance and

ambivalence of touch, between protection and surveillance (particularly regarding path- and context-dependency) and between the benefits and challenges of invisibility (especially in relation to control and governance implications). In addition, the analysis revealed the need for information and consent about AI-CS, and clarified possible technical implementations and fields of application.

**Conclusions:** This study provides a comprehensive and empirically grounded ethical analysis of stakeholder attitudes towards AI-CS in health. Its multi-stakeholder approach offers a unique and nuanced understanding of the social and moral landscape surrounding these emerging technologies. The findings offer valuable guidance for the responsible development, implementation, and governance of AI-CS in healthcare contexts.

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## Original Manuscript

## Exploring attitudes towards AI-based contactless sensors in health – a qualitative study with five stakeholder groups

### Abstract

#### Background

Contact is a central issue in health and medicine. The rapid rise of AI-based contactless sensors (AI-CS) is expected to significantly transform how patients are measured, monitored, and understood. These technologies offer a versatile, non-invasive approach to data collection and health assessment. Despite increasing implementation in clinical and research settings, there is a lack of empirical research specifically focusing on AI-CS in health. Moreover, existing studies tend to focus on medical or patient perspectives, neglecting other stakeholders such as researchers, political actors or the general public. Both shortcomings – the lack of empirical research on contactless sensor technologies in health and a broad stakeholder perspective – have not yet been addressed in any empirical study.

#### Objective

The study aims providing an in-depth empirical ethical analysis and, through a multi-stakeholder-approach, a uniquely comprehensive overview by addressing the research question: What are attitudes of different stakeholders (patients, healthcare professionals (HCPs), researchers, political stakeholders, and the general public) towards AI-CS and their applications in health?

#### Methods

This cross-sectional study employed stratified sampling, following the concept of an innovation pipeline approach. Interviews used a semi-structured interview guide. Interviews were analyzed using qualitative content analysis with atlas.ti software, applying content-related and scaling structuring techniques. By combining deductive category assignment and inductive category formation, a three-component model of feelings, thoughts, and behavioural aspects was developed as coding scheme. The study followed COREQ (Consolidated Criteria for Reporting Qualitative Research) guidelines.

#### Results

The results of the study provide an in-depth analysis of attitudes towards AI-CS in health of different stakeholders, namely their feelings, their thoughts (focusing on opportunities, challenges and values), as well as behavioural aspects (experiences, formulated implications, and preferred actions). Overall, the results show a high level of openness to AI-CS in health across all stakeholder groups. In terms of feelings and their correlation with behavioral aspects, two key trends emerged: First, greater experience and knowledge correlated with a reduced tendency to react emotionally. Second, participants with positive experiences with technologies were generally more open and positive towards contactless sensors. The combined findings on thoughts and behavioural aspects highlighted three key tensions – around contact(lessness) and the importance and ambivalence of touch, between protection and surveillance (particularly regarding path- and context-dependency) and between the benefits and challenges of invisibility (especially in relation to control and governance implications). In addition, the analysis revealed the need for information and consent about AI-CS, and clarified possible technical implementations and fields of application.

#### Conclusions

This study provides a comprehensive and empirically grounded ethical analysis of stakeholder attitudes towards AI-CS in health. Its multi-stakeholder approach offers a unique and nuanced

understanding of the social and moral landscape surrounding these emerging technologies. The findings offer valuable guidance for the responsible development, implementation, and governance of AI-CS in healthcare contexts.

**Keywords:** attitudes – values – (contactless) sensors – AI – health

### Strengths & Limitations

- The study provides in-depth insights into attitudes towards contactless measurement technologies in health.
- The sample includes a multi-stakeholder perspective and addresses the lack of a broad stakeholder perspective.
- Conducting the interviews both onsite and online allowed for a wide age range and both tech-savvy and non-tech-savvy participants to be included in the study.
- Recruitment took place both in and outside Germany, but the proportion of participants resident in Germany was still predominant (n = 97 resident in Germany, n = 7 resident in other countries). Although the study focused on the situation in Germany, consequences for other countries as well as for the global development of AI-based technologies can be drawn from it.
- Despite numerous attempts, we could not reach the same number of participants for the group of political stakeholders as for the other stakeholder groups.
- The participants' level of education was higher than the average level of education in Germany.

## 1. Introduction and Background

The emergence of new AI-based technologies opens up new possibilities in health. Among these, sensor technologies have emerged as a versatile tool for data collection and health monitoring. Although still in their infancy, AI-based contactless sensors (AI-CS) are partly used in telemedicine, e-health and home-based medical applications – and are thus proposed to change protocols and procedures in health. In this study, we aim to better understand and analyse the attitudes of different stakeholders towards the use of AI-CS in health: patients, healthcare professionals (HCPs), political stakeholders, researchers and the general public. Of particular interest are the two important characteristics of AI-CS (their contactless and often invisible character) and how they are perceived in health data collection.

A better understanding of the attitudes of the involved stakeholder is crucial because various studies have shown that the mere possibility of new technical systems always also brings about changes in moral values and socio-technical practices [1, 2]. We decided for the term ‘attitudes’, considering it as an umbrella term and referring to the understanding that “[a]ttitudes are a complex combination of things we tend to call personality, beliefs, values, behaviors, and motivations” [3]. We do not limit attitudes to a temporal aspect by dividing them into states and traits. Instead, we follow the distinction “[...] between the inner tendency that is attitude and the evaluative responses that express attitudes” [4], to acknowledge the fact that a person can hold several attitudes at the same time [4, 5]. Accordingly, the expression of attitudes is composed of cognitions (often referred to as thoughts or beliefs), affects (often called feelings or emotions) and behaviours (i.e. actions) [4].

Several quantitative and some qualitative-empirical interview studies have investigated the attitudes of certain stakeholder groups towards AI applications in health in order to predict the likelihood of their acceptance. Attitude studies have mainly focused on opportunities (primarily accuracy [6], efficiency and enhanced workflow and speed [7] and challenges such as the lack of human empathy [8-10], data security, and concerns about accuracy and diagnostic quality [11, 12], leading to a lack of confidence in the results [13, 14]. A survey in the United States found that people often see both the opportunities and challenges, while those who take sides are less optimistic about the potential benefits and more concerned about the potential risks [15, cf. 16]. People were more open-minded to the use of AI in cases where human decision-making, care or other processes are merely enhanced by the technology, rather than replaced [16, 17]. In particular, quantitative interview studies with physicians and medical students revealed an eagerness to incorporate AI into health [10, 14, 18].

The current state of research shows two intertwined deficiencies that lead to the research gap we are addressing:

First, attitudes towards contactless sensor technologies in health have been less explored than those towards AI-based applications in general. Empirical research into sensor technologies in health has mostly been conducted in the field of smart homes, as a way to enable older adults to remain independent at home by monitoring their health status [e.g., 19]. However, sensor technologies in health can serve a multitude of different options. In various areas of health, motion, biometric and light sensors (radar sensors and photonic sensing cameras, including infrared cameras and depth cameras), most of which operate contactlessly, are of great importance [e.g., 20, 21]. Contactless sensor technologies can be used to detect and assess the physiological states and functions of the human body (e.g. the musculoskeletal systems with diseases such as inflammatory joint disease), as well as human behaviour [22].

Second, the few existing studies on attitudes towards sensor technologies, and even more so on AI in health, tend to focus on only one or two stakeholder groups, with the exception of [6, 13, 23], which address three different stakeholder groups. HCPs [23-25] and patients [6, 23, 26-30] were most

frequently interviewed, sometimes also relatives [6, 29], caregivers [23] or visitors [31]. This is a severe problem, as there is ample evidence that data collection and measurement in health and medicine often are a multifactorial as well as multi-actor endeavour [32].

The combination of these two shortcomings – (1) the lack of empirical research on contactless sensor technologies in health and (2) the lack of a broad stakeholder perspective (including non-medical and non-patient perspectives, such as researchers or political stakeholders) – has not yet been explored in any empirical study. To address both of these deficiencies, we have developed our research question as follows: What are attitudes of different stakeholders (patients, HCPs, researchers, political stakeholders, and the general public) towards AI-CS and their applications in health?

## 2. Methods

We conducted a cross-sectional study [33] to analyse the attitudes of different stakeholder groups towards AI-CS in health. The research process (Figure 1) is based on the eight steps of qualitative coding analysis [34]. It follows the consolidated criteria for reporting qualitative research (COREQ) guideline [35].

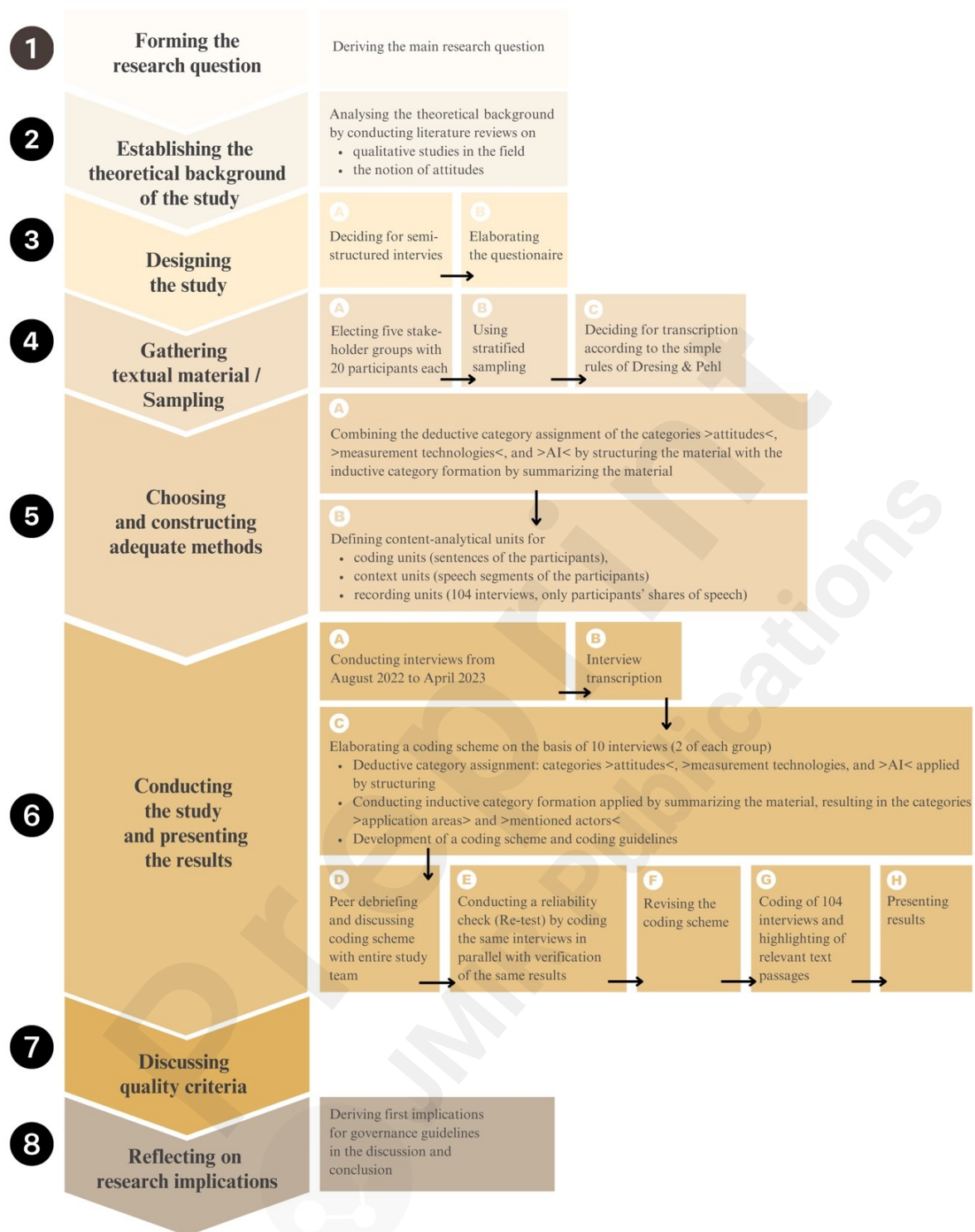


Figure 1: Scheme of the study design and research process (Mayring, 2022)

## 2.1. Sampling & Recruitment

Stakeholder groups were selected through stratified sampling [36] along the idea of an innovation pipeline approach [37]: Who are the people likely to come into contact with AI-CS? Who will be involved in their development and regulation? We have identified five stakeholder groups as relevant (Figure 1, step 4): (1) PATIENTS who are the target of sensor-based measurements, (2) HCPS who use sensors as monitoring tools, (3) RESEARCHERS who develop and investigate sensors, (4) POLITICAL STAKEHOLDERS who decide on their use, and (5) unaffiliated representatives of the GENERAL PUBLIC.

To be included, participants had to be at least 18 years old, able to complete the interview in English or German, willing to sign a consent form and agree to be audio recorded.

The study was widely promoted nationally and internationally in medical institutions, research networks, associations, public places and social media. To ensure a similar number of interviews in each group, PATIENTS were approached personally in hospitals and other medical practices, and POLITICAL STAKEHOLDERS by contacting ministries, NGOs, and individuals. To avoid overrepresentation of people with particular sociodemographic characteristics, recruitment took place in deliberately chosen public locations (e.g., hospitals, shops).

## 2.2. Participants' characteristics

A total of 104 participants, aged 20 to 87 years, were included in our interview study, 55% of whom were female (Figure 2). Figure 3 depicts the sociodemographic status of all participants. The participants were asked to assign themselves to a group: 22 identified themselves as PATIENTS, 23 as HCPs (i.e. working as physicians, medical assistants, care specialists, or nurses), 25 as RESEARCHERS (e.g. in computer science and engineering, psychology, radiology, or law science), 8 as POLITICAL STAKEHOLDERS and 26 as members of the GENERAL PUBLIC. A total of 8 participants showed a critical value on the HADS. As these individuals were evenly distributed across the four stakeholder groups, no clear correlation can be drawn.

The interviews, which were conducted on-site at the university building (n=11), remotely (n=89), and by telephone (n=4), lasted between 23 and 58 minutes. Most interviews were conducted in German (n=98), few in English (n=6).

|                      | ALL PARTICIPANTS<br>(N=104) | PATIENTS<br>(N=22) | HEALTHCARE PROFESSIONALS<br>(N=23) | RESEARCHERS<br>(N=25) | POLITICAL STAKEHOLDERS<br>(N=8) | GENERAL PUBLIC<br>(N=26) |
|----------------------|-----------------------------|--------------------|------------------------------------|-----------------------|---------------------------------|--------------------------|
| FEMALE<br>N (%)      | 57 (55)                     | 11 (50)            | 19 (83)                            | 11 (44)               | 2 (25)                          | 14 (54)                  |
| MALE<br>N (%)        | 47 (45)                     | 11 (50)            | 4 (17)                             | 14 (56)               | 6 (75)                          | 12 (46)                  |
| DIVERS<br>N (%)      | 0 (0)                       | 0 (0)              | 0 (0)                              | 0 (0)                 | 0 (0)                           | 0 (0)                    |
| AGE<br>(MEAN, RANGE) | 42 (20-87)                  | 50 (22-87)         | 44 (26-66)                         | 32 (24-60)            | 34 (26-44)                      | 43 (20-76)               |

Figure 2: Overview of the age and gender of participants within the five stakeholder groups

| HIGHEST LEVEL OF EDUCATION                                                                   | MARITAL STATUS                   | PROFESSIONAL SITUATION                                      | HEALTH INSURANCE                                         | MONTHLY EXPENSES FOR TECHNICAL APPLICATIONS/ DEVICES | MEMBERSHIP OF RELIGIOUS COMMUNITY |
|----------------------------------------------------------------------------------------------|----------------------------------|-------------------------------------------------------------|----------------------------------------------------------|------------------------------------------------------|-----------------------------------|
| N (%)                                                                                        | N (%)                            | N (%)                                                       | N (%)                                                    | N (%)                                                | N (%)                             |
| No degree 1 (1)                                                                              | Living in partnership(s) 71 (68) | Working 67 (64)                                             | Public health insurance 83 (80)                          | No money 10 (10)                                     | Yes 56 (54)                       |
| Qualified secondary school leaving certificate 4 (4)                                         | Single 30 (29)                   | Apprenticeship/student 15 (14)                              | Private or with supplementary hospital insurance 20 (19) | 1-10€ 17 (16)                                        | Christianity 47 (36)              |
| Technical baccalaureate or entrance qualification for universities of applied sciences 1 (1) | Custodian of a minor 8 (8)       | Pension 12 (12)                                             | Other 1 (1)                                              | 11-25€ 25 (24)                                       | Islam 1 (1)                       |
| A-Level-equivalent (general university entrance-qualification) 9 (9)                         | Caregiver for relatives 1 (1)    | Started working First two years since start of work 10 (10) |                                                          | 26-50€ 27 (26)                                       | Not specified 8 (17)              |
| Completed Apprenticeship 7 (7)                                                               | Not specified 1 (1)              | On sick leave 4 (4)                                         |                                                          | 51-100€ 20 (19)                                      | No 43 (41)                        |
| Technical college/ technical school/trade school 4 (4)                                       |                                  | Other 3 (3)                                                 |                                                          | 101-250€ 1 (1)                                       | Not specified 5 (5)               |
| Master craftsman's diploma 1 (1)                                                             |                                  | Unemployed 2 (2)                                            |                                                          | Over 250€ 1 (1)                                      |                                   |
| Bachelor's Degree 11 (11)                                                                    |                                  | Job change 1 (1)                                            |                                                          | Not specified 3 (3)                                  |                                   |
| Master's Degree (Diploma, State Exam or similar) 47 (45)                                     |                                  |                                                             |                                                          |                                                      |                                   |
| Doctorate 19 (18)                                                                            |                                  |                                                             |                                                          |                                                      |                                   |

Figure 3: Sociodemographic status of participants

### 2.3. Data collection

Based on an extensive literature review, a semi-structured *interview guide* [38] (Figure 1, step 3) was designed by identifying the pressing issues regarding AI-CS in health. The key issues of control [39], consent [40, 41] and human-machine interaction [42, 43] were incorporated into the interview guide, resulting in five different sections (I. Foundation; II. Human-machine interaction; III. Application example; IV. Control related aspects; V. Consent related aspects). The interview guide was discussed with other researchers and pilot tested, resulting in the addition of two practical examples of the use of AI in health (stress monitoring and palliative care). Due to the abundance of the data collected, this paper mainly focuses on sections I-III.

The day before the interviews, participants received written information about the study and *two questionnaires*: The Hospital Anxiety and Depression Scale (HADS) *questionnaire* [44] was assessed to rule out the possibility that attitudes are influenced by anxiety or depression. To avoid sampling bias, a *sociodemographic questionnaire* (Appendix 2) was implemented.

Before the interviews started, the interviewers (EH *female*, HB *female*, DS *male*) explained the setting of the study and asked for the participants' informed consent for the audio recording. Participants could choose to be interviewed on-site, remotely or by telephone to ensure the representation of different age groups and levels of technical knowledge. All interviews were conducted between August 2022 and April 2023 and were pseudonymised and transcribed [45].

### 2.4. Data analysis

The interviews were analysed using *qualitative content analysis* [34]. The techniques of content-related and scaling structuring were applied using atlas.ti software [46]. We combined deductive category assignment to refer to the current state of research with inductive category formation to consider the insights highlighted by the participants (Figure 1, step 5). We assigned three deductive

categories: (1) *attitudes*, including the subcategories *feelings* (codes: positive, negative, mixed), *thoughts* (codes: opportunities, challenges, values), and *behavioural aspects* (codes: experiences, implications, preferred actions); (2) different *measurement technologies*, in order to be able to compare the above mentioned forms of contactless sensor technologies with other contactless measurement technologies such as MRI and X-ray and contact measuring devices such as wearable sensors; (3) *AI* in order to gauge the participants' understanding to differentiate attitudes towards contactless sensor technologies and data analysis processes.

Based on ten interviews (two from each stakeholder group), the developed coding scheme was extended by forming *inductive subcodes* (Figure 1, step 6) within the deductively derived codes of the categories of feelings, thoughts and behavioural aspects. The developed coding scheme (Figure 4) was discussed and refined in a peer debriefing (Figure 1, step 6). To check for possible discrepancies, the three coders (EH, CS, LG) carried out a reliability check by coding the same interviews in parallel, resulting in a revision of the coding scheme. All 104 interviews were then coded by two coders each, with the coding scheme being continually updated and disagreements were discussed in biweekly meetings.

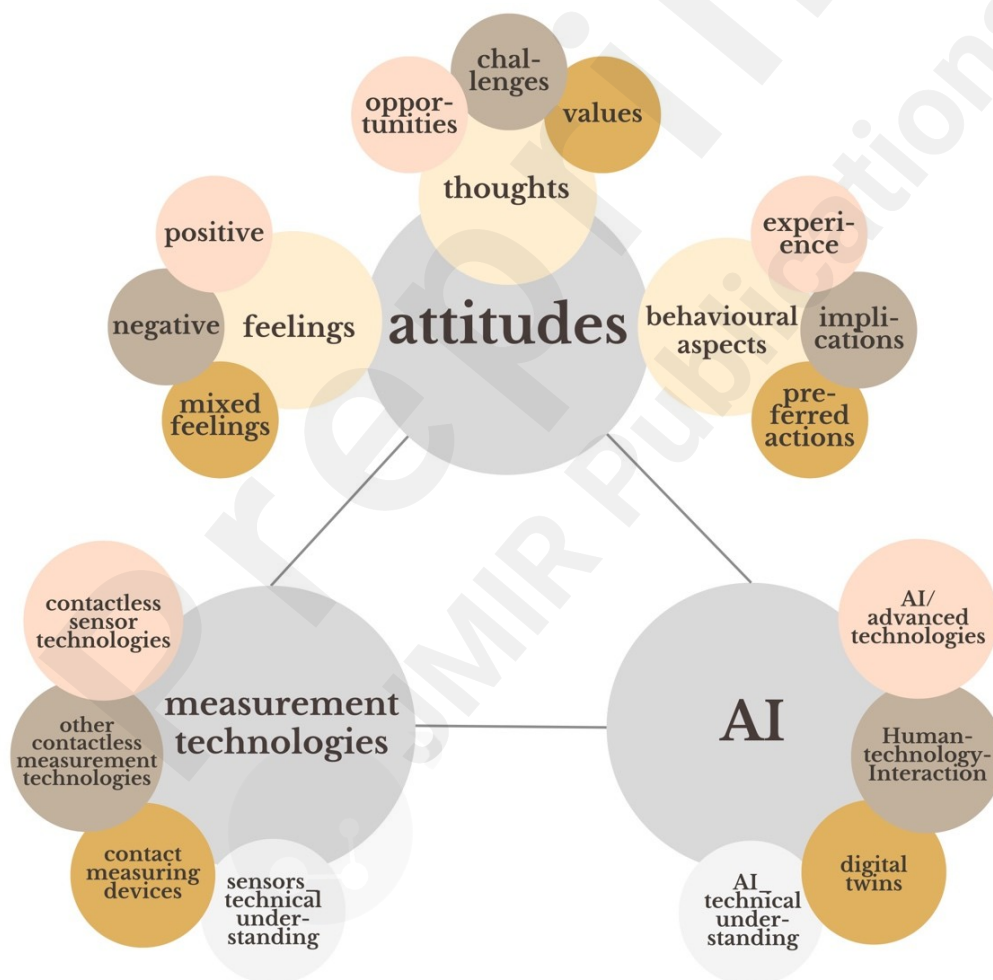


Figure 4: Code scheme

All results are visualised in the online tool called *SENSAI* [47], using the Graph View plug-in of the Obsidian software [48].

### 3. Results

#### 3.1. Feelings

Feelings were first coded deductively into *positive*, *negative*, and *mixed feelings*. Second, inductive subcodes were added within each of these codes (Figure 5).



Figure 5: Overview of feelings identified by different stakeholder groups

##### 3.1.1. Positive

Almost all participants expressed a great *openness* towards AI-CS (e.g., PS97:59)<sup>1</sup> (Figure 6). In addition to the willingness to engage with the application, different forms of *curiosity* were expressed: the overall interest in sensors and their technical possibilities (P91:76, H83:26, R31:48, PS97:73, G48:106), the specific expectation of advantages with personal or general benefits (P96:30, H74:54, R46:165, PS100:48, G64:211) or hopes for the improvement of personal or general circumstances in the clinical context and healthcare (P58:31, P70:190, H74:54, PS102:153, G7:260). *Strong positivity* was expressed in ALL STAKEHOLDER GROUPS (e.g., G4:72) and linked to individual experiences: “I have never had any negative experiences [...]” (G37:96) Some participants mentioned their *unconcernedness* about using sensors in health (PS100:83): “[...] I don’t see any problem with that at all.” (P79:45)

Notions of *hope* were expressed as positive feelings, with particular findings in the different groups: PATIENTS hoped that the use of AI-CS could have an immediate (P45:87), but also long-term benefit (P9:130). With regard to treatment, PATIENTS saw no drawbacks of contactless over other sensory systems as long as it is conducive to successful treatment (P22:107). HCPs also expressed their hope (H83:161), but with a strong focus on the application in treatment and care (H39:150). RESEARCHERS rarely expressed their hope (R25:13), as they did not perceive any substantial difference between contactless or contact sensors: “This is simply [...] a different sensor [...]” (R16:19). POLITICAL

<sup>1</sup> In the extracts, the stakeholder groups are abbreviated by their initial letters (P for PATIENTS, H for HCPs, R for RESEARCHERS, PS for POLITICAL STAKEHOLDERS, G for GENERAL PUBLIC).

STAKEHOLDERS associated clear hopes with AI-CS in regard to their use in health in general (PS102:153) and in specific areas (e.g., palliative care PS100:14). The GENERAL PUBLIC rarely expressed specific hopes (G47:25), rather curiosity about the sensor technology prevailed (G67:139).

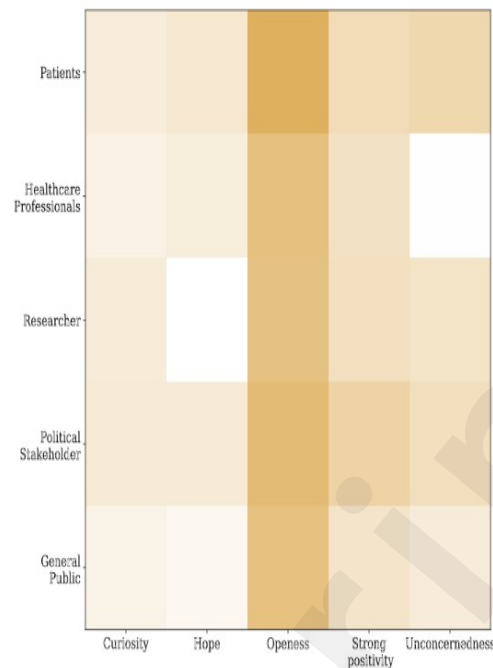


Figure 6: Overview of positive feelings expressed by different stakeholder groups

### 3.1.2. Negative

In ALL STAKEHOLDER GROUPS, *concerns* were particularly emphasised in relation to AI-CS (“problematic” P9:237; “difficult” R25:9/H85:11/G48:16; “would not feel comfortable” R38:32) (Figure 7). Where these concerns were assumed as a possible outcome, rejection occurred (“don’t need it” P35:115; “don’t want that” H44:22; “would reject it” R46:32; “would fight against it” G3:123).

Aspects of *fear* (“discomfort” R38:32; “worrying” PS101:28; „not daring” G37:28) were mentioned less frequently, and either regarding specific developments (“I’m afraid this will eventually replace me [...]” H74:155), partial aspects (“Because I’m [...] a bit afraid of this electrosmog.” P94:7) or the technology as a whole (“Sometimes I find that frightening.” H66:110).

*Pessimistic* or *sceptical feelings* were expressed regarding the potential future effects (H28:12, G20:65, PS101:138) or the technical feasibility: “But have we already reached the point where today’s data can be used to predict conditions in a few years’ time?” (P22:93). HCPS in particular raised *fears* that related to, among other things, the possible replacement of their own workforce (H74:155) or to the possibility of unconscious (mis)use (H66:110, PS101:28) in sensitive environments (palliative care H75:41; non-medical H77:90).

*Strong negativity* occurred in the form of intense rejection, concern or fear (“quite terrible” G23:142; “highly critical” H78:108; “great danger” G24:71), relating to specific effects (H78:108, R13:168) and areas: “[...] for something as vague as stress and depression, I find myself kind of flinching and thinking, oh, this is dangerous.” (P95:23) The strong polarity within the stakeholder groups is particularly striking: The most frequent negative feeling expressed by PATIENTS was an associated potential for misuse (P73:32, P91:64), a non-health-related use by the GENERAL PUBLIC (economic G48:112, public G37:138, work-related G23:20). The other stakeholder groups rarely came forward with strong negative opinions (H78:108, R46:32, PS101:116), presumably due to a stronger focus on the application. It is striking that RESEARCHERS expressed very few *negative feelings*.



Figure 7: Overview of negative feelings expressed by different stakeholder groups

### 3.1.3. Mixed feelings

A strong *need for contextualisation* came up in ALL STAKEHOLDER GROUPS, referring to the type of sensor technologies (R15:138), the area of application (H83:31, PS100:28, G18:15) and other effects (P96:31) (Figure 8). PATIENTS emphasised the need for contextualisation (P56:24) also by noting that the attitude is strongly situational: “I don’t think anyone can say, oh, I’ll do it no matter what. It’s always a matter of the moment when the question is asked [...] am I sure I’m comfortable with it or not?” (P70:107).

Related to that, there was a frequent emphasis on the *lack of knowledge* (“I can’t really imagine what they might be doing, because I can’t think of anything else to use them for, other than the practical examples from before.” P73:116) or *experience* (“And personally, I find it difficult to put myself in that position.” R46:152). Often, this was combined with a great level of *uncertainty*: “I haven’t made up my mind [...] on that for now.” G59:58). Uncertainty was expressed, especially regarding the technical feasibility and the possible effects: “Uh, in stress research, it’s not really clear to me what’s going to come from [...] knowing [...] whether a person is stressed or not. [...] I don’t have any idea yet how [...] it will help us with diagnostics [...]” (H88:55).

The aforementioned feelings resulted in an expression of *inner division* (“divided” G67:127, “ambivalent” R54:145, “torn” H89:82) in varying degrees. HCPs put a strong emphasis on feelings of *inner division* between potential benefits (H75:3) and misuse (H66:193, H72:34). POLITICAL STAKEHOLDERS perceived the advantages of AI-CS, but contrasted them with possible challenges for the individual or society: “So there are two hearts beating in my chest, you know? [...] If you realise later that you could also do this and that cool thing with the data collected [...] you really have to think very carefully about whether that really serves its purpose.” (PS101:91) Members of the GENERAL PUBLIC perceived a trade-off between collective medical progress and personal data protection (G18:15), also resulting in inner division (G67:127). Remarkably, PATIENTS expressed no *inner division*.

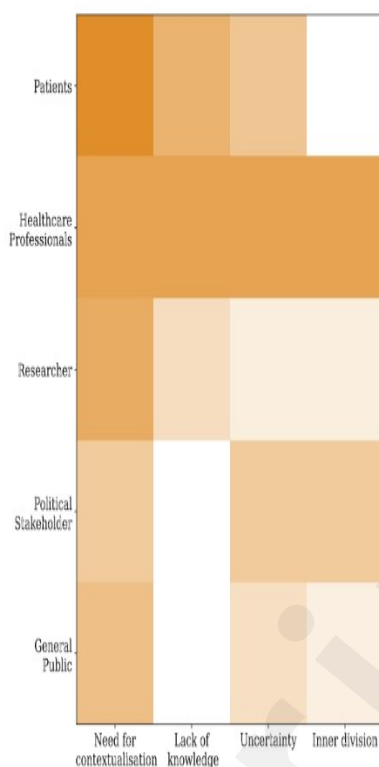


Figure 8: Overview of mixed feelings expressed by different stakeholder groups

## 3.2. Thoughts

Participants identified various opportunities, challenges and values for AI-CS, often weighing different opportunities and challenges against each other. The range and breadth of opportunities and challenges identified by stakeholders were inductively categorised into *medical*, *technical*, *economic*, *socio-political* and *regulatory* domains.

### 3.2.1. Medical opportunities and challenges

Medical opportunities and challenges were identified by all stakeholder groups in relation to different medical functions. A range of specific medical challenges and opportunities can be found in Appendix 3, categorised according to the different medical specialties.

| MEDICAL OPPORTUNITIES |   |   |    |   | MEDICAL CHALLENGES                                                  |                                                                                        |   |   |   |
|-----------------------|---|---|----|---|---------------------------------------------------------------------|----------------------------------------------------------------------------------------|---|---|---|
| P                     | H | R | PS | G | MONITORING                                                          |                                                                                        |   |   |   |
| X                     | X | X |    | X | Better monitoring in general                                        | Possibility of incidents despite regular monitoring                                    | X |   | X |
| X                     | X | X |    |   | Continuous/constant monitoring                                      | Use of other measurement methods in some cases medically more useful                   | X |   |   |
| X                     |   |   |    |   | Opportunity of long-term monitoring                                 | Occurrence of medical harm due to radiation exposure                                   |   | X |   |
| X                     | X | X | X  | X | Automatic alerts on limit exceedances/approaches                    | Causing anxiety in patients (by prescribing or measuring with sensors)                 |   | X | X |
| P                     | H | R | PS | G | TREATMENT                                                           |                                                                                        |   |   |   |
| X                     |   |   |    |   | Special application opportunities in treatment                      | Incorrect treatments due to data/analysis errors or false alarms                       | X |   | X |
| X                     | X | X | X  | X | Better treatment options                                            | Possibility of intervening too late (e.g. in the case of an attack or a fit)           | X |   |   |
| X                     | X | X |    | X | Earlier/Faster treatment                                            | Unequal treatment of patients on the basis of their choice of measurement method       |   | X |   |
|                       | X |   |    |   | More targeted treatment                                             |                                                                                        |   | X | X |
| X                     |   |   |    | X | Better overview of treatment progress                               |                                                                                        |   |   |   |
| X                     |   |   |    |   | Easier adjustments in the treatment process                         |                                                                                        |   |   |   |
| P                     | H | R | PS | G | PREVENTION                                                          |                                                                                        |   |   |   |
| X                     |   |   |    |   | Special application opportunities in prevention                     |                                                                                        |   |   |   |
| X                     | X | X | X  | X | Possibility of more preventive work                                 |                                                                                        |   |   |   |
| X                     | X |   |    | X | Increasing prevention                                               |                                                                                        |   |   |   |
|                       | X |   |    |   | Strengthening/increasing the focus on health (rather than illness)  |                                                                                        |   |   |   |
| X                     | X |   |    | X | Early detection before the onset of symptoms or deterioration       |                                                                                        |   |   |   |
| X                     |   |   |    |   | Use of Prevention to limit the extent of treatment                  |                                                                                        |   |   |   |
| P                     | H | R | PS | G | RESEARCH / SCIENTIFIC UNDERSTANDING                                 |                                                                                        |   |   |   |
| X                     | X |   |    |   | Great potential for research use                                    |                                                                                        |   |   |   |
| X                     | X | X | X  |   | Advancing medical research                                          |                                                                                        |   |   |   |
| X                     |   |   |    |   | Defeating diseases                                                  |                                                                                        |   |   |   |
|                       |   | X |    |   | More empirical data                                                 |                                                                                        |   |   |   |
| X                     | X | X |    |   | Improving the quality of research                                   |                                                                                        |   |   |   |
| X                     | X | X |    |   | Medical progress through individualisation and linking correlations |                                                                                        |   |   |   |
| MEDICAL OPPORTUNITIES |   |   |    |   | MEDICAL CHALLENGES                                                  |                                                                                        |   |   |   |
| P                     | H | R | PS | G | DIAGNOSTICS                                                         |                                                                                        |   |   |   |
| X                     | X |   |    | X | Special application opportunities in diagnostics                    | Misdiagnosis due to incorrect measurements/incorrect learning data                     |   |   | X |
| X                     | X | X | X  | X | Increasing the diagnostic quality in general                        | Misdiagnosis due to (automated) misinterpretation of symptoms                          | X | X | X |
| X                     | X |   |    |   | Supplementing the anamnesis with a third method                     | Risk of premature diagnosis                                                            | X |   |   |
| X                     | X | X | X  | X | Facilitating diagnoses                                              | Risk of false positive diagnosis                                                       |   | X |   |
| X                     | X | X |    | X | Faster diagnoses                                                    | Risk of limiting health parameters to measured data only                               |   | X |   |
| X                     | X |   |    |   | Enabling diagnoses despite hidden symptoms                          | Risk of unreliable data leading to false prognosis                                     |   | X | X |
| X                     | X | X | X  | X | Early diagnoses                                                     | Unintended/unwanted diagnosis of further diseases                                      | X | X | X |
|                       | X |   |    |   | Access to patient data outside the patient's room                   | Failure to recognise other symptoms due to complete reliance on sensor readings        | X |   | X |
| X                     |   |   |    |   | Implementing individual parameters                                  | Doctors' overconfidence in technology and lack of confidence in their skills           |   | X |   |
| X                     |   |   | X  |   | Possibility to create a health profile                              | Patient uncertainty due to data flooding                                               |   |   | X |
| X                     |   |   |    |   | Possibility of predicting future health status                      | Difficulty in defining necessary standard health parameters                            | X | X |   |
| X                     |   | X |    |   | Secondary use of collected data                                     | Restriction of the doctor's medical activity                                           |   | X | X |
|                       |   |   |    |   |                                                                     | Questioning the diagnosis of mental disorders based on quantitative data               | X | X | X |
|                       |   |   |    |   |                                                                     | Questionable value of diagnosing patients at certain stages of life (e.g. dying stage) |   | X | X |

Figure 9:

Medical opportunities and challenges identified by different stakeholder groups

ALL STAKEHOLDER GROUPS highlighted the opportunities in terms of *monitoring*, *diagnostics*, *treatment*, *prevention*, and *research* as very important (Figure 9). Firstly, respondents saw medical opportunities in improving (home) *monitoring* particularly through continuous and long-term monitoring (R25:16). ALL STAKEHOLDER GROUPS pointed out the benefits of improved patient self-monitoring in order to be better informed about their current situation and to develop a better sense of their own body (R50:19). Secondly, for *diagnostics*, this means that diseases and changes in the body can be detected at an early stage (R15:117). Thirdly, by providing a better overview of the course of *treatment*, a more targeted treatment and better preparation for focus on patient consultations are enabled (H71:22). Fourthly, participants mentioned that *prevention* could potentially play a greater role in health systems due to a changed understanding of health and disease (H74:141). Fifthly, medical progress and *research* could be advanced, especially through individualisation and the linking of contexts.

The aspect of potential harm to patients – through missed alarms despite medical urgency (PS103:72) in monitoring, through incorrect diagnosis or treatment – cuts across all challenges. With regards to *monitoring*, one RESEARCHER described their uncertainty about medical harm caused by data transmission (R27:11). In the field of *diagnostics*, “data that would be unproblematic [could] become a problem just by being collected.” (H65:127) One RESEARCHER asked: “What is the normal range? What is outside? And there I think it is a bit critical to say or to define what is normal and what is abnormal. And maybe to reflect that back to people, that they are also in the abnormal range, and what does that do to people psychologically?” (R54:27)

### 3.2.2. Technical opportunities and challenges

Figure 10: Technical opportunities and challenges identified by different stakeholder groups

[unpublished, non-peer-reviewed preprint]

It's the best you can get. [...] someone does the monitoring and cares for you in the background [...]” (PS 102:86). Other possible measurement distortions such as the white coat syndrome, unfamiliar measurement environments, touching the patient or study participant and others are reduced or even avoided by the unconscious nature of the measurement (H65:5, G4:106). In terms of the *data* generated, contactless measurement is perceived to contribute to more accurate, reliable and objective data (R63:168). Four out of five stakeholder groups highlighted the potential to measure what cannot yet be measured, such as micro-movements in joints, as a *medical-technical progress*. PATIENTS, HCPS, and RESEARCHERS described the possibility of measuring and detecting diseases based on large movements and movement patterns, but also small ones such as tiny muscle movements invisible to the naked eye. The ability to gather information about conditions that previously could only be asked about verbally, such as anxiety, restlessness, and pain, is considered great potential (R34:44).

Across all challenges, ALL STAKEHOLDER GROUPS placed particular emphasis on the technical challenges. Concerning the *development* of AI-CS, in particular, the set-up and the lack of technical expertise in using the sensors (e.g. lack of digital literacy among older patients, H89:77) was considered to potentially pose problems for the *implementation* in health (H39:23). In terms of *use*, an important consideration was how to ensure that the device worked smoothly, without by-catch or interference (R38:20). At the same time, contactless sensors were described as having limited alignment capability (R32:107) and their accuracy and reliability was questioned several times (R43:1). With regard to the collected *data*, the significance of the data was described as limited due to the individuality of the parameters, which makes comparisons difficult (P73:172).

### 3.2.3. Economic opportunities and challenges

| ECONOMIC OPPORTUNITIES |   |   |   |   | ECONOMIC CHALLENGES                                              |                                                                           |   |   |   |   |   |   |   |   |
|------------------------|---|---|---|---|------------------------------------------------------------------|---------------------------------------------------------------------------|---|---|---|---|---|---|---|---|
| P                      | H | R | P | G | WITH REGARD TO HEALTH SYSTEMS                                    |                                                                           |   |   |   | P | H | R | P | G |
|                        | X | X | X |   | Development and modernisation                                    | Increased performance pressure for hospitals/healthcare systems           |   |   | X |   |   |   |   |   |
|                        | X | X | X |   | Increasing efficiency                                            | Lack of basic structures in hospitals                                     |   |   |   | X |   |   |   |   |
| X                      |   | X | X |   | Cost savings                                                     | Development of sensor farms in hospitals for mass monitoring              |   |   | X |   |   |   |   |   |
| X                      |   | X | X | X | Improving service provision in healthcare                        | Use of sensors for economic reasons without medical indication            | X | X | X |   |   |   |   |   |
| P                      | H | R | P | G | WITH REGARD TO MEDICAL STAFF                                     |                                                                           |   |   |   | P | H | R | P | G |
| X                      | X | X | X |   | Time savings for medical staff                                   | Tying up medical staff resources                                          |   |   | X | X |   |   |   |   |
| X                      |   | X |   |   | Savings in personnel resources                                   | Increasing staff overload (instead of staff relief)                       | X |   | X | X |   |   |   |   |
| X                      |   |   |   | X | Possible solution to the shortage of medical staff               | Staff reduction through the use of sensors to maximise profits            | X | X | X |   |   |   |   |   |
| P                      | H | R | P | G | WITH REGARD TO PATIENTS                                          |                                                                           |   |   |   | P | H | R | P | G |
| X                      | X | X | X | X | Time savings for patients                                        | Reduced time spent with patients                                          |   |   | X |   |   |   |   | X |
|                        | X | X |   |   | More time for patient concerns during doctor's visits            | Pressure on patients to take responsibility for reducing healthcare costs |   |   |   |   |   |   |   | X |
| P                      | H | R | P | G | WITH REGARD TO THE PRODUCTION OF SENSOR                          |                                                                           |   |   |   | P | H | R | P | G |
| X                      |   | X |   | X | Affordability                                                    | Lack of long-term research funding as a barrier to development            |   | X |   |   |   |   |   |   |
|                        |   | X |   |   | Competition from different providers                             | Quality differences between sensors from different suppliers              |   |   | X |   |   |   |   |   |
|                        |   | X |   |   | Faster ways to produce                                           | Rejection of over-the-counter sale of sensors                             |   |   |   |   |   |   |   | X |
|                        |   | X |   |   | Faster deployment of devices possible                            |                                                                           |   |   |   |   |   |   |   |   |
|                        |   |   |   |   | WITH REGARD TO HEALTH INSURANCES                                 |                                                                           |   |   |   | P | H | R | P | G |
|                        |   |   |   |   | (Fear of) individualised health insurance premium contributions  |                                                                           |   |   | X | X |   |   |   |   |
|                        |   |   |   |   | Risk of abandoning solidarity-based health insurance systems     |                                                                           |   |   |   |   |   |   |   | X |
|                        |   |   |   |   | Patient transparency through massive data collection and storage |                                                                           |   |   | X |   |   |   |   | X |
|                        |   |   |   |   | NON-HEALTH-RELATED DATA USE                                      |                                                                           |   |   |   | P | H | R | P | G |
|                        |   |   |   |   | Use of commercial data as a risk in itself                       |                                                                           |   |   | X |   |   |   |   | X |
|                        |   |   |   |   | Refusal to use data outside the health sector                    |                                                                           |   |   | X |   |   | X |   | X |
|                        |   |   |   |   | Lack of transparency on how companies use and process data       |                                                                           |   |   | X |   |   | X |   |   |
|                        |   |   |   |   | Large-scale data ownership by tech giants                        |                                                                           |   |   |   |   | X |   |   |   |

Figure 11: Economic opportunities and challenges identified by different stakeholder groups

It is striking that a common motif across all economic opportunities are savings of time, money, and resources (Figure 11). In terms of *health systems*, time savings through self-measurements at home

and more efficient doctor visits and cost savings through the early detection and reduction of treatment costs were mentioned. These opportunities are expected to relieve HCPs by making their work more efficient and easier, as there is no need for extensive training to operate the equipment (R38:37). In terms of *product-specific* economic opportunities, participants thought that contactless sensors could be produced and achieve widespread coverage more quickly due to the low cost of the devices (R15:43, G53:93).

With regard to HCPs and PATIENTS, fears of overburdening, additional pressure and extra work were expressed as challenges. HCPs would have to learn to use the systems intensively; system errors and incompatibility with other systems would mean extra work and tie up resources (G24:14), leading to a rubberband effect for HCPs (G61:110). Pressure on individual patients could increase, similar to the pressure on *hospitals* and *health systems* to reduce costs through behavioural change (G57:22). To cope with this pressure, hospitals could set up “sensor farms” (R46:25) to cut costs and use sensors without medical indication (P73:93). In particular, a possible increase in patient transparency vis-à-vis *health insurance companies* was seen critically (H41:21). Great fears were also expressed regarding the solidarity principle of public health insurance systems such as the German one, “whether [...] health services could not also be linked to certain lifestyles, [...] and that is actually an imperative that is categorically ruled out in Germany.” (G57:54)

### 3.2.4. Socio-political opportunities and challenges

| SOCIAL OPPORTUNITIES                                                           |  |  |  |  | P | H | R | P | S | G |
|--------------------------------------------------------------------------------|--|--|--|--|---|---|---|---|---|---|
| Positive social benefit through utilisation                                    |  |  |  |  | X |   | X |   |   | X |
| Accessibility for everyone                                                     |  |  |  |  |   |   | X |   |   |   |
| Improving communication                                                        |  |  |  |  |   | X | X |   |   | X |
| Relief for relatives                                                           |  |  |  |  |   |   | X |   |   | X |
| POLITICAL OPPORTUNITIES                                                        |  |  |  |  | P | H | R | P | S | G |
| Acceptance of use                                                              |  |  |  |  |   | X | X | X |   |   |
| Potential for managing demographic change                                      |  |  |  |  |   |   |   |   | X |   |
| Removing barriers                                                              |  |  |  |  | X | X |   |   |   |   |
| Civil protection                                                               |  |  |  |  |   | X | X |   |   |   |
| An opportunity in itself: balancing risk and opportunity                       |  |  |  |  |   |   | X |   |   |   |
| SOCIAL CHALLENGES                                                              |  |  |  |  | P | H | R | P | S | G |
| INDIVIDUAL RISKS                                                               |  |  |  |  | P | H | R | P | S | G |
| Social consequences of increasing contactlessness                              |  |  |  |  |   | X |   |   |   |   |
| Loneliness                                                                     |  |  |  |  |   | X |   |   |   |   |
| Risk of seeing oneself as superfluous                                          |  |  |  |  | X |   |   |   |   |   |
| Overconcentrating on own medical data                                          |  |  |  |  |   |   |   |   |   | X |
| Decreased awareness of one's own body                                          |  |  |  |  | X |   |   |   |   |   |
| Increasing pressure to meet the expected data parameters                       |  |  |  |  | X |   |   |   |   | X |
| Pressure for self-optimisation                                                 |  |  |  |  |   | X |   |   |   | X |
| Increases in patient anxiety/stress                                            |  |  |  |  |   | X | X |   |   | X |
| Risk of accelerating life                                                      |  |  |  |  | X |   |   |   |   |   |
| FEARS                                                                          |  |  |  |  | P | H | R | P | S | G |
| Fear of surveillance and anxiety caused by surveillance measures               |  |  |  |  | X | X |   |   |   | X |
| Fear of losing touch                                                           |  |  |  |  |   | X | X |   |   |   |
| Fear due to invisibility of measurement                                        |  |  |  |  |   | X |   | X |   |   |
| Fear of radiation                                                              |  |  |  |  | X | X | X |   |   |   |
| Fear of electric shocks                                                        |  |  |  |  | X |   |   |   |   |   |
| Fear of people being reduced to numbers and facts                              |  |  |  |  |   |   | X |   |   |   |
| Fear of having fundamental rights violated                                     |  |  |  |  | X |   |   | X |   |   |
| Fear of (social) selection                                                     |  |  |  |  | X |   |   |   |   |   |
| Fear of job cuts                                                               |  |  |  |  |   | X |   |   |   |   |
| INTERACTION                                                                    |  |  |  |  | P | H | R | P | S | G |
| Loss of interpersonal and psychosocial interaction                             |  |  |  |  | X | X | X |   |   | X |
| Loss of the human connection                                                   |  |  |  |  | X |   | X |   |   |   |
| Loss of empathy                                                                |  |  |  |  |   |   | X |   |   |   |
| Need for interpersonal interaction (for certain diseases/medical specialties)  |  |  |  |  | X |   | X |   |   |   |
| Medical staff focused on machines rather than patients                         |  |  |  |  |   | X |   |   |   | X |
| Diffused responsibility of medical staff                                       |  |  |  |  |   |   |   | X |   |   |
| Social pressure on patients when medical staff insist on a measurement         |  |  |  |  |   | X |   |   |   |   |
| Reliability of measurement or doctor visit associated with touch               |  |  |  |  |   |   | X |   |   |   |
| Influencing the development of a society                                       |  |  |  |  |   |   | X |   |   |   |
| Challenging social norms and concepts of society                               |  |  |  |  | X |   | X |   |   |   |
| Restriction of social participation                                            |  |  |  |  |   |   | X |   |   | X |
| POLITICAL CHALLENGES                                                           |  |  |  |  | P | H | R | P | S | G |
| ACCEPTANCE                                                                     |  |  |  |  | P | H | R | P | S | G |
| Expected low acceptance and difficulties in accepting                          |  |  |  |  |   | X | X | X |   |   |
| Society's discomfort with radiation                                            |  |  |  |  |   | X | X |   |   |   |
| Influence of different educational backgrounds on acceptance                   |  |  |  |  | X |   |   |   |   |   |
| Various reasons for refusal (lack of knowledge, personal preferences, etc.)    |  |  |  |  | X | X |   |   |   |   |
| Lack of education and public information                                       |  |  |  |  |   |   | X | X | X |   |
| PREIMPLEMENTATION CONSIDERATIONS                                               |  |  |  |  | P | H | R | P | S | G |
| Limited benefits                                                               |  |  |  |  |   |   | X |   |   | X |
| Challenging assessment of the advantages and disadvantages of sensor use       |  |  |  |  |   | X |   | X | X |   |
| Power of the insurance companies to decide on the use of the sensors           |  |  |  |  |   |   |   |   |   | X |
| IMPLEMENTATION                                                                 |  |  |  |  | P | H | R | P | S | G |
| Long implementation time of new technologies in healthcare systems             |  |  |  |  |   |   | X | X |   |   |
| Nationwide availability of sensors                                             |  |  |  |  |   | X |   |   |   |   |
| Lack of cultural change from a reactive to a preventive healthcare system      |  |  |  |  |   |   |   |   | X |   |
| Patient-related and process-related difficulties                               |  |  |  |  |   | X |   | X |   |   |
| Uncertainty about unforeseen consequences of use                               |  |  |  |  |   |   |   |   | X | X |
| Need to clarify sensor distribution, prescription and billing responsibilities |  |  |  |  |   |   |   |   | X |   |

Figure 12:

Socio-political opportunities and challenges identified by different stakeholder groups

*Social* opportunities (Figure 12) were only touched upon, mainly by RESEARCHERS: Health in general is increasingly taking centre stage, and the societal benefits outweigh this. In addition to being accessible to the masses (R27:23), the use of sensors could contribute to “[...] be more mindful, especially if you [...] do different training sessions or exercises or just know [...] what your body needs [...] and maybe the togetherness is more balanced because you are in control of yourself”

(G59:76). It can also reduce the burden on relatives, both by providing a useful measurement tool, and by relieving them of the need to be present during disease-altering events (R13:143).

Particular *political* opportunities are to overcome barriers (such as language, or to sustain accessibility in the patient's room; P80:67) and to reach people who avoid hospitals because of fear (H83:61). One POLITICAL STAKEHOLDER described the use of sensors for immobile patients as an opportunity to address demographic change despite the shortage of physicians (PS104:80).

Identified social challenges include various types of *fears* (of surveillance, loneliness, staff cuts, and others) and *risks* to individuals. More direct access to one's own data could make patients feel anxious and discouraged, and quickly lead to over-focus: "[P]hysical health even more steps out of the private sphere [...] and becomes an object [...] of public display. [...] [T]his display of inner strength, of health and vitality, also creates pressure [...] on people who are unable to do so because they may simply be ill." (G57:2) In terms of *interaction*, a possible influence on social development (R46:179), on social participation (R76:22) and an increasing lack of physical contact were mentioned. In relation to human-human-interaction (H74:44), one PATIENT described the importance of human contact from their own experience: "I managed to get back on track to a certain extent. But only with the human element. With technology alone [...] I would [...] no longer see any sense in life." (P69:85) Several participants highlighted the role and importance of touch in the healing process: "[Y]ou can also simply reassure people, establish contact with people [...] by simply touching them" (H75:104). Contactless data collection often leaves a feeling of unreliability or a feeling of not having been properly examined (R15:139, R43:24). Some participants drew parallels with the contactless situation during the SARS-CoV-2 pandemic (H74:71, H86:103).

Low levels or lack of *acceptance* were identified as a political challenge, which may be due to the human impulse to initially reject the unknown (PS97:18), the presumed slow build-up of acceptance among PATIENTS and HCPs (PS102:43), and societal reservations about radiation (R8:127, H92:47). One PATIENT suggested that "[...] a discussion should only take place on a scientific level, [...] if the general [...] population takes part in a discussion, um, the topic is already lost anyway." (P68:40) In terms of *pre-implementation issues*, the benefits of contactless measurement were questioned in general, not just for patients who were already wired (R15:46, PS102:55). The judicious use of AI-CS was described as a challenging balancing process. The resources needed to operate the technology should not be wasted (G52:99). POLITICAL STAKEHOLDERS in particular saw *implementation* challenges, e.g. due to the slowness of change in the medical field (R30:118). Another challenge is also a not yet realised "[...] paradigm shift, which then favours a preventive [...] health protection, health care" (PS102:55). Further ambiguities exist in the exact procedure (PS101:78).

### 3.2.5. Regulatory opportunities and challenges

| REGULATORY CHALLENGES                                                  |  |   |   |   |        |   |                                                                                    |  |   |   |   |        |   |
|------------------------------------------------------------------------|--|---|---|---|--------|---|------------------------------------------------------------------------------------|--|---|---|---|--------|---|
| ABUSE OF SENSORS                                                       |  | P | H | R | P<br>S | G | ABUSE OF DATA                                                                      |  | P | H | R | P<br>S | G |
| Fine line between use and potential abuse                              |  | X |   |   | X      |   | Large scope for data abuse in general<br>(by companies/employers/individuals/etc.) |  |   | X | X |        | X |
| High risk of abuse due to invisibility of the measurement              |  | X | X | X |        |   | Hacking/phishing                                                                   |  |   |   |   |        | X |
| Dual-use risk (high potential for misuse outside the health sector)    |  | X | X | X | X      | X | Interception of data                                                               |  |   |   | X |        |   |
| Increased surveillance possibilities (by states/employers/individuals) |  | X | X | X |        | X | Unauthorised disclosure of data                                                    |  |   | X | X |        | X |
| Misuse by states/employers to control citizens/employees               |  |   |   | X | X      | X | Unauthorised secondary use of data already collected                               |  |   |   |   | X      |   |
| Risk of excessive control                                              |  |   |   |   | X      |   | Attribution of even anonymised data to individuals<br>(e.g. based on gait)         |  |   |   |   | X      |   |
| CONSENT                                                                |  | P | H | R | P<br>S | G | REGULATION                                                                         |  | P | H | R | P<br>S | G |
| Being measured unknowingly (e.g. bycatch)                              |  |   | X | X |        | X | Regulation as a general challenge                                                  |  | X |   |   | X      | X |
| Being measured without consent                                         |  | X | X |   | X      | X | Challenge of regulating and approving digital medical devices                      |  |   |   |   | X      |   |
| Difficulty in obtaining informed consent from certain patient groups   |  |   | X | X | X      | X | Legal admissibility of monitoring/recording moving patterns questioned             |  |   | X |   | X      |   |
| Patient involvement                                                    |  |   | X |   |        |   | Limited effectiveness of laws and ethical standards to prevent abuse               |  |   | X |   |        | X |
| Enabling choice in consent as a major effort                           |  |   | X | X |        | X | Liability/accountability/responsibility in the event of damage/harm                |  |   |   |   | X      | X |
| Dealing with rejection of the technology                               |  |   | X |   |        | X | Ambivalence between intended awareness (law) & non-awareness (measurement)         |  |   |   | X |        |   |
| Patients' sense of uncontrollability of the measurements               |  |   |   | X |        | X |                                                                                    |  |   |   |   |        |   |
| Lack of understanding of the consequences of one's own consent         |  |   |   | X |        |   |                                                                                    |  |   |   |   |        |   |
|                                                                        |  | P | H | R | P<br>S | G | GENERAL DATA-RELATED CHALLENGES                                                    |  | P | H | R | P<br>S | G |
|                                                                        |  |   |   |   |        |   | Data control                                                                       |  |   | X | X |        | X |
|                                                                        |  |   |   |   |        |   | Data protection/data security                                                      |  | X | X | X |        |   |
|                                                                        |  |   |   |   |        |   | Data ownership                                                                     |  | X |   |   |        | X |

Figure 13: Regulatory challenges identified by different stakeholder groups

Only *regulatory* challenges (Figure 13) were identified by the participants. Several challenges related to *consent* – mainly mentioned by HCPS, RESEARCHERS, and the GENERAL PUBLIC – focused on the invisibility of AI-CS (R12:3). Consent was emphasised as all the more important, especially for radar-based technologies (G64:36, R31:13), because of the greater safety risk of measuring people without their awareness (compared with contact measurement technologies, G61:112). ALL STAKEHOLDER GROUPS identified a high risk of *abuse of the sensors* (e.g., stalking or surveillance in public spaces/by employers PS101:89, R31:120, R31:98 or for use in a state sanction mechanism), even leading to dystopian fantasies of total surveillance (G47:5). Challenges were also described for the management of the *collected data*, i.e. how individuals could retain control over and manage their data (H92:62), while at the same time ensuring data security (R32:96), privacy (R36:132) and transparency about their own data (R63:97, G64:162). Regarding *regulation*, a “regulatory hole” (PS40:93) was addressed. Medical device approval was described as challenging (PS40:124; PS102:124). Another problem identified was the reactive nature of the law, which does not provide a framework for future settings (PS102:60). Contrary to the POLITICAL STAKEHOLDERS, a HCP mentioned that they believe that legal and ethical rules would not prevent misuse (H66:64, H85:25).

In summary, the analysis revealed a wide range of perceived opportunities in medical, technical and economic terms. Opportunities, such as the impact on society, were mainly focused on by RESEARCHERS and POLITICAL STAKEHOLDERS. Naturally, HCPS and PATIENTS focused strongly on the application and effects of AI-CS in health. The broad range of challenges mentioned across ALL STAKEHOLDER GROUPS showed the perceived ambivalence of AI-CS (e.g. in the technical implementation and data generation), leading to the need for good communication, preventive governance and the overall importance of human interaction in the health system.

### 3.2.6. Values

Trust, legal certainty, sociality, autonomy, individuality, and usefulness could be identified as core values of the different stakeholder groups towards AI-CS in health (Figure 14).

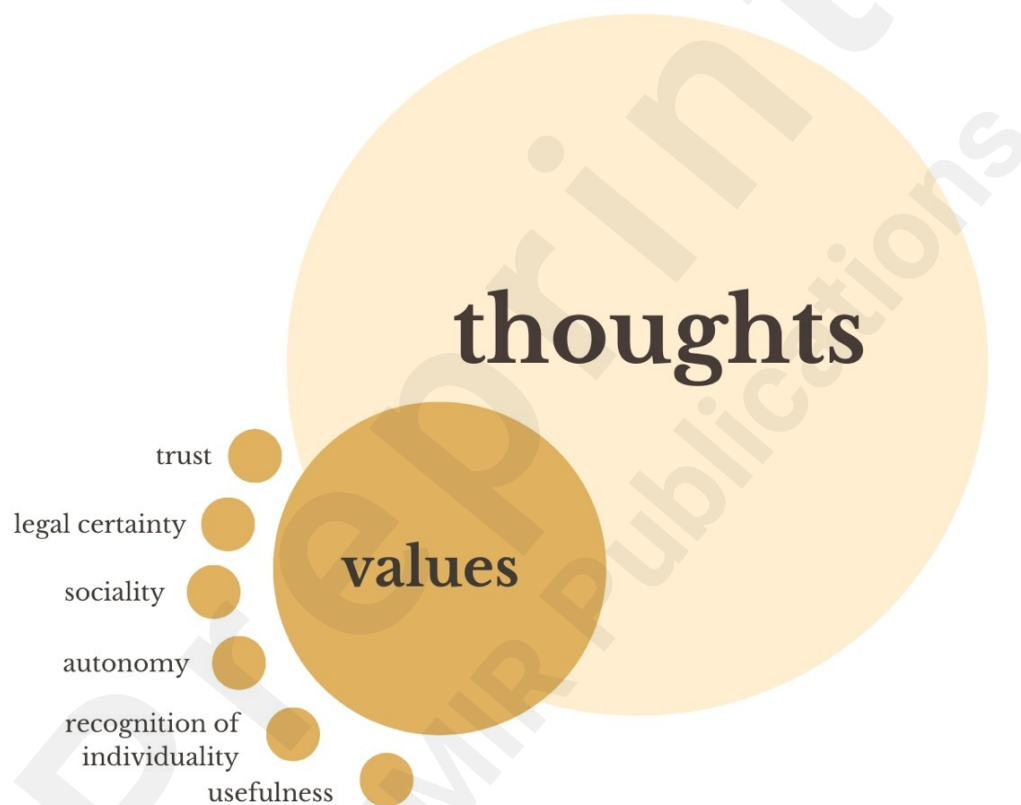


Figure 14: Overview of values identified by different stakeholder groups

ALL STAKEHOLDER GROUPS emphasised the need to build *trust* in the use of AI-CS in health, particularly with regard to the need for transparency, reliability, accuracy and proven usability: “[...] if [...] it is transparent beforehand what will be done with it, of course I would be in favour of that.” (R30:26) PATIENTS referred to trust regarding the implementation of contactless sensors and AI, which is seen as “[...] a result of the relationship of trust that has developed between the patient and the doctor.” (P22:96) Trust in these technologies is not yet there due to their recency, so it needs to be built: “There is still no basis of trust because you don't know it yet [...]” (P73:119). Some PATIENTS also expressed a leap of faith in new technologies, particularly relating to their expectations of better healthcare or due to a perceived objectivity of the technologies, i.e. seeing AI as a form of “objective value” (P9:261). On the other hand, HCPS took a comparatively matter-of-fact approach for formulating the conditions for trust, demanding scientific evidence, explainability and validated usability of new technologies. HCPS also addressed the pitfalls and consequences of changing trust attributions and perceptions of AI for the individual doctor: “[D]o I trust the person who’s been doing this somehow for years, or do I trust the AI that has all my data?” (H78:57)

Second, the *need for legal certainty* for the acceptance of new technologies was identified across all stakeholder groups – in particular for the authorisation of new technologies, but also for the secure storage of data that is not accessible to third parties (“neighbours” G60:59).

Third, different stakeholder groups emphasised the importance of human interaction, humanity, and human connection, as well as care in health, summarised as *sociality*. PATIENTS feared that the central relational aspect of being human would be lost using contactless sensors (H83:40). Contactless sensors would lack empathy – that’s why some participants would prefer to have a human in the loop who “[...] is somehow able to absorb even more than a sensor.” (P95:44)

Fourth, *autonomy* was identified as a crucial value, with stakeholders underlining the importance of self-control and decision-making in the context of health (G64:40). This value was further embraced by the notion of freedom to make an informed decision, including the choice not to know certain pieces of health-related information). The unpredictability of the future, together with an openness to various outcomes and the fragility of life, are some of the values that were articulated across ALL STAKEHOLDER GROUPS (e.g., G57:44).

Fifth, the *recognition of individuality* came up as a topic of conversation, particularly in interviews with PATIENTS, HCPs, and the GENERAL PUBLIC. Concerns were raised about the potential for contactless sensors to overlook individual differences: “Oops, I’m no longer an individual here, I’m [...] this biological entity, a human being. And one is like the other. And I don’t like that.” (P22:63)

The sixth value mentioned across ALL STAKEHOLDER GROUPS was *usefulness*, particularly in terms of medical usefulness for a patient’s individual health or for the medical-technical progress in general (H92:102). One RESEARCHER mentioned: “[...] I would certainly also benefit from the research results [...] through other people. In the same way, I would participate in order to advance research. To steer the progress of knowledge.” (R38:29)

### 3.3. Behavioural aspects

#### 3.3.1. Experience

Across ALL GROUPS, very few respondents described specific *experiences* with contactless measurement technologies in a medical context (P68:27). Detailed reports of experiences with AI-CS came only from RESEARCHERS (R32:138, R38:246). At the same time, however, there were numerous analogies to the operating of the technology, which can be divided into two main observations: Firstly, a link was made between the way sensors work and human capabilities (e.g., P73:15). The human capacity to evaluate internal states without physical touch is thought to be reinforced and/or substantiated by AI-CS. Secondly, analogies were drawn to existing analogue technologies that measure from the outside without contact – e.g. X-rays (P73:122).

Another important role played the question of whether the use of AI-CS leads to more (perceived) supervision, which however was contested by the experience of HCPs (H92:64). In addition, some RESEARCHERS pointed out that the patient’s previous experiences were significant: “If someone has ever been in intensive care [...] and was completely wired up for a fortnight and had to press the bell every time, [...] they will immediately say, [...] I want to be monitored [...] contactlessly [...]” (R42:63f.).

#### 3.3.2. Implications

Three *implications* were raised. The first one concerns *changes in the doctor-patient relationship* caused by new contactless measurement technologies. Some anticipate changes in the level of monitoring, which could lead to uncertainty and sometimes even anger (P87:88), while

HCPs described the developments as a logical progression towards further personalisation of medicine (H39:132). RESEARCHERS expressed similar sentiments: “Why should it suddenly be any different with contactless sensors if it happens in a medical setting [...]” (R76:70)? Nevertheless, conditions for a successful introduction of the sensors, such as transparency and education (e.g., PS103:31), individual medical background and attitude (e.g., PS104:30), as well as serial application (PS102:89) were emphasised particularly by POLITICAL STAKEHOLDERS. One participant of this group assumed that the sense of surveillance of patients will be much less in a medical context than when the sensors are used in private homes or for other purposes (PS100:22). This is consistent with the also mentioned assertion that the medical benefits are likely to outweigh any legal concerns (PS102:66).

The second implication relates to *shifts in the values recorded*. In particular, the question of possible changes in the conception of *trust* plays a central role here. Some respondents seemed to trust in the prevention of misuse and general regulation by legal measures (G37:90). This especially means that decision-making authority remains with the HCPs: “And if the data collection from the contactless sensors has shown that, then the doctor will say: ‘[...] now we’ll do it like this.’ Then I would have so much confidence in the doctor that they can interpret what the AI says [...]” (G47:81, also G90:134)

A third implication concerns *anthropological issues*: In addition to the ascribed analogy between the functioning of the sensor and human abilities, the discussion also centered on how the use of contactless sensors is changing the understanding of what it means to be human. With the elimination of touch as a basic element of measurement, the loss of its significance as a deeply human need is presumed (e.g., H86:103). AI-CS are also expected to have an impact on self-interpretation techniques and experiences of efficacy: “Yes, I’m quite convinced of that. In the same way that people have forgotten how to find their way around since there are navigation systems [...] and so on.” (P95:57)

### 3.3.3. Preferred actions

The *preferred action* relates to three main areas: Firstly, the impact of AI-CS on forms and ways of establishing practices of *consent* was discussed. Some participants seemed to be largely indifferent: “But if the doctor explains that we have now come so far as to be able to make the whole thing contactless from other, uh, indicators, uh, that can be obtained from other bodily functions, then I can say: Well, fine, please.” (P22:163), while others were rather positive (P70:114). Although AI-CS may change the established routines of giving consent, the importance of this consent is strongly emphasised (H41:30, R65:16). As ALL GROUPS thought, it is important for patients to know when a measurement is being taken and when it is not.

A second area concerns the assessment of (*institutional*) *responsibility*. Here, the prevention of abusive data collection was a rather important issue. POLITICAL STAKEHOLDERS focused strongly on responsibility and its precise organisation (e.g., PS40:153), distinguishing between different levels of moral and legal responsibility, affecting both manufacturers and HCPs (e.g., PS97:89). One POLITICAL STAKEHOLDER argued that responsibility lies with the manufacturer and the user (PS40:153), but that the explicit approval of the patient must be taken into account (PS40:24). It was considered crucial, especially by HCPs, that AI-CS be embedded and evaluated in institutional decision-making pathways (H44:36, H75:6). The use of these sensor technologies should intend to support staff, not replace them (H28:22, G67:95). In addition, further research and institutionalised monitoring should ensure the functionality and safety of the sensors (G67:131). Furthermore, within the area of responsibility, all groups saw education as an important institutional aspect (P35:17, H26:10, R19:47, PS102:40, G5:31): There is a need of training in the skills required – not only to explain the new measurement techniques, but also to understand their implications and limitations.

A third area of preferred action concerns the question whether new measurement technologies will lead to the *medicalisation of everyday life*. In other words, health issues also play a role in areas where they are not (or should not be) the focus of attention. Very different assessments of such a possible extension emerged: “Yes, so perhaps not [...] in working life, in the office.” (P45:122) In contrast: “Well, I don’t know if I’m raving too far or thinking too high, but for me it would be ideal to have such a sensor in my pocket, day and night, really.” (P58:31)

## 4. Discussion

### 4.1. Interpretation of the results

The study addresses two key shortcomings: the lack of empirical research on attitudes towards AI-CS and the lack of a comprehensive stakeholder approach.

Regarding the latter, the study offers an innovation pipeline approach and responds to the current debates on AI that call for the inclusion of diversity and multiplicity of stakeholders to avoid harm [49]. Furthermore, it explicitly “[...] account[s] for the potential limitations of one group speaking for another group, which may in fact disagree” [50]. Different particularities emerged between the groups: PATIENTS showed an altruistic moment of great willingness with regard to sharing data if they see a medical benefit, while POLITICAL STAKEHOLDERS put an emphasis on practical implementation and suggested concrete proposals by taking into account current regulatory developments. At a thematic level, ALL STAKEHOLDER GROUPS identified technical opportunities, but PATIENTS, HCPS, and RESEARCHERS provided more detailed insights, reflecting their direct involvement in the development, evaluation, and application of sensor technologies. The multi-stakeholder approach ensures that different perspectives are well-represented. The sample size of 104 participants allows commonalities and divergences across all stakeholder groups to be highlighted. Despite some overlap between groups (e.g., between PATIENTS and the GENERAL PUBLIC, or HCPS and RESEARCHERS), self-classification facilitated nuanced insights from each stakeholder group.

Regarding the first shortcoming, the results go beyond other studies by providing a comprehensive picture of attitudinal aspects towards AI-CS by following the analytical three-component model. Overall, the results show a high level of openness to AI-CS in health across ALL STAKEHOLDER GROUPS. Besides, two trends emerge from the results:

First, greater experience and knowledge correlated with a reduced tendency to react emotionally. In particular, RESEARCHERS were less likely to express strong emotions, both negative and positive, while HCPS showed little to no strong negativity. BOTH GROUPS tended to take a sober view, with a focus on realistic expectations. In contrast, those with little or no experience or knowledge of the technology expressed stronger attitudes (showing both very enthusiastic, very uncertain and/or negative feelings) towards certain aspects of the technologies.

Second, participants with good experiences with technologies were generally more open and positive towards contactless sensor technologies. This finding is, on the one hand, supported by previous research linking attitudes to prior experience [51]. On the other hand, it highlights the observation that attitudes are very likely to be based on the perceived social changes associated with a new technology, which is in line with similar empirical studies on people's attitudes and values when interpreting emerging technologies [52-54]. This observation also backs the theoretical assessment that AI should not be viewed as an abstract technical variable, but rather in terms of sociotechnical systems [55-58]. In this sense, AI-CS do not represent a completely new case, but rather raise issues that are inherent to human-technology interactions in a similar way to other AI-driven technologies used in health, such as issues of trust [59].

However, there is currently a lack of clarity about what AI-CS are. Participants frequently asked

what applications could be considered as contactless. They gave different interpretations of the term and pointed to a wide range of associations with the technology (Figure 15, categorised alongside temporal and spatial application), based on their prior experiences (e.g., previous illnesses, social events such as the SARS-CoV-2 pandemic), personal health and non-health experiences, knowledge, technical understanding, and imagination. Overall, the results show a lack of information and technical knowledge that led to uncertainty and created discomfort for some participants, which, if exacerbated, could contribute to rejection, influenced by pseudoscientific reasoning.

|                                                         |             | SPATIAL USE                                                               |                                                                                                                               |
|---------------------------------------------------------|-------------|---------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|
|                                                         |             | STATIONARY                                                                | PORTABLE                                                                                                                      |
| T<br>E<br>M<br>P<br>O<br>R<br>A<br>L<br><br>U<br>S<br>E | CONTINUOUS  | RADAR-BASED MEASUREMENTS<br>(R19:109; G64:132, PS102:4)                   | CONTACT WEARABLE SENSORS<br>(smartwatches H39:77; R54:103, G64:181; H71:103; P91:10)<br>(blood glucose sensors P9:11; H88:81) |
|                                                         |             |                                                                           | CONTACTLESS WEARABLES<br>(automatic emergency buttons PS40:109; P70:16; PS102:81)                                             |
|                                                         | SITUATIONAL | ULTRASONIC SENSORS<br>(G64:18; H72:89; P96:8)                             | INFARED THERMOMETER<br>(R3:17; R38:44)                                                                                        |
|                                                         |             | LIGHT SENSORS<br>(R11:118; R19:37; PS102:16)                              |                                                                                                                               |
|                                                         |             | AUDIO AND VIDEO RECORDING<br>(R27:104; P29:22; R42:73; PS102:4; PS103:10) | OTHER TECHNOLOGIES<br>(flying objectives similar to drones H74:114; H86:188)                                                  |
|                                                         |             | NOT FURTHER DEFINED<br>(G59:99; P79:95; P81:139; H92:112)                 |                                                                                                                               |

Figure 15: Overview of technologies participants associated with AI-CS

## 4.2. Implications

Two key lessons emerge from the findings: First, *providing clear and targeted information and facilitating (non-medical) hands-on experience* with AI-CS can play a crucial role in mitigating rejection. Understanding of the term ‘contactless’ emerged as a key factor in shaping attitudes, suggesting that targeted information could address misconceptions effectively. At the same time, the diversity of associations highlighted by ALL STAKEHOLDER GROUPS points to the overarching *importance of attitudes* over detailed technical knowledge. While technical understanding may reduce initial uncertainties, acceptance of AI-CS is ultimately influenced by broader attitudes and the ideas that participants associate with them. In our study, three tensions were shown to be important:

First, the tension around contact(lessness), the importance and ambivalence of touch, second the tension between protection and surveillance in relation to the path- and context-dependency, and third, the tension between the benefits and challenges of invisibility, particularly in relation to control and governance implications.

Starting with the first tension, the concept of ‘contactless’ revolves around the question of whether or not one is being touched. ALL STAKEHOLDER GROUPS identified this question as crucial, showing an *ambivalence about the importance of touch and the potential benefits of avoiding it*: On the one hand, touch and especially being touched was described as a deeply human experience that was considered an integral part of medical consultations, especially by HCPs. Touch is considered essential in the relationship between people, but also in the relationship with oneself, one’s body, and its capabilities. A contactless sensor may not be able to capture all parts of the (bodily) self, but will be limited to quantitative parameters, which in turn will limit the understanding of a healthy and a sick body. This could eventually lead to a problematic image of the body as always potentially ill. It resonates with wider debates about the quantification and datafication of health, where complex,

embodied experiences risk being reduced to discrete, measurable parameters [60]. Such reductionist tendencies are particularly relevant in sensory and embodied health care, where touch plays both diagnostic and relational roles [61].

On the other hand, the absence of touch was seen by ALL STAKEHOLDER GROUPS as an important way by of avoiding unwanted intimate physical contact, potentially removing one of the barriers to seeking medical advice. Beyond this practical dimension, participants agreed that the recording of symptoms and parameters is not mere measurement, but also involves an anthropological dimension. To be measured means to be under the gaze of an 'other'. This interaction shapes the understanding of what it means to have an experience of one's own bodily experience classified and interpreted from the perspective of another. The use of technologies such as contact or contactless systems introduces additional layers of complexity to this notion. For example, when a cable is used to measure parameters, a physical boundary is established between a person's body and its environment. In contrast, contactless technologies challenge traditional notions of where these boundaries lie. This highlights the sociotechnical dimension of such innovations in that it is necessary to renegotiate where the boundaries of a human body are seen [62, 63].

Second, ALL STAKEHOLDER GROUPS pointed to a *particular path- and context-dependency* and its significance for attitudes by drawing a clear distinction between health data collection within a defined institutional context and outside of it, marking a strong tension between *protection* and *surveillance*. The use of AI-CS within institutional health contexts (such as hospitals or doctors' surgeries) was identified as a helpful tool for protection by facilitating the need for constant monitoring. The ability to monitor without restricting movement was seen as one of the key benefits of contactless automated systems, particularly for people with dementia or in fields such as palliative care. Outside of health and institutional settings, ALL STAKEHOLDER GROUPS raised concerns about illegitimate monitoring and surveillance, potentially leading to a loss of control or even knowledge of one being monitored. Concerns about a strong intrusion into privacy were repeatedly highlighted, as well as the potential for harmful effects on both the individual and the society [64]. This tension between protection and surveillance is a major challenge for the use of AI-CS, as the boundaries between these contexts are becoming increasingly blurred by the ability and flexibility to use them in everyday life and in different locations due to the portability of the devices.

Related to this, a third tension emerged around the *benefits and challenges of the invisibility* of the measurement using AI-CS. While some RESEARCHERS highlighted the invisibility of the data collection as a major advantage in minimising measurement distortions (e.g., movement changes due to measuring devices attached to the body), other RESEARCHERS and HCPs expressed concern that the the use of AI-CS could lead to a loss of visibility and thus an important basis for control [39]. These different perspectives highlight the dual nature of invisibility as both a technical strength and a potential source of institutional challenges. To mitigate the risks associated with invisible measurement, it is essential to ensure the visibility of (interaction) interfaces. This aspect becomes even more critical when contactless sensor technology converges with automation through AI: automation can contribute to more efficient analyses of the collected data and can provide a more robust basis for decision-making in complex situations. However, the integration of AI-CS requires good interface design and careful consideration of innovation processes within institutional decision-making pathways in the clinic [65]. Moreover, defining benchmarks and criteria for defining the benefits and harms of technical systems requires particular scrutiny [66]. These criteria should be aligned with broader societal goals, aiming to provide a common good and contribute to the reduction of structural inequalities [67, 68]. For example, tensions between individual benefits and benefits for the largest possible group need to be taken into account.

In this context, regulatory frameworks play a pivotal role in navigating the ethical complexities of AI-CS in health. Well-designed regulations are essential to balance the tensions between *protection* and *surveillance*, and to address the challenges posed by *invisible* measurement. Regulations such as

the Medical Device Regulation [69] provide a basis for mitigating these tensions and preventing harm. The findings highlight the importance of proactive governance to ensure the ethically aligned implementation of AI-CS in health.

### 4.3. Conclusion

Our contribution to research on AI-CS is threefold: First, it provides the first comprehensive overview of attitudes towards AI-CS in health, addressing the moral values and socio-technical practices. By analysing the attitudes of five different stakeholder groups along feelings, thoughts, and behavioural aspects, the study yields nuanced insights that can be further explored in the [SENSAI](#) online tool [47]. Additionally, it presents a detailed examination of potential applications (e.g. home monitoring for dementia) and potential users (from children to older adults) (see Appendix 3).

Secondly, we have demonstrated the importance of exploring attitudes towards AI-CS, which have not yet been empirically investigated. The study provides a broad picture of different components of attitudes, as participants expressed enthusiasm, rejection, or indifference (*feelings*), acknowledged certain opportunities and challenges, and considered which values were touched upon (*thoughts*), based on their experiences, formulated implications, and preferred actions (*behavioural aspects*). The use of semi-structured interviews allowed the participants to bring in their own experiences and to draw parallels with other devices they are familiar with, as AI-CS are still relatively new technologies. Furthermore, by providing a clear, deductively derived concept of attitudes that paves the way for avoiding the fuzzy equation with the terms perspectives, values, views and others, the study makes an important methodological contribution to AI ethics and social science research on AI-based technologies.

Thirdly, the study identifies three key tensions that have been analysed in the light of current research: The role of touch and contactlessness in health, highlighting aspects of human boundaries and the body; the tension between protection and surveillance in relation to path- and context-dependency, particularly in relation to concerns about harm; and finally, the tension between the benefits and challenges of invisibility, particularly in relation to control and governance implications. These findings call for robust regulatory frameworks to prevent the misuse of AI-CS, and promote acceptance, including targeted information and facilitation of hands-on experience.

Through these three contributions, the study aimed to address the two shortcomings of the lack of a multi-stakeholder approach and the lack of empirical analysis of a hitherto unexplored technology by applying the concept of attitudes and its analytical precision. The study provides important entry points into different areas of research and practice and acts as a springboard for further research on AI-based health technologies in general and AI-CS in particular, as it highlights crucial points regarding to sensor development at different stages, data analysis, and application opportunities and challenges in different medical specialties and functions. The findings on acceptance and preferred actions will be particularly useful for political consideration and possible implementation processes that could advance the governance and regulation of sensor technologies. By implementing these findings, AI-CS could contribute to preventing patient harm and improving patient safety [70].

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### Author contributions

Conceptualization/Project administration: MB, EH

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### Conflicts of interest

The authors declare no conflicts of interest.

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## Supplementary Files

Appendix 1\_Interview guide\_English.

URL: <http://asset.jmir.pub/assets/7fcf30466072b4cc745c817e18431a8e.pdf>

## CONSORT (or other) checklists

Appendix 2\_Sociodemographic Questionnaire\_German.

URL: <http://asset.jmir.pub/assets/493e04661ab545a2999238fdab86dc59.pdf>

Appendix 2\_Sociodemographic Questionnaire\_English.

URL: <http://asset.jmir.pub/assets/137501b32285e23c4fba8e2cb708fe91.pdf>

Appendix 3\_Medical specialties.

URL: <http://asset.jmir.pub/assets/db8c491361da286e1032c5c43071d202.pdf>

Appendix 0\_COREQ Checklist.

URL: <http://asset.jmir.pub/assets/a39791d2ca558c6ad0c176bbe16fdc0a.pdf>

Appendix 1\_Interview guide\_German.

URL: <http://asset.jmir.pub/assets/fc5a4a766c229bfbc634819001045f9a.pdf>