# Artificial Intelligence in Medical Diagnosis: A Qualitative Study of General Practitioners' Attitudes Towards AI-Enabled Systems


## Abstract

**Background:** General practitioners (GPs) take care of a large number of patients with various diseases in very short timeframes under high uncertainty. Thus, systems enabled by artificial intelligence (AI) are promising and time-saving solutions that may increase the quality of care.

**Objective:** This study seeks to understand GPs' attitudes towards AI-enabled systems in medical diagnosis.

**Methods:** We interviewed 18 GPs from Germany between March and May 2020 to identify determinants of GPs' attitudes towards AI-based systems in diagnosis. By analyzing the interview transcripts, we identified 307 open codes, which we then further structured to derive relevant attitude determinants.

**Results:** We merged the open codes into 21 concepts and finally into five categories: (1) concerns, (2) expectations, (3) environmental influences, (4) individual characteristics, and (5) minimum requirements of AI-enabled systems. Concerns include all doubts and fears of the interviewees regarding AI-enabled systems. Expectations reflect GPs' thoughts and beliefs about expected benefits and limitations of AI-enabled systems in terms of GP care. Environmental influences include influences resulting from an evolving working environment, key stakeholders' perspectives and opinions, the available IT hardware and software resources, and the media environment. Individual characteristics are determinants that describe a physician as a person, including character traits, demographic specifics, and knowledge. Besides, the interviews also revealed minimum requirements of AI-enabled systems, which are preconditions that must be met for GPs to contemplate using AI-enabled systems. Moreover, we identified relationships between these categories, which we conflate in our proposed model.

**Conclusions:** This study provides a thorough understanding of the perspective of future users of AI-enabled systems in primary care and lays the foundation for successful market penetration. We contribute to the research stream of analyzing and designing AI-enabled systems and the literature on attitude towards technology and practice by fostering the understanding of GPs and their attitude towards such systems. Our findings provide relevant information to technology developers and policymakers, and stakeholder institutions of GP care.



**Keywords:** Artificial intelligence; AI; attitude; primary care; general practitioner; GP; qualitative interview; diagnosis; clinical decision support system.

## Introduction

### Overview

As artificial intelligence (AI) enabled systems have surpassed human performance in different aspects of economy and society, the increasing technological maturity and widespread applicability of such systems is leading to skyrocketing expectations [1]. The technological progress in various fields such as machine learning, robotics, Big Data Analytics, Decision Support Systems (DSS), as well as the ubiquity and availability of data, and the prevalence of information systems (IS) are opening previously unavailable value creation potentials [2–5]. We understand AI as a set of value-adding technological solutions that use self-learning algorithms to perform cognitive tasks at a level that is comparable to humans [6]. Various AI solutions that provide decision support typically associated with human cognition are emerging and hold the potential to reshape the nature of work [1, 7–9]. Thus, AI is also a promising approach for the health care domain [10]. AI and related technologies, such as Big Data Analytics and DSS, are distinct phenomena with important conceptual differences, although some of the underlying technologies might overlap. In health care, AI technology advances health information technologies (HITs) such as clinical decision support systems (CDSS). These systems assist medical professionals in tasks related to medical decision-making [11], such as diagnosis, prescription, or the prevention of medication errors [12, 13]. Among others, typical functions are alerts, reminders, and recommendations [14, 15].

There are two forms of CDSS in health care, knowledge-based systems, and non-knowledge-based systems. Knowledge-based systems match their knowledge base with individual patient characteristics and make decisions based on pre-formulated rules [16, 17]. As such, knowledge-based CDSS are designed to inform skilled actors. That is, to provide actors in the health care system, eg, physicians, with relevant information to comprehend internal and external structures and processes. Non-knowledge-based CDSS, on the other hand, use AI technologies, which eliminate the writing of rules and the need to follow expert medical input. This integration of AI technology allows the CDSS to learn from experience and find patterns in medical data [18]. Hence, the vision of AI is to enable systems to be on human-level intelligence. Here, intelligence refers to an agent's ability to achieve goals in a wide range of environments [19, 20] and goes beyond the mere preparation of information. Instead, AI highlights the ambition to develop artificial agents that are able to learn, decide, and act autonomously [9, 21].

AI-enabled systems have already successfully entered various sub-disciplines of health care, such as image recognition, diagnosis, and precision medicine [10]. Most AI-enabled systems have immediate relevance in health care and several potentials for value creation, such as higher efficiency and accuracy in diagnosis and lower error rates [22–24]. Further, AI-enabled systems are more enduring in repetitive tasks compared to humans, enhancing cost-efficiency [25].

Regarding these promised benefits, AI-enabled systems have particular potential in the field of primary care. General practitioners (GPs) serve as the first point of medical contact and, therefore, must diagnose with high levels of uncertainty and under high time pressure. For instance, in Germany, primary care is one of the most frequently used health care services, leading to an average doctor-patient contact time of 7.6 minutes [26]. Moreover, GPs are responsible for the initial diagnosis, thus, setting the direction for whether a patient receives the right care. Making misdiagnosis in this early stage of diseases can have severe impact on medical quality in terms of injuries, avoidable illnesses, hospitalizations, and, in 10% of cases, death [27, 28]. Besides the potentially tragic individual consequences, such misdiagnoses also increase the cost of care [29].

To prevent these risks, the health care system depends on innovative, reliant, and fast approaches to decision-making processes in GP care [30]. Seen as an integrative system, AI-enabled systems free up physicians' time for more sophisticated tasks [31]. Further, AI-enabled systems can ensure stronger doctor-patient relationships [32], which is especially valuable in GP care since it enables the therapeutic benefit of improved continuity of care and more holistic and individualized treatments [32]. In addition, AI-enabled systems can reduce diagnostic errors, which are considered the greatest threat to patient safety in GP care [33].

Although AI-enabled systems in primary care diagnosis are gradually becoming feasible and useful, their widespread implementation still remains a future scenario [10, 34]. Among others, reasons for the slowdown in adoption are the physicians' lack of trust [35, 36] and acceptance [16, 37] in AI-enabled systems. These adoption barriers arise, for instance, from the concern that AI-enabled systems might be trained with a heterogeneous database due to the diversity and individuality of medicine, leading to biased or over-adapted outcomes. Overcoming these hurdles requires to balance GP's trust in AI-enabled systems [35]. On the one hand, developing trust in such a system is beneficial to its adoption and use. On the other hand, AI-enabled systems may bear risks when physicians blindly rely on such systems' suggestions and outcomes. Furthermore, factors like the anticipated threat to professional autonomy and legal liabilities from using AI-enabled systems are hindering factors, as known so far [38].

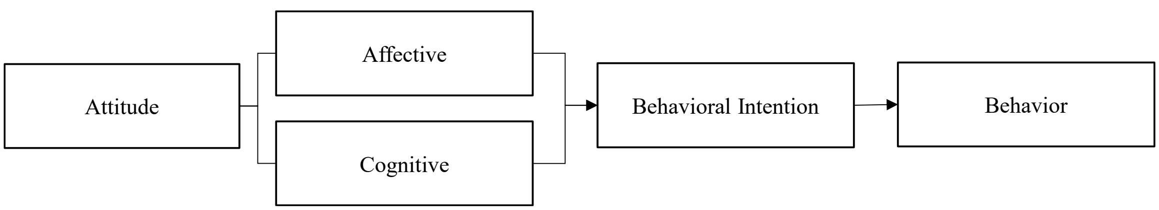
A key driver for a successful implementation and for the uptake of AI-enabled systems is the attitude of physicians. By discussing our findings on GPs' attitudes towards AI-enabled systems within a facilitating context for practical implementation, we extend the previous work of Blease et al. [39], who recognized the topic's relevance and investigated the opinions of GPs about the possible impact of AI on GP care.

## The Construct of Attitude as our Theoretical Lens

We understand attitude as a psychological tendency that determines how GPs evaluate their favor or disfavor against AI-enabled systems [40]. Following Rosenberg and Hovland [41], the most widespread construct of attitude – the three-component model – comprises the affective, cognitive, and behavioral dimensions of attitude. First, the affective component refers to the respondent's emotional reaction to an attitude object, including their empathy, preferences, and feelings. Second, a person's thoughts and beliefs towards an attitude object form the cognitive component, which includes the idea, the opinion, or the individual's knowledge of it [41]. Third, the behavioral component rests on the attitude-behavioral consistency assumption, described as the extent to which an attitude predicts a behavior, including the willingness or intention to act in order to deal with an object [41, 42]. Overall, the attitude construct assumes a consistent and dependent relationship between the affective, cognitive, and behavioral components, suggesting that a change in one component leads to changes in the other components [41].

However, researchers acknowledge that the behavioral intention (ie, the behavioral component) does not always correspond to the feelings (ie, the affective component) and opinions (ie, the cognitive component) [eg, [42]]. This challenges the behavioral component as an integral part of the attitude construct. Thus, the two-component model of attitude was developed based on this critique (see Figure 1) [43]. According to this model, attitude consists of an affective and a cognitive component that simultaneously form the behavioral intention, which – in turn – explains a de facto behavior [44].

**Figure 1.** The two-component model of attitude [44, 45]




Extant work describes the behavioral intention as the mediator in the relationship between attitude and behavior [46, 47]. Thus, it is assumed that the stronger the intention, the higher the likelihood of the behavior occuring [48]. According to the principle of compatibility, behavior is only predicted by attitude to the extent of both being on the same level of specificity or generality regarding their objective, context, and time elements [49]. However, regardless of the intensity of influence, there is broad agreement that attitude fosters behavioral intention [50]. Drawing on its relevance for users' subsequent intentions and behavior, we use the attitude construct to foster our understanding of how to better exploit AI-enabled systems' potential in GP care and promote their future use.

Different quantitative studies investigate the relationship between attitude and the intention to use AI-enabled systems, for example, regarding medical students [51, 52]. In this context, research theories such as the Unified Theory of Acceptance and Use of Technology (UTAUT) and the Theory of Reasoned Action (TRA) find application. These established approaches of technology acceptance research, originating in social psychology, primarily focus on users' intention [48, 53–55]. However, these approaches do not provide a comprehensive understanding of GPs' attitudes towards AI-enabled systems, as they use abstract constructs and variables and do not capture detailed, even emotionally based, and spontaneous responses from the (potential) users [56]. Apart from this, however, there is a more important criterion, why we chose not to use these models for our study. GPs hardly use AI-enabled systems so far [34], so research in this respect considers a rather hypothetical usage scenario than actual use. Investigating the intention to use, which is a direct determinant of the actual usage according to UTAUT, is therefore not feasible as the possible system features and functions are not yet available today. Nevertheless, it is possible to look at the underlying attitude towards the technology, which exists outside the de facto experience of use.

### Goal of This Study

Despite the relevance of AI technologies for the health care sector, a profound understanding of GPs' attitudes towards AI-enabled systems and their underlying determinants is still absent. Therefore, the purpose of this study is to investigate which determinants influence GPs' attitudes towards AI-enabled systems in diagnosis. We see this as an important step in developing user-centered solutions, which will positively affect the intention to use and support a successful introduction of AI-enabled systems in primary care.

## Methods

### Data Collection

To identify determinants of GPs' attitudes towards AI-enabled systems in diagnosis, in-depth insights are vital. Following the interpretative paradigm, qualitative methods were utilized to get an understanding of individuals' technological attitudes in the medical context [57]. Thus, we did not prescribe and narrow the phenomenon to only the testing of variables but emphasized the complexity of human understanding and behavior [58].

Data collection followed an interplay of continuous and iterative matching steps of sample selection (recruiting of participants), interview guideline creation (and improvement), data collection (interview conduction), data analysis (transcription and coding), and revision of the process steps. Because the iterative process and constant comparison make it challenging to provide a timeline or sequence of these steps, it is reflected upon as a constant effort in creating a comprehensive and growing understanding of the interviewees' attitudes, which are not always distinctively observable [59, 60]. In terms of saturation approaches, this study emphasizes Nelson's [61] term of 'conceptual depth', whereby researchers cumulatively judge the sufficiency of depth of understanding, thus, allowing for incremental development. Following Schultze und Avital [60], the choice of semi structured expert interviews allowed for a concentration on the research topic while also providing in-depth information [62]. This approach offered a modular structure through which the participants could access and reflect upon their experiences and perceptions regarding AI-enabled systems. We derived overarching interview topics from the given practical research objective and by means of reflective discussions within the author team, resulting in the exploratory interview questions. Castillo-Montoya's [63] four phase process to interview protocol refinement served as a basis for developing the interview guideline, including pre-testing the first version of the interview guideline with three volunteers: a health economist, a nurse, and a physician. The first version of the interview guide addressed the topics of personal experiences, assessments of perceived diagnostic support, design requirements, and motivations for the use of AI-enabled systems in a broader perspective. It underwent nine iterations, receiving more detailed and tailored questions about the research topic with each interview. The final interview guideline (see Appendix 1) was designed to question the interviewees on their understandings of AI-enabled systems and provide this paper's literature-based definition, aiming towards a shared understanding of AI-enabled systems and comparable interview results. Owing to the nature of semi structured interviews, the results were not limited to collecting attitude determinants. Besides, this approach allowed us to capture insights into GP care's challenges and special characteristics, which contributed to a profound understanding of the determinants of attitudes in the medical context.

The interviews took place both in person and via phone and guaranteed anonymity to all participants within the study. Since face-to-face interviews create a trusting and comfortable atmosphere and enable more detailed information on interviewees' feelings and attitudes, the interviewers preferred them for data collection [64]. With the interviewees' consent, audio-recording and transcription took place to allow for thorough data analysis by means of MAXQDA 2020.

### Data Analysis

In analyzing the interview transcripts, grounded theory analysis techniques were applied. As stated by Glaser [65], traditional Grounded Theory Methodology (GTM) seeks to develop a conceptual theory that depicts a relevant and/or problematic behavior pattern (in this case, GPs' attitudes towards AI-enabled systems in diagnosis). GTM focuses on behavioral aspects where attitude behaves as an antecedent and is therefore equally suitable for the application. Applying the GTM approach allowed to handle the unstructured qualitative data sets, discover relevant categories and relationships among them, and contextualize and interpret them [66]. According to GTM, the analysis begins with the first collected data set, as the experiences with the first interview process already influence the researcher and thus the upcoming interviews. In the interview process, interviewees' responses and clarified check-backs were closely scrutinized and documented [67]. This knowledge about misconceptions fed into the iterative development of the interview guideline. Further, it allowed for the clarification and precise alignment of the research question [66].

The interview data were paraphrased into relevant bits (open coding) in line with the three-step Straussian approach for coding (open, axial, and selective coding). Thus, the first step consisted of an initial and careful read of the interview transcripts, highlighting any phrases that may have proven relevant to the research topic. Over the course of data analysis, 307 open codes emerged. Following Glaser and Strauss [68] specifications, the codes were further examined and paraphrased, merging those with common themes into concepts. Thus, we assigned special value to the wording of and syntactical differentiation between expressions. After comparing the allocation of the concepts, these were merged into categories. Moreover, relationships between them were identified, which refers to the axial coding step. By setting all elements in relation to one another, the core category *attitude determinants* was distinguished from other categories (selective coding) [66]. In line with GTM, the three coding steps followed a flexible and iterative process instead of a fixed sequence [68].

For enhanced validity of the coding results, two authors performed a card-sorting allocation. Thus, the open codes and concepts identified by one author in a first round served as the foundation for a second author, but in an unmatched format. The second author conducted a blind card-sorting round with this groundwork and commented on the constructs and protocolled challenges that arose in the allocation of open codes to a specific construct. This second author added further, not initially identified open codes along the process. In case of deviations in matching open code to constructs between the two authors, the entire research team discussed said allocations. An agreement was found in all cases of card-sorting deviations. Further, in all coding rounds, the authors iteratively discussed the constructs' abstraction levels and their various definitions and revisited their coding results for adjustments, which the literature calls a "constant comparison method" [66]. Whenever the authors gained new insights from their constant comparison and iterations, they repeated open coding steps for all interview sets backward and forward.

## Results

### Descriptive Results and Study Population

We interviewed 18 GPs from Germany between March and May 2020, selecting them via convenience sampling [69]. Thereby, we contacted 110 physicians within the geographic reach of the research team via mail and further relied on personal network contacts. Additionally, we asked acquired interviewees for the contact information of further colleagues who might be interested in participation. All interviewees had at least one year of work experience in GP care.[69] From the 18 GPs, seven were situated in urban areas with a range of 75.000 to 127.000 inhabitants, while eleven participants were situated in rural and small-town areas with a range of 3.200 to 23.000 inhabitants. For a more accurate evaluation of the interviewees' statements in light of relevant demographic and structural data, individual characteristics of the participating GPs and descriptive characteristics on our data collection appear in Table 1. We further report specifics on the interview lengths and styles.

**Table 1** Descriptive characteristics of the participants and the data collection.

| Participant number | Age | Gender | Working situation | Interview duration | Interview style |
|---|---|---|---|---|---|
| **GP 1** | 70 | F | JP | 27.0 mins | in person |
| **GP 2** | 51 | M | JP | 28.0 mins | in person |
| **GP 3** | 50 | M | JP | 31.0 mins | via phone |
| **GP 4** | 41 | M | JP | 22.0 mins | in person |
| **GP 5** | 52 | F | JP | 36.0 mins | in person |
| **GP 6** | 50 | F | | | |
| **GP 7** | 50 | F | JP | 23.0 mins | via phone |
| **GP8** | 36 | F | JP | 25.0 mins | in person |
| **GP9** | 45 | F | JP | 23.0 mins | via phone |
| **GP10** | 58 | M | JP | 46.0 mins | in person |
| **GP11** | 38 | M | Ind. p. | 30.0 mins | via phone |
| **GP12** | 44 | F | JP | 35.0 mins | via phone |
| **GP13** | 52 | M | JP | 60.0 mins | via phone |
| **GP14** | 43 | F | JP | 25.0 mins | via phone |
| **GP15** | 40 | M | GPC | 29.0 mins | via phone |
| **GP16** | 34 | F | Ind. p. | 40.0 mins | in person |
| **GP17** | 47 | M | JP | 23.0 mins | via phone |
| **GP18** | 51 | M | Ind. p. | 44.0 mins | via phone |
| | **Ø 47.33** | | | **Ø 30.38 mins** | |

*JP = joint practice; Ind. p. = individual practice; GPC = GP centre.*

## Three-Step Coding Results

We will describe the five categories and 21 concepts that determined our GPs' attitudes towards AI-enabled systems, as derived from our qualitative data sets. Our baseline for considering the attitude determinants is the AI literacy level among the interviewees. Long and Magerko [70] define AI literacy "*as a set of competencies that enables individuals to critically evaluate AI technologies; communicate and collaborate effectively with AI; and use AI as a tool online, at home, and in the workplace*." Hence, the identified attitude determinants rest upon the interviewees' statements and the knowledge of GPs regarding AI-enabled systems, irrespective of whether this knowledge is true to facts. Most interviewees had poor AI literacy in the data set and had not yet come into contact with AI-enabled systems. For example, AI-enabled system's self-learning ability was known to only six respondents. Although these six GPs were familiar with this AI technology component, they often did not fully understand what AI is. For example, GP 3 mentioned:

> *In the end, every time I turn on a computer, I use artificial intelligence.* [Participant 3]

Only four of the GPs had experience with AI-enabled systems, and only two of these explicitly mentioned having used it in their GP work. In answering the question of why GPs had not had experiences with AI-enabled systems, the participants gave three explanations: First, they said they did not know about any AI-enabled tools for the GP sector [eg, Interview 15]. Second, they did not see the necessity to use AI-enabled systems [Interview 9]. Third, a general aversion towards the use of technology in medicine is the reason for this [eg, Interview 8]. Although most interviewees had not had contact with AI-enabled systems, most agreed on AI-enabled system's role in GP care in the future. One interviewee said:

> *You cannot decide against [AI technology] because it will come. Because without [AI technology] [diagnosis] is not possible*. [Participant 1]

The participants associated expected time effort with the utilization of AI-enabled systems in routine diagnoses due to the necessary AI technology integration to an established and effortless routine process. Therefore, the interviewees limited the scope of application to cases of rare diseases and to cases in which the doctors cannot reach a diagnosis without additional help [Interview 8].

When grouping the statements, we paid particular attention to the wording and syntactic differentiation that the physicians used in their answers. The interview data revealed five main categories that summarize the influencing determinants of GPs' attitudes towards AI-enabled systems in diagnosis. When we raised questions on potentially using AI-enabled systems in clinical practice, the GPs had various (1) *concerns* and (2) *expectations*. Also, we found that the (3) *environmental influences* and certain (4) *individual characteristics* influenced their attitudes. Whenever GPs stated that AI-enabled systems must meet certain requirements for them to consider using it, we categorized them as (5) *minimum requirements of AI-enabled systems*. Table 2 shows an overview of all categories and concepts, which is followed by a description of the determinants, as supported by interview quotes.

**Table 2.** Overview of the categories and concepts.

| Determinants of attitudes towards AI-enabled systems | Concepts | Open codes | Σ |
|---|---|---|---|
| **Concerns** | ***Existential anxiety*** | 12 | **57** |
| | ***Change of the doctor-patient relationship*** | 7 | |
| | ***Misuse of data*** | 14 | |
| | ***Diagnostic bias*** | 24 | |
| **Expectations** | ***Diagnostic quality*** | 35 | **112** |
| | ***Diagnostic efficiency*** | 19 | |
| | ***Legal liability*** | 4 | |
| | ***Lack of human competences*** | 43 | |
| | ***Time expenditure*** | 11 | |
| **Environmental influences** | ***Changing working conditions*** | 8 | **37** |
| | ***Stakeholder influences*** | 13 | |
| | ***Media*** | 12 | |
| | ***IT infrastructure*** | 4 | |
| **Individual characteristics** | ***Age*** | 11 | **17** |
| | ***Affinity with technology*** | 6 | |
| **Minimum requirements of AI-enabled systems** | ***Time efficiency*** | 40 | **84** |
| | ***Diagnostic quality*** | 15 | |
| | ***Data security*** | 10 | |
| | ***Economic viability*** | 12 | |
| | ***Transparency*** | 3 | |
| | ***Autonomy*** | 4 | |

## Concerns

*Concerns* include all doubts and fears concerning AI-enabled systems. Overall, this category consists of four concepts: (1) *existential anxiety,* (2) *change of the doctor-patient relationship,* (3) *misuse of data,* and (4) *diagnostic bias*.

### *Existential Anxiety*

Half of the interviewees expressed *existential anxiety* connected with AI-enabled systems since they perceive that this technology can take over some of their tasks. GP2 said:

> *At one point, the own decision and the own expertise threatens to be pushed into the background or to become redundant.* [Participant 2]

GP14 also perceived the threat of being replaceable by AI-enabled systems and provided an example of an AI-enabled system that has achieved higher diagnostic accuracy than physicians [Participant 14]. This concept includes the fear of no longer being useful and of being replaceable by AI-enabled systems, as well as the worry of losing their unique status as physicians. One participant said:

> *Surely, many doctors probably see their unique medical status endangered, that they are under the surveillance of others, that they think there is a bit of an attack on their own vanity.* [Participant 12]

### *Change of the Doctor-Patient Relationship*

The interviewees mentioned that AI-enabled systems could be threatening to the doctor-patient relationship. Endangerment of this relationship, which fundamentally defines GP care, further compromises appropriate patient care [Participant 3]. Since patients could feel that the AI-enabled system performs the treatment, the physicians assumed that the use of AI-enabled systems might negatively impact the doctor-patient relationship [Participant 11]. In this regard, one participant mentioned:

> *Since [the patient] has the feeling [...] that the machine takes care of it and the doctor would only have to put his signature under it.* [Participant 11]

Interviewees mentioned the impairment of the doctor-patient conversation through the use of technology as threatening to the doctor-patient relationship. The concern is that, by using AI-enabled systems during patient consultations, a GP cannot devote all their attention to the patient sitting in front of them but instead must also focus on the screen to follow an AI-enabled system's recommendations. One participant commented:

> *[The treatment] may drift off into a standardized interview, and that's probably not necessary.* [Participant 12]

GP13 was concerned that AI-enabled systems would generally reduce doctor-patient contact, which is a core component of GP care and is inevitable for successful treatment and patient care [Participant 13]. The potential endangerment of the doctor-patient relationship by the use of AI-enabled systems was also often linked to misuse of data.

### *Misuse of Data*

With the use of AI-enabled systems and the disclosure of both patients' and physicians' data, *misuse of data* is a key concern and impacts GPs' attitudes towards AI-enabled systems. In this context, GP3 saw the problem in the connection between AI-enabled systems used in practice as well as the interconnectedness between these systems and the internet:

> *[AI-enabled systems] are not stand-alone systems but are networked, and […] actually, work over the internet with such simple things as voice recognition. And in my view, this will change the doctor-patient contact considerably. […] I consider the fundamental trust in the patient-physician-conversation [...] to be a very important basis for our work. And I also see [the trusting relationship between the patient and the physician] as being in danger due to the increasing use of such procedures. I find this very worrying.* [Participant 3]

Internet access makes the data accessible and renders the patient and doctor transparent, violating data privacy and having serious consequences for patients. One participant described:

> *Patient data are very sensitive data. Disease data are very sensitive data. [There is the risk that] they are passed on somewhere, that some authorities who have nothing to do with it or should have nothing to do with it could intercept the data and use this to the disadvantage of the patients.* [Participant 11]

Thus, the physicians are concerned about the data being misused by other stakeholders, as supported by GP4:

> *The problem is that large companies use AI to gain access to lucrative patients and to control them via AI.* [Participant 4]

Further, GP3 warned of the danger of pharmaceutical companies programming AI-enabled systems for their purposes, referring to medication proposals that are not medically indicated but instead deliver a monetary benefit for the producing company. They justified this concern with experiences from working with other technologies [Participant 3]. This concept also summarizes physicians' concerns about being monitorable and controllable at work when using AI-enabled systems. Owing to connection to the Internet, GP10 assumed that every step of physicians will be transparent and can be monitored [Participant 10]. However, the GPs did not explicitly mention who would have interests in observing and controlling them.

### *Diagnostic Bias*

According to the interviewees, AI-enabled systems can cause *diagnostic bias*, whereby the technology influences GP's decision-making in ways that can negatively affect the course and success of treatment. Once a GP has received suggestions from an AI-enabled system, he or she may not consider further possible diagnoses [Participant 11]. In this context, GP8 spoke of the fear of being put on a completely wrong track and the likelihood that the AI-enabled system indicates a diagnosis that does not fit and therefore leads a GP to mistreat the patient [Participant 8]. A frequent concern was that doctors might become over-reliant on the technology, neglecting their own medical and experience-based knowledge. Further, the interviewees also mentioned the risk of over-expansion of treatment services, as supported by participant 17:

> *The AI will recommend examinations that I would personally put last, ie. it will possibly lead to so-called device medicine, involving a lot of safeguard diagnostics, which I consider to be quite questionable.* [Participant 17]

## Expectations

Besides *concerns*, we also found *expectations* to be determinants of GPs' attitudes. This category reflects GPs' thoughts and beliefs about AI-enabled systems' expected benefits and limitations regarding GP care. While the expected benefits had a positive connotation in the interview data (concepts regarding (1) *diagnostic quality*, (2) *diagnostic efficiency,* and (3) *legal liability*), the expected limitations depict a negative perspective (concepts encompassing statements relating to a (4) *lack of human competences* and (5) *time expenditure*).

### *Diagnostic Quality*

*Diagnostic quality* represents the expectation that AI-enabled systems can improve the quality of care via more accurate and precise diagnosis. It is GPs' job to provide patients with the best possible care, which is why the expected benefits of AI-enabled systems positively influenced the GPs' attitudes. Especially in rare diseases, which GPs do not regularly treat, the expectation towards AI-enabled systems is an improvement of diagnostic quality since AI-enabled systems can work with a larger database than the human brain [Participant 18]. Thus, AI-enabled systems should act as support, a backup for the physician, in parallel or subsequent to a medical diagnosis. GP12 assumed that AI-enabled systems could assist GPs in the decision-making process and thought that this would positively impact the outcome quality:

> *But for rarer diseases, when it comes to making a diagnosis; for example, a red skin spot that I can't classify at all, then it would be conceivable [...] to reaffirm or reassure oneself [by means of AI].* [Participant 12]

Further, the expectation towards an AI-enabled system is that it is more enduring than humans. Unlike a doctor, an AI-enabled system does not tire, and the diagnostic quality does not suffer from human-like, lower-concentration performance in the course of a day. One participant said:

> *If AI is well programmed or if there are no failures in it, then AI is more accurate than a person, who is sometimes tired [and thus] makes bad decisions.* [Participant 2]

### *Diagnostic Efficiency*

Besides the expected diagnostic quality, the interviewees stated that an AI-enabled system's ability to make rapid diagnoses is a further expected benefit. We refer to this expectation as *diagnostic efficiency*. GP2 transferred the time advantages of using AI-enabled systems to the area of image recognition and expected AI-enabled systems to be three times faster than a physician:

> *While a radiologist might manage 60 diagnostic findings a day, the AI could work day and night and deliver perhaps 180 or 200 findings. And if that happens with similar quality, then [...] you could examine many more patients than a human alone could.* [Participant 2]

Based on this benefit of AI-enabled systems, GP14 expected the use of AI-enabled systems to influence disease progression positively [Participant 14]. Also, GP1 emphasized the necessity of fast-working AI-enabled systems in the detection of health threats:

> *Now a completely new virus has appeared in China or Japan, and to get ahead of it, you need artificial intelligence which can detect [the virus] much faster.* [Participant 1]

*Diagnostic efficiency* includes the GPs' expectations regarding physician support via AI-enabled systems, reducing the daily workload by preselection [Participant 7], and patient prioritization [Participant 13]. This time-saving effort would give GPs some relief and would allow them to concentrate on more serious cases [Participant 7].

### *Legal Liability*

*Legal liability* includes the expectation that AI-enabled systems will give GPs legal backing. All decisions get documented using AI-enabled systems, allowing the providers to prove the correct decision-making approach in a legal proceeding [Participant 12]. Further, the interviewees added the assumption that AI-enabled systems could hedge the physician's choice of treatment. In this context, GP 13 mentioned:

> *[With] AI, you can then understand how [the physician] came to a decision because AI said the risk was 0.001.* [Participant 13]

This was supported by the expectation of built-in legal protection and shifting responsibility from the GP towards the AI-enabled system [Participant 4].

### *Lack of Human Competences*

Besides the above-mentioned positive determinants**,** the following *expectations* depict perceived limitations of AI-enabled systems. The expected *lack of human competencies* of AI-enabled systems was mentioned with high emphasis. It includes the GPs' assumption that AI-enabled systems do not have certain human competencies, which are, in fact, crucial for adequate and appropriate treatment in GP care. The respondents agreed that AI-enabled systems will not – some said never – be able to have certain human competencies. In this context, empathy [Participant 5], intuition [Participant 1], gestures [Participant 13], experience [Participant 12], and clinical reasoning ability [Participant 3] were mentioned. These competencies are important in GP care to collect all relevant information so as to be able to provide optimal care. Two participants said the following:

> *There is something behind almost every illness that makes [diagnosis] even more challenging. And if this is not considered, it will not be possible to help a patient comprehensively. And I think [AI] can probably not do this*. [Participant 5]

> *Experience can hardly be replaced by AI. Experience and intuition. And empathy. This is just how I treat people, to get something out of them. So, this is something that defines a good physician and cannot be replaced by AI. Empathy.* [Participant 1]

Further, describing and verbalizing much of the information collected in GP care (such as mimic or gestures) is not always possible. However, it is essential data input for the proper operation of any technology [Participant 13]. Participants expressed that many patients just make an appointment in order to have some human interaction, for instance, lonely elderly patients. GP 15 explained:

> *My experience every day with patients is that they want to be touched, and they want to look you in the eyes.* [Participant 15]

For them, AI-enabled systems seemed to be unable to fulfill these needs. In the context of human competencies, GP13 underlined AI-enabled systems' limitations:

> *People are certainly beaten by [AI] in many ways. But not in the emotional one.* [Participant 13]

#### *Time Expenditure*

*Time expenditure* includes the expectation that in most cases, GPs would need more time for the decision-making process by involving AI-enabled systems, since in routine cases, GPs usually diagnose on their own within seconds. In this context, Participant 11 commented:

> *[...] in routine cases, [AI] would not be a time saver for me.* [Participant 11]

With AI-enabled systems, additional effort is expected by the interviewees since they fear that data must be entered in the documentation as well as fed into the AI-enabled system. GP2 assumed additional time expenditure due to a person's need to critically reflect on the results of the AI-enabled system [Participant 2].

### Environmental Influences

Besides the two main categories, we also identified *environmental influences* to influence GPs' attitudes towards AI-enabled systems. The summarized determinants include influences resulting from an evolving working environment (*changing working conditions*), the perspectives and opinions of key stakeholders (*stakeholder influences*), as well as the available IT hardware and software resources (*IT infrastructure*) and the media environment (*media*).

#### *Changing Working Conditions*

*Changing working conditions* includes GPs' impacts on the challenges caused by demographic change [Participant 10], a changing spectrum of diseases [Participant 1], and the constant increase in medical knowledge [Participant 3]. Regarding demographic change, GP1 stated:

> *The lack of physicians comes with giant steps, and what is also urgently needed is telemedicine. And this, of course, needs AI with it.* [Participant 1]

However, demographic change also includes the necessity to modernize a practice's equipment with new technologies in order to be interesting for younger physicians [Participant 10]. AI-enabled systems were also considered necessary to get on top of the increasing medical knowledge and provide the patients with the best and latest information about their health care [Participant 3]. Regarding the changing spectrum of germs and viruses and the resulting need for AI-enabled systems, GP 1 referred to the outbreak of the COVID-19 pandemic [Participant 1].

***Stakeholder Influences***

Another environmental influence is *stakeholder influences*, which indicates how certain groups of people and organizations influence GPs' opinions. The interviews revealed that patients and institutions are key stakeholders in this context. GP 7 said:

> *I think we can be influenced [by the patients' opinions] because, in the end, a medical practice follows the market like a small business. If the patients want [AI technologies] and demand [AI technologies], more and more practices will offer it.* [Participant 7]

However, the GPs also stated that they do not expect patients to disapprove of AI-enabled systems [Participant 11]. In contrast to the patients' opinions, the GPs agreed that the opinions of institutions such as the German Society of General Medicine (Deutsche Gesellschaft für Allgemeinmedizin und Familienmedizin) or the German General Practitioners Association (Deutscher Hausärzteverband) have key roles in the formation of German GPs' attitudes. GPs place trust in these institutions and regard them as scientific and validated committees of their profession [Participant 11]. Supported by the fact that physicians wish to receive more recommendations on which technologies they should use in practice, the influences of these institutions' attitudes are evident [Participant 7].

***Media***

The concept *Media* refers to all informative sources in which physicians had heard or read about AI-enabled systems. Since most interviewees had not yet worked with AI-enabled systems, we assume that the media strongly contributes to AI literacy, which describes what GPs believe AI is and can do. One participant said:

> *Except for what I have read about it in medical journals, [I hardly come in contact with AI]".* [Participant 11]

GP14 suggested that physicians should be informed about AI technology via regular journal articles [Participant 14].

***IT Infrastructure***

Another factor that influences attitudes is the often inadequate *IT infrastructure* in physicians' practices. In the event of technical problems, AI-enabled systems cannot be used properly or at all, which can undermine optimal patient care. Physicians are skeptical about AI-enabled systems in this regard and lean on established ways of performing their routines since they cannot rely on the overall infrastructure, which needs integration of AI technologies in order to function properly. In this context, one participant mentioned:

> *If my system goes down, my AI is on standby, then sorry, I can't diagnose, my system strikes out. That is why it's nice to be able to write down with a pen on paper what a patient has and has received.* [Participant 16]

### Individual Characteristics

While *environmental influences* are external influences, *individual characteristics* are determinants that describe a physician as a person, including character traits, demographic specifics, and knowledge. Although there are many individual characteristics, we found that *age* and *affinity with technology* are particularly relevant to the GPs.

#### *Age*

The participants who brought up *age* disagreed on whether it has a role in determining their attitudes. GP10, an older physician, said:

> *I am convinced it needs much work because there is certainly much resistance, which clearly depends on age.* [Participant 10]

While GP11, a younger physician, stated:

> *I also know young colleagues who are my age, and they also have strong reservations [regarding AI].* [Participant 11]

Thus, we included *age* as a relevant characteristic and leave future research endeavors to challenge its influence on a larger scale.

#### *Affinity with Technology*

A further influencing factor was *affinity with technology*, which indicates whether being open to new technologies supports a positive attitude towards AI-enabled systems. One participant said:

> *Well, there are also people in my generation who were already technically inclined […]. So, I think that's the key to why people [would use AI] or not.* [Participant 18]

### Minimum Requirements of AI-enabled systems

Besides the above-mentioned categories and concepts, the interviews also revealed *minimum requirements of AI-enabled systems*, which are preconditions that must be met for GPs to contemplate using AI-enabled systems. Although many of the requirements are thematically related to *expectations* and *concerns*, our qualitative data collection allowed us to distinguish between the attitude determinants and the essential/must-have criteria. We will now explain the six identified minimum requirements and underline their intensities with statements from the interviews.

#### *Time Efficiency*

Most interviewee statements that expressed demands of AI-enabled systems contributed to the minimum requirement *time efficiency.* GPs need AI-enabled systems to be fast and easy to use since they have limited time for each patient consultation. One participant mentioned:

> *First of all, [AI] should be fast. There is always time pressure.* [Participant 14]

Also, participants stated that AI-enabled systems must not take additional time since this would keep a doctor from essential tasks [Participant 15]. Thus, the focus was also on practical relevance and system compatibility with existing practice IS. The interviewees demanded a self-explanatory design that can be operated quickly and in a few simple steps. The time component's importance in the use of AI-enabled systems was shown by GP15, who has already tested an AI-enabled system and decided against further usage, as stated:

> *[…] [the use of AI] took me far too long* [Participant 15].

### *Diagnostic Quality*

Besides the time components, *diagnostic quality* was mentioned as another key requirement of AI-enabled systems. For physicians to consider the use of AI-enabled systems, the AI-enabled system must be validated, must not make mistakes, and must provide accurate diagnoses so that there is no threat to patient care [Participant 7]. Further, some interviewees demanded accurate diagnoses and even better results through AI-enabled systems compared to human engagement since otherwise, AI-enabled systems would be obsolete [Participant 2]. Also, AI-enabled systems must be evidence-based and must follow guidelines. In this context, GP 10 said:

> *[AI must be] scientifically grounded and must provide validated results that [the physician] may not be able to produce in their entirety*. [Participant 10]

### *Data Security*

Interviewees also named guaranteed *data security* as a requirement for using AI-enabled systems. The physicians justified this requirement with concerns about privacy and the misuse of data, and they do not want patient and physician data to be accessible to anyone. One participant explained:

> *Of course, it is also important to me that there is corresponding data security. I do not want the patients and us to be completely transparent. That is certainly not in the overall interest*. [Participant 10]

Data security issues were the second reason, along with time expenditure, that made GP15 decide to refrain from further using that AI-enabled system [Participant 15].

### *Economic Viability*

*Economic viability* summarizes the statements regarding AI-enabled systems' affordability as well as questions about financing them. In this regard, GP 2 mentioned:

> *If they are affordable [then I would use AI applications].* [Participant 2]

Further, the participants made the willingness to use AI-enabled systems dependent on how the technology is financed and stated that the cost-benefit ratio must be consistent.

### *Transparency*

*Transparency*, and thus, the comprehensibility of AI algorithms, is another key requirement of AI-enabled systems. To trust AI-enabled systems, it was important to the GPs that the proposals submitted by the AI-enabled system are comprehensible.

So, one participant said:

> *I must know how [AI] obtains information and how [it] works.* [Participant 11]

### *Autonomy*

*Autonomy* represents another requirement, indicating that an AI-enabled system must be self-managed by the providers. Only if a physician can continue to work autonomously and the next treatment steps are not mandatory by an AI-enabled system, using the technology is feasible. However, the interviewees had a negative attitude towards intervention in a physician's self-determined work. One participant explained:

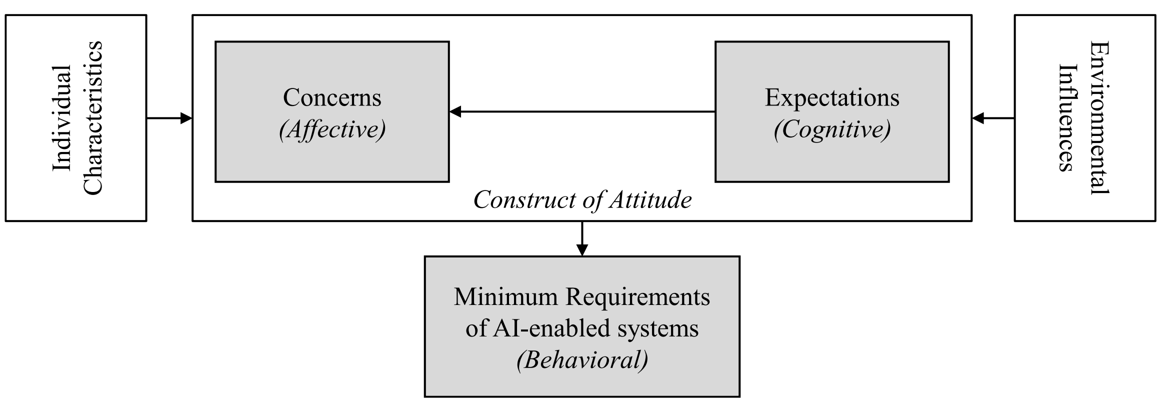
> *I would participate only [on a] voluntarily [basis].* [Participant 15]

## Discussion

### Key Findings

We now discuss GPs' *attitude determinants* regarding AI-enabled systems in GP care and the relationships between these determinants. We conflate our findings to propose a model (see Figure 2) and to derive theoretical and practical contributions. Considering the lack of existing solutions and experiences of GPs with AI-enabled systems, our findings emphasize the relevance of GPs' *AI literacy*. Hence, the interview statements and the resulting discussion rest upon GPs' knowledge of AI, whether this is factual or not. The results underline that the participating physicians formed an opinion, even if they, as potential end-users, did not have the necessary knowledge to understand the technology comprehensively or differentiate AI-enabled systems from knowledge-based CDSS. Given that this will be the case for a large proportion of solely medically educated GPs, it is all the more important to investigate the determinants of attitude in rich detail. In doing so, research and practice can derive levers for the successful adoption of AI-enabled systems. Thus, and as the verisimilitude of GPs' AI literacy is debatable, it emphasizes and gives important clues to understanding their attitude and implications for practice.

**Figure 2.** Model of the general practitioners' determinants of attitudes towards artificial intelligence-enabled systems.



Our attitude determinants *concerns*, *expectations*, and *minimum requirements of AI-enabled systems* corroborate Rosenberg and Hovland's three-component model of attitude [41]. The data analysis revealed: (1) the identified *concerns,* which represent the interviewees' expressed emotions towards AI-enabled systems, and refer to the affective component of attitude; (2) the identified *expectations,* which picture GPs' beliefs towards AI-enabled systems, and address the cognitive component; (3) and the identified *minimum requirements of AI-enabled systems,* which are preconditions that must be met for GPs to contemplate using AI-enabled systems, and address the behavioral component of attitude.

However, since the relationships between these three determinants lack consistency and dependency according to our findings, we could not confirm the three-component model [43]. Instead, the interviews revealed that GPs' *concerns* and *expectations* form the *minimum requirements of AI-enabled systems*. This approach is consistent with the two-component model of attitude, which indicates that the affective and cognitive components explain the behavioral intention [44]. For instance, the interviewees clarified that concerns about data misuse trigger the GPs' demand for data security in AI-enabled systems. The importance of data security in HITs is not a novelty but rather a recurring theme in practice and research [71, 72]. Another example is the expected time expenditure when using AI-enabled systems, which leads to the requirement that AI-enabled systems must be time efficient and simple to use. As for most health complaints, GP care is the first point of contact, and GPs must treat a large number of patients. For instance, in Germany, GP care is one of the most frequently used health care services, with more than 200 consultations per week per physician [73] and an average doctor-patient contact time of 7.6 minutes [26]. Thus, GPs are always under time pressure, which is why every additional action or additional use of new technologies must be well considered [74]. In part, these constraints in GP care are due to an aging population [74]. GP consultations increase as age correlates with doctor visits, particularly in primary care, where a high service utilization level by the older population is significant [75]. Besides elderly patients, the aging population also causes an increasing GP shortage due to retirements and insufficient numbers of successors to GP care [76]. These interdependent developments further reduce the time available for a GP to make an initial diagnosis, which decides whether a patient receives the correct follow-up treatment, is treated at the right time, or receives treatment at all. Thus, a GP's decision strongly impacts the course of treatment and outcome quality [28]. Consequently, an increased workload and diagnostic suggestions with the potential to harm patients resulting from the use of AI-enabled systems would likely hamper technology adoption by GPs [77]. Based on our findings, we assume that GPs would not use AI-enabled systems if these involve additional time or harm patients, despite AI-enabled systems' benefits. Thus, we consider *diagnostic quality* and *time efficiency* to be the most important *minimum requirements of AI-enabled systems*. Obligations to use AI-enabled systems by regulations or by superiors are neglected in this assumption.

However, we found not only minimum requirements of AI-enabled systems to be influenced by concerns and expectations but also *concerns* and *expectations* to be interrelated and to form a construct of attitude. For instance, the interviewees' concern of being replaceable roots in their perception of AI-enabled systems formulating more accurate diagnoses than physicians. Yet, most of our interviewees did not fear being replaceable, as AI-enabled systems are unable to have and perform human competencies such as empathy and clinical reasoning. To the same conclusion come Songhee et al. [78] who conducted an online survey with physicians with the result, that most of the participants do not believe that AI will replace physicians [78]. In GP care, decisions are often made with incomplete and fragmented patient-specific information, requiring human competencies such as experience, intuition, and clinical reasoning [79]. Further, in GP care, human competencies are of particular importance to build up a doctor-patient relationship. To glean relevant information for the decision-making process, GP care places great importance on interpersonal continuity in the doctor-patient relationship [39]. Especially regarding GPs' gatekeeping role and their focus on an emotional bond in medical service provision, this interpersonal relationship is valuable since it enables the therapeutic benefit of improved continuity of care and more holistic and more individualized treatments [32]. In summary, interpersonal interaction with patients is very important to GPs, whereas the GPs assume AI-enabled systems to have an insufficient ability to recognize and incorporate important individual aspects gained through the interpersonal relationship. Thus, where and when AI-enabled systems in GP care are useful is to be critically reflected [80]. Considering the potential of AI-enabled systems and their limitations from other research streams, we consider hybrid human-AI decision-making a promising scenario to mitigate the weaknesses of each other [36]. Enabling this scenario requires a profound understanding of GPs' barriers to adoption [eg, 80], underlining the relevance of our identified attitude determinants.

We also found *individual characteristics* and *environmental influences* to determine GP's attitude towards AI-enabled systems*.* Regarding individual characteristics, our results for the influence of GP's age are inconclusive. The GPs in our sample presumed that both old and young physicians would have a negative attitude towards AI-enabled systems. However, both old and young participants in our sample generally had a positive attitude towards AI-enabled systems. Since this may be due to a bias in our sampling, we encourage further examinations of age as an attitude determining *individual characteristics.* Regarding *environmental influences*, our respondents indicated that a positive attitude from institutions such as the German General Practitioners Association would positively impact their attitudes toward AI-enabled systems. Moreover, GPs' individual context like office size and facilities (cf. *IT infrastructure*) might prove themselves in further studies as determinants for GPs' attitude towards AI-enabled systems. By uncovering *individual characteristics* and *environmental influences* as attitude determinants, we found similarities to the factors *social influence* and *age* of the UTAUT. Albeit, in the UTAUT, these determinants influence the intention to use [48, 53, 54]. However, in contrast to our findings regarding environmental influences, Jeng and Tzeng [81] concluded that social influence does not affect physicians in Taiwan in adopting CDSS. This divergence may stem from different cultures and differences in medical education and practice as well as AI characteristics and GPs' AI literacy, compared to more established CDSS. We leave it to future research to further explore these relationships regarding environmental influences.

Further, our findings explicate that the consideration of the affective component of attitude is crucial in the medical context despite being often neglected in well-known theories of behavior and acceptance research [54, 82, 83]. Our interview data show that GPs' concerns about data privacy and patient safety have high importance in the context of patient care and must not be endangered. AI-enabled systems can mitigate cognitive errors resulting from, among others, GPs' fatigue or distraction [23]. Thus, diagnostic accuracy and patient safety increase [84]. However, at the same time, the integration of AI technologies can also lead to biases such as automation bias [eg, 85]. By blindly relying on the AI-enabled systems' suggestions, physicians would no longer critically review them, which can reduce accuracy [eg, 86] and increase medical errors [87]. Whether AI-enabled systems promote or minimize cognitive biases depends on how they are used [84]. Since AI-enabled systems bear certain concerns, such as this fear of being negatively biased by AI-enabled systems' suggestions, the affective component of attitude also plays a key role in the context of AI. Eventually, the affective component is particularly relevant regarding investigating GPs' attitudes towards AI-enabled systems. Detecting concerns early on can positively determine GPs' attitudes. At the time when GP care comes into widespread contact with AI technologies, this form of attitude can contribute to a positive intention to use, which in turn lays the foundation for successful implementation.

Besides theoretical contributions, we derived valuable implications for practice by reflecting on GPs' attitudes prior to the use of AI-enabled systems and familiarization with the technology. We suggest making the topic of AI more prominent in politics, health-related associations, and stakeholder institutions of GP care. Via these institutions, knowledge and education on AI-enabled systems can be offered, improving GPs' AI literacy. This allows for the mitigation of concerns such as the *change of the doctor-patient relationship* and, thus, the diminution of restraints is possible. For this purpose, the distribution of evidence-based information via GP-specific journals and the involvement of advocacy groups are highly recommended since the GPs value their viewpoints. However, it is also important that potential users are not only informed about the potential of AI technology but also about its limitations and shortcomings on the basis of evidence. In this way, physicians can be empowered to use AI-enabled systems in a reflective manner and thus, for example, prevent automation bias.

Moreover, the identified *minimum requirements of AI-enabled systems* are of particular interest concerning the practical implications. First, AI-enabled systems must be programmed and designed to make usage as easy and fast as possible, as stated by participants and widely spread in the literature on user-centricity [88]. Second, AI-enabled systems must be reliable and free of errors in order to prevent any harm to patients. In addition, AI-enabled systems must ensure data protection and allow the GP to work autonomously. Besides, politics and health insurance companies should consider monetary subventions for AI-based systems since one remarkable result of the review of Ajami and Bagheri-Tadi [89] is the positive influence of financial support on physicians' willingness to use and engage with technologies [89].

Furthermore, AI-enabled systems may foster so-called "black-box-medicine", as decisions are less transparent to the patient and to the GP. With this lack of transparency, various types of biases may occur, both for the end-users and for the AI-enabled system. Such biases may result in patient security, data, and privacy concerns [84, 90]. Therefore, along with the responsibility of making an AI-augmented diagnosis, there is also the need to create accountability structures for patient-related outcomes. In a recent study of Khullar et al. [91], physicians believed that vendors or the employing health care organizations should be held accountable for AI-induced errors, while the general public believed that the physicians themselves should be liable. We see suitable liability regulations and their implications for GP's attitude determinants as a promising field for further research.

Further, AI-enabled systems should be developed to diagnose rare cases since GPs assume that they are faster in routine cases than using AI technology. This information can help developers to narrow the application area and to create better-fitting software solutions. This result also indicates that integrating AI technology is not the solution for every problem. Rather, a critical assessment must be made when using an AI-enabled system makes sense and improves decision-making and when this is not the case. Especially when it comes to human competencies and interpersonal relationships, AI-enabled systems cannot replace GPs. Rather, AI-enabled systems should be designed to free up GPs' time, as therefore, they have more time to nurture relationships with their patients, which is of particular relevance for diagnosis in GP care. Our findings may serve for a better understanding of how to design AI-enabled systems in a conducive manner and how to foster GP's acceptance in the later adoption of such systems.

### Limitations and Future Research

Although we rigorously followed our designed research approach, our study has limitations, some of which are bound to the choice of a qualitative-explorative approach. By design, qualitative interviews do not focus on drawing conclusions for entire populations, which affects the generalizability of the results. Nevertheless, a qualitative approach is appropriate before a quantitative study when dealing with a new and emotionally charged topic. This approach is reinforced by recent research that puts traditional IS adoption models to the test for AI, thus, calling for in-depth reflections [21]. Blease et al. [39] also recommended a qualitative approach since they reported lacking detailed information on GPs' views of AI-enabled systems owing to their quantitative approach. Further, conducting interviews just in one country, more precisely, in one geographic area within that country, might be a limitation of our study. As depicted in existing research, attitudes towards technology might differ between rural areas attitudes and urban areas [92]. We recommend collecting data in other countries and conducting cross-country studies to detect differences between these settings. Further, GPs' mostly basic AI literacy is another limitation of our study. Although all study participants were given the same definition of AI-enabled systems at the start of the interview, their statements reflect different understandings. However, the early consideration of the GPs' attitudes, regardless of their technical knowledge is important to identify barriers to implementation early on and derive basic conclusions for AI system design. We must also assume that only GPs who are interested in AI-enabled systems might have a general affinity with technology or who have a strong opinion on AI agreed to be interviewed. This could also explain why none of the interviewees had a solely negative attitude towards AI-enabled systems.

We further suggest examining the role of the affective attitude component since we revealed the importance of the identified concerns in our study, whereas, in well-known theories of technology acceptance, this component is often neglected. A closer examination of the affective component will make it possible to determine the extent to which it is relevant in the medical and IS context.

## Conclusions

AI-enabled systems are seen as promising solutions to enhance both the effectiveness and quality in health care. Especially in GP care, which is the first point of contact for most medical needs, physicians deal with a shrinking doctor-to-patient time and incomplete or sometimes incorrect information. Here, AI technology promises new solutions to support physicians and decrease diagnostic errors with their extensive consequences. While the application potential of AI-enabled systems in health care has been widely discussed theoretically and conceptually, a widespread application in the professional practice of GPs is still dreams of the future. In order to tap the undisputed potential of AI-enabled systems in practical use, a fundamental investigation of the technical systems and the social actors is required. As academic research, in this respect, is still in its infancy, we investigated the attitudes of GPs towards AI-enabled systems. Thereby, we seek to contribute to a better understanding of GPs' attitudes, which is crucial for developing and implementing suitable AI-enabled systems. Thus, we used in-depth qualitative-explorative interview data with German GPs and proposed a preliminary research model. We identified three determinants of GPs' attitudes: *concerns*, *expectations*, and *minimum requirements of AI-enabled systems*. Further, we revealed *individual characteristics* and *environmental influences* as two conditional determinants for GPs' attitudes towards AI-enabled systems. The findings emphasize the importance of attitude's affective component at the interface of medical and AI research. Moreover, the findings show that diagnostic quality and time efficiency are mandatory for GPs to even consider the use of AI-enabled systems. Therefore, integrating user groups' attitudes and needs is a fundamental prerequisite for user-centered design, which leads to a higher willingness and inclusion of the systems into everyday use. Considering that the GPs in our interview study predominantly corroborated AI-enabled systems' seminal role in the future of GP care, our findings may serve as a foundation for future research. Besides investigating the attitudes of user groups in other fields in the health care system, research endeavors should also focus on how the attitudes of GPs towards AI-enabled systems can be proactively promoted. In addition, future work should include and conflate findings from related research areas such as human-computer interaction, psychology, sociology, or computer science to account for AI's interdisciplinary implications to health care.

## Acknowledgments
This publication was funded by the University of Bayreuth Open Access Publishing Fund.

## Conflicts of Interest
None declared.

## References
1 Frank MR, Autor D, Bessen JE, et al. Toward understanding the impact of artificial intelligence on labor. Proceedings of the National Academy of Sciences of the United States of America; 2019 April;**116**(14):6531–6539. doi:10.1073/pnas.1900949116
2 Ågerfalk PJ. Artificial intelligence as digital agency. European Journal of Information Systems; 2020;**29**(1):1–8. doi:10.1080/0960085X.2020.1721947.
3 Bundy A. Preparing for the future of Artificial Intelligence. AI & Society; 2017;**32**(2):285–287. doi:10.1007/s00146-016-0685-0
4 Jiang F, Jiang Y, Zhi H, et al. Artificial intelligence in healthcare: past, present and future. Stroke and Vascular Neurology; 2017;**2**(4):230–243. doi:10.1136/svn-2017-000101
5 Jordan MI, Mitchell TM. Machine learning: Trends, perspectives, and prospects. Science; 2015;**349**(6245):255–260. doi:10.1126/science.aaa8415.
6 Russell SJ, Norvig P, Davis E, et al. Artificial intelligence: A modern approach, 3rd edition. Boston: Pearson; 2016. ISBN:9781292153964
7 Ngiam KY, Khor IW. Big data and machine learning algorithms for health-care delivery. The Lancet Oncology; 2019;**20**(5):262-273. doi:10.1016/S1470-2045(19)30149-4
8 Pham BT, Nguyen MD, Bui K-TT, et al. A novel artificial intelligence approach based on Multi-layer Perceptron Neural Network and Biogeography-based Optimization for predicting coefficient of consolidation of soil. CATENA; 2019;**173**:302–311. doi:10.1016/j.catena.2018.10.004
9 Rai A, Constantinides P, Sarker S. Next generation digital platforms: toward human-AI hybrids. Management Information Systems Quarterly; 2019;**43**(1):iii–ix.
10 Davenport T, Kalakota R. The potential for artificial intelligence in healthcare. Future healthcare journal; 2019;**6**(2):94–98. doi:10.7861/futurehosp.6-2-94
11 Fowler A. The role of AI-based technology in support of the knowledge management value activity cycle. The Journal of Strategic Information Systems; 2000;**9**(2):107–128. doi:10.1016/S0963-8687(00)00041-X
12 Castaneda C, Nalley K, Mannion C, et al. Clinical decision support systems for improving diagnostic accuracy and achieving precision medicine. Journal of Clinical Bioinformatics; 2015;**5**(1):1–16. doi:10.1186/s13336-015-0019-3
13 Hersh WR. Medical Informatics: Improving Health Care Through Information. Journal of the American Medical Association; 2002;**288**(16):1955–1958. doi:10.1001/jama.288.16.1955

14 Bright TJ, Wong A, Dhurjati R, et al. Effect of Clinical Decision-Support Systems: A Systematic Review. Annals of Internal Medicine; 2012;**157**(1):29–43. doi:10.7326/0003-4819-157-1-201207030-00450
15 Jaspers MWM, Smeulers M, Vermeulen H, et al. Effects of clinical decision-support systems on practitioner performance and patient outcomes: a synthesis of high-quality systematic review findings. Journal of the American Medical Informatics Association; 2011;**18**(3):327–334. doi:10.1136/amiajnl-2011-000094
16 Khairat S, Marc D, Crosby W, et al. Reasons For Physicians Not Adopting Clinical Decision Support Systems: Critical Analysis. JMIR medical informatics; 2018;**6**(2):e24. doi:10.2196/medinform.8912
17 Sim I, Gorman P, Greenes RA, et al. Clinical decision support systems for the practice of evidence-based medicine. Journal of the American Medical Informatics Association; 2001;**8**(6):527–534. doi:10.1136/jamia.2001.0080527
18 Sutton RT, Pincock D, Baumgart DC, et al. An overview of clinical decision support systems: benefits, risks, and strategies for success. npj Digital Medicine; 2020;**3**:17. doi:10.1038/s41746-020-0221-y
19 Legg S, Hutter M. Universal Intelligence: A Definition of Machine Intelligence. Minds and Machines; 2007;**17**(4):391–444. doi:10.1007/s11023-007-9079-x.
20 Russell SJ. Human compatible: Artificial intelligence and the problem of control. New York: Viking; 2019. ISBN:9780525558613
21 Schuetz S, Venkatesh V. "Research Perspectives: The Rise of Human Machines: How Cognitive Computing Systems Challenge Assumptions of User-System Interaction ". Journal of the association for Information Systems; 2020:460–482. doi:10.17705/1jais.00608
22 The Lancet. Artificial intelligence in health care: within touching distance. The Lancet; 2018;**390**(10114):2739. doi:10.1016/S0140-6736(17)31540-4
23 Topol EJ. High-performance medicine: the convergence of human and artificial intelligence. Nature Medicine; 2019;**25**(1):44–56. doi:10.1038/s41591-018-0300-7
24 Yu K-H, Beam AL, Kohane IS. Artificial intelligence in healthcare. Nature Biomedical Engineering; 2018;**2**(10):719–731. doi:10.1038/s41551-018-0305-z
25 Pannu A. Artificial intelligence and its application in different areas. International Journal of Engineering and Innovative Technology; 2015;**4**(10):79–84.
26 Deveugele M, Derese A, van den Brink-Muinen A, et al. Consultation length in general practice: cross sectional study in six European countries. British Medical Journal; 2002;**325**(7362):472–474. doi:10.1136/bmj.325.7362.472
27 Singh H, Giardina TD, Meyer AND, et al. Types and Origins of Diagnostic Errors in Primary Care Settings. Journal of American Medical Association Internal Medicine; 2013;**173**(6):418–425. doi:10.1001/jamainternmed.2013.2777
28 van Such M, Lohr R, Beckman T, et al. Extent of diagnostic agreement among medical referrals. Journal of Evaluation in Clinical Practice; 2017;**23**(4):870–874. doi:10.1111/jep.12747
29 Lambe KA, O'Reilly G, Kelly BD, et al. Dual-process cognitive interventions to enhance diagnostic reasoning: a systematic review. BMJ Quality & Safety; 2016;**25**(10):808–820. doi:10.1136/bmjqs-2015-004417

30 Police RL, Foster T, Wong KS. Adoption and use of health information technology in physician practice organisations: systematic review. Informatics in Primary Care; 2010;**18**(4):245–258. doi:10.14236/jhi.v18i4.780
31 Aronson SJ, Rehm HL. Building the foundation for genomics in precision medicine. Nature; 2015;**526**(7573):336–342. doi:10.1038/nature15816
32 Harbishettar V, Krishna KR, Srinivasa P, et al. The enigma of doctor-patient relationship. Indian journal of psychiatry; 2019;**61**(4):776-781. doi:10.4103/psychiatry.IndianJPsychiatry_96_19
33 Nurek M, Kostopoulou O, Delaney BC, et al. Reducing diagnostic errors in primary care. A systematic meta-review of computerized diagnostic decision support systems by the LINNEAUS collaboration on patient safety in primary care. The European journal of general practice; 2015;**21 Suppl**:8–13. doi:10.3109/13814788.2015.1043123
34 Bryan C, Boren SA. The use and effectiveness of electronic clinical decision support tools in the ambulatory/primary care setting: a systematic review of the literature. Informatics in Primary Care; 2008;**16**(2):79–91. doi:10.14236/jhi.v16i2.679
35 Asan O, Bayrak AE, Choudhury A. Artificial Intelligence and Human Trust in Healthcare: Focus on Clinicians. Journal of Medical Internet Research; 2020;**22**(6):e15154. doi:10.2196/15154
36 Dellermann D, Ebel P, Söllner M, et al. Hybrid Intelligence. Business & Information Systems Engineering; 2019;**61**(5):637–643. doi:10.1007/s12599-019-00595-2
37 Bhattacherjee A, Hikmet N. Physicians' resistance toward healthcare information technology: a theoretical model and empirical test. European Journal of Information Systems; 2007;**16**(6):725–737. doi:10.1057/palgrave.ejis.3000717
38 Liberati EG, Ruggiero F, Galuppo L, et al. What hinders the uptake of computerized decision support systems in hospitals? A qualitative study and framework for implementation. Implementation Science; 2017;**12**(1):113. doi:10.1186/s13012-017-0644-2
39 Blease C, Kaptchuk TJ, Bernstein MH, et al. Artificial Intelligence and the Future of Primary Care: Exploratory Qualitative Study of UK General Practitioners' Views. Journal of Medical Internet Research; 2019;**21**(3):e12802. doi:10.2196/12802
40 Eagly AH, Chaiken S. The psychology of attitudes. 1st edition. New York: Harcourt Brace Jovanovich; 1993. ISBN:9780155000971
41 Rosenberg MJ, Hovland CI, McGuire WJ, et al. Attitude organization and change: An analysis of consistency among attitude components. 3rd edition. Oxford: Yale University Press; 1960. ISBN:9780300008647
42 Bierhoff H-W. Sozialpsychologie. 6th edition. Stuttgart: Kohlhammer; 2006. ISBN:9783170188426
43 Fischer L, Wiswede G. Grundlagen der Sozialpsychologie, 3rd edition. München: Oldenbourg; 2009. ISBN:9783486587562
44 Bagozzi RP, Burnkrant RE. Attitude measurement and behavior change: A reconsideration of attitude organization and its relationship to behavior. ACR North American Advances; 1979;**6**:295–302

45 Bagozzi RP, Burnkrant RE. Attitude Organization and the Attitude–Behavior Relationship. Journal of Personality and Social Psychology; 1979;**37**(6):913–929. doi:10.1037/0022-3514.37.6.913
46 Bagozzi RP. Attitudes, intentions, and behavior: A test of some key hypotheses. Journal of Personality and Social Psychology; 1981;**41**(4):607–627. doi:10.1037/0022-3514.41.4.607
47 Fishbein M, Ajzen I. Belief, attitude, intention and behavior: An introduction to theory and research. Reading: Addison-Wesley; 1975. ISBN:9780201020892
48 Ajzen I. The Theory of Planned Behavior. Organizational Behavior and Human Decision Processes; 1991;**50**(2):179–211. doi:10.1016/0749-5978(91)90020-T
49 Ajzen I, Fishbein M. The Influence of Attitudes on Behavior. The handbook of attitudes 2005;**173**(221):31.
50 Hussein Z, Oon SW, Fikry A. Consumer Attitude: Does It Influencing the Intention to Use mHealth? Procedia Computer Science; 2017;**105**:340–344. doi:10.1016/j.procs.2017.01.231
51 Pinto Dos Santos D, Giese D, Brodehl S, et al. Medical students' attitude towards artificial intelligence: a multicentre survey. European radiology; 2019;**29**(4):1640–1646. doi:10.1007/s00330-018-5601-1
52 Sit C, Srinivasan R, Amlani A, et al. Attitudes and perceptions of UK medical students towards artificial intelligence and radiology: a multicentre survey. Insights into imaging; 2020;**11**(14):1–6. doi:10.1186/s13244-019-0830-7
53 Ajzen I, Fishbein M. Understanding attitudes and predicting social behavior. Englewood Cliffs: Prentice Hall; 1980. ISBN:9780139364358
54 Venkatesh V, Morris MB, Davis FD. User Acceptance of Information Technology: Toward a Unified View. Management Information Systems Quarterly; 2003;**27**(3):425–478. doi:10.2307/30036540
55 Venkatesh V, Thong JYL, Xu X. Unified theory of acceptance and use of technology: A synthesis and the road ahead. Journal of the association for Information Systems; 2016;**17**(5):328–376. doi:10.17705/1jais.00428
56 Hirschheim R. Introduction to the Special Issue on "Quo Vadis TAM – Issues and Reflections on Technology Acceptance Research. Journal of the association for Information Systems; 2007;**8**(4):203–205. doi:10.17705/1jais.00128
57 Walsham G. Interpreting information systems in organizations. Chichester: Wiley; 1993. ISBN:9780471938149
58 Kaplan B, Maxwell JA. Qualitative Research Methods for Evaluating Computer Information Systems. In: Anderson JG, Aydin CE, eds. Evaluating the Organizational Impact of Healthcare Information Systems. New York: Springer-Verlag; 2005. p. 30–55.
59 Polkinghorne DE. Language and Meaning: Data Collection in Qualitative Research. Journal of Counseling Psychology; 2005;**52**(2):137–145. doi:10.1037/0022-0167.52.2.137
60 Schultze U, Avital M. Designing interviews to generate rich data for information systems research. Information and Organization; 2011;**21**(1):1–16. doi:10.1016/j.infoandorg.2010.11.001

61 Nelson J. Using conceptual depth criteria: addressing the challenge of reaching saturation in qualitative research. Qualitative Research; 2017;**17**(5):554–570. doi:10.1177/1468794116679873
62 Myers MD, Newman M. The qualitative interview in IS research: Examining the craft. Information and Organization; 2007(17):2–16. doi:10.1016/j.infoandorg.2006.11.001
63 Castillo-Montoya M. Preparing for Interview Research: The Interview Protocol Refinement Framework. The Qualitative Report; 2016;**21**(5):811–831.
64 Ryan F, Coughlan M, Cronin P. Interviewing in qualitative research: The one-to-one interview. International Journal of Therapy and Rehabilitation; 2009;**16**(6):309–314. doi:10.12968/IJTR.2009.16.6.42433
65 Glaser BG. Theoretical sensitivity. Mill Valley: Sociology Press; 1978. ISBN:9781884156014
66 Corbin JM, Strauss AL. Basics of qualitative research: Techniques and procedures for developing grounded theory. Thousand Oaks: Sage; 2015. ISBN:9781412997461
67 Kallio H, Pietilä A-M, Johnson M, et al. Systematic methodological review: developing a framework for a qualitative semi-structured interview guide. Journal of advanced nursing; 2016;**72**(12):2954–2965. doi:10.1111/jan.13031
68 Glaser BG, Strauss AL. The discovery of grounded theory: Strategies for qualitative research. 1st edition. London: Routledge; 2017. ISBN: 9780202302607
69 Etikan I. Comparison of Convenience Sampling and Purposive Sampling. American Journal of Theoretical and Applied Statistics; 2016;**5**(1):1–4. doi:10.11648/j.ajtas.20160501.11
70 Long D, Magerko B. What is AI Literacy? Competencies and Design Considerations. Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems; 2020 Apr 1-16; New York, USA.
71 Grood Cd, Raissi A, Kwon Y, et al. Adoption of e-health technology by physicians: a scoping review. Journal of multidisciplinary healthcare; 2016;**9**:335–344. doi:10.2147/JMDH.S103881
72 Steininger K, Stiglbauer B. EHR acceptance among Austrian resident doctors. Health Policy and Technology; 2015;**4**(2):121–130. doi:10.1016/J.HLPT.2015.02.003
73 Irving G, Neves AL, Dambha-Miller H, et al. International variations in primary care physician consultation time: a systematic review of 67 countries. British Medical Journal Open; 2017;**7**(10):1-15. doi:10.1136/bmjopen-2017-017902
74 Reed M, Lehmann B, Herrmann M. The Evolving State of General Practice and GP Education in Germany. Health Care Current Reviews; 2017;**5**(3):1–4. doi:10.4172/2375-4273.1000203
75 Nie JX, Wang L, Tracy CS, et al. Health care service utilization among the elderly: findings from the Study to Understand the Chronic Condition Experience of the Elderly and the Disabled (SUCCEED project). Journal of Evaluation in Clinical Practice; 2008;**14**(6):1044–1049. doi:10.1111/j.1365-2753.2008.00952.x
76 Natanzon I, Ose D, Szecsenyi J, et al. Does GPs' self-perception of their professional role correspond to their social self-image?--a qualitative study from Germany. BMC family practice; 2010;**11**:10. doi:10.1186/1471-2296-11-10

77 Young AJ. New technologies and general practice. The British Journal of General Practice; 2016;**66**(653):601–602. doi:10.3399/bjgp16X688021
78 Songhee O, Jae Heon K, Sung-Woo C, et al. Physician Confidence in Artificial Intelligence: An Online Mobile Survey. Journal of Medical Internet Research; 2019;**21**(3):1-13. doi:10.2196/12422
79 Yazdani S, Hosseinzadeh M, Hosseini F. Models of clinical reasoning with a focus on general practice: a critical review. Journal of Advances in Medical Education & Professionalism; 2017(4):177–184
80 Knop M, Mueller M, Freude H, et al. Perceived limitations of telemedicine from a phenomenological perspective. Proceedings of the 33rd Bled eConference – Enabling Technology for a Sustainable Society: 2020 June 28 – 29; Online Conference; University of Maribor Press; 2020.
81 Jeng DJ-F, Tzeng G-H. Social influence on the use of Clinical Decision Support Systems: Revisiting the Unified Theory of Acceptance and Use of Technology by the fuzzy DEMATEL technique. Computers & Industrial Engineering; 2012;**62**(3):819–828. doi:10.1016/j.cie.2011.12.016
82 Davis FD, Bagozzi RP, Warshaw PR. Extrinsic and Intrinsic Motivation to Use Computers in the Workplace. Journal of Applied Social Psychology; 1992;**22**(14):1111–1132. doi:10.1111/j.1559-1816.1992.tb00945.x
83 Kulviwat S, Bruner II GC, Kumar A, et al. Toward a unified theory of consumer acceptance technology. Psychology and Marketing; 2007;**24**(12):1059–1084. doi:10.1002/mar.20196
84 Felmingham CM, Adler NR, Ge Z, et al. The Importance of Incorporating Human Factors in the Design and Implementation of Artificial Intelligence for Skin Cancer Diagnosis in the Real World. American journal of clinical dermatology; 2021;**22**(2):233–242. doi:10.1007/s40257-020-00574-4
85 Bond RR, Novotny T, Andrsova I, et al. Automation bias in medicine: The influence of automated diagnoses on interpreter accuracy and uncertainty when reading electrocardiograms. Journal of electrocardiology; 2018;**51**(6S):S6-S11. doi:10.1016/j.jelectrocard.2018.08.007
86 Tsai TL, Fridsma DB, Gatti G. Computer decision support as a source of interpretation error: the case of electrocardiograms. Journal of the American Medical Informatics Association; 2003;**10**(5):478–483. doi:10.1197/jamia.M1279
87 Lyell D, Magrabi F, Raban MZ, et al. Automation bias in electronic prescribing. BMC medical informatics and decision making; 2017;**17**(1):28. doi:10.1186/s12911-017-0425-5
88 Nguyen BV, Burstein F, Fisher J. Improving service of online health information provision: A case of usage-driven design for health information portals. Information Systems Frontiers; 2015;**17**(3):493–511. doi:10.1007/s10796-014-9507-4
89 Ajami S, Bagheri-Tadi T. Barriers for Adopting Electronic Health Records (EHRs) by Physicians. Acta Informatica Medica; 2013;**21**(2):129–134. doi:10.5455/aim.2013.21.129-134
90 Reddy S, Allan S, Coghlan S, et al. A governance model for the application of AI in health care. Journal of the American Medical Informatics Association; 2020;**27**(3):491–497. doi:10.1093/jamia/ocz192

91 Khullar D, Casalino LP, Qian Y, et al. Public vs physician views of liability for artificial intelligence in health care. Journal of the American Medical Informatics Association; 2021. doi:10.1093/jamia/ocab055
92 Müller M, Knop M, Ressing C, et al.; Bui T, ed.  Constituting Factors of a Digitally Influenced Relationship between Patients and Primary Care Physicians in Rural Areas. Proceedings of the 53rd Hawaii International Conference on System Sciences; 2020 January 7-10; Maui, Hawaii; 2020.

## Abbreviations

AI: artificial intelligence
CDSS: clinical decision support systems
DSS: decision support systems
GP: general practitioner
HITs: health information technologies
IS: information systems
TRA: Theory of Reasoned Action
UTAUT: Unified Theory of Acceptance and Use of Technology