Design and validation of a questionnaire to measure the acceptance of telemedicine by healthcare professionals in Germany

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Methodology

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Abstract

Background: Telemedicine allows healthcare professionals to manage patient treatments remotely and to benefit from the interaction of telemedicine centers. Even though telemedicine responds to the current burdens in healthcare systems, these complex infrastructures depend on technology, financing, organization, policy, legislation, and, not least, on their corresponding acceptance by the user. Little is known in this context about the drivers for this acceptance by healthcare professionals giving treatment. Germany, with the highest healthcare spending in the world, is particularly lagging here.

Methods: A literature review was conducted to identify the acceptance factors that had already been detected and frequently confirmed. These factors were evaluated according to the coverage of the interactive infrastructures with telemedicine centers and how accurately they fitted Germany. The identified factors were adapted, and missing factors were designed, via an idea collection for items. The reliability of the developed constructs was tested using a field test to check the constructs using item revision analysis.

Results: Frequently supported external variables, taken from 17 filtered studies covering the technical, organizational, social, legal, and individual context, were identified. However, the review showed that there was less focus on the German setting and the interactive aspect, so the market-related variables were adapted and new constructs of “trust in the telemedicine center” and “relationship to patient” were added. Ten variables were proven to have a reliability, measured with Cronbach’s Alpha, of more than 0.7.

Conclusion: This paper enhances the already existing technology acceptance studies in healthcare by covering German specifications and the interactive character of TSSs. A corresponding questionnaire has been developed ready for future research.

Background

Several societal developments make it likely that telemedicine will be an important future solution in healthcare. In particular, this potential has been enhanced by the current Sars-CoV2 pandemic, since telemedicine allows physicians to make contact with their patients while reducing face-to-face contact and controlling virus transfer [1,2,3]. Telemedicine in rural medical care and for the monitoring of the growing numbers of chronically sick persons can be an answer to the lack of medical specialists in the countryside, the demographically triggered aging population, and the increase in chronic diseases [4]. Several studies discuss the controversies in the effectiveness of telemedicine [5,6]. However, the significant potential for improving the quality of life for patients can clearly be seen [7]. For this reason, this paper focuses on Germany; on the one hand, Germany is a strongly industrialized and innovative nation but, on the other, it still faces challenges in terms of digitalization and eHealth, with a gradient from East to West Germany as well as rural and urban differences. Looking at the healthcare system in Germany, healthcare spending is the highest in Europe but, on the other hand, there is a lack of specialists and there is high mortality due to behavioral and lifestyle-influenced risks [7,8]. Looking specifically at telemedicine, Germany has seen the advantages in different past projects: for example, a reduction of the frequency of adverse events and an increase in treatment safety in cardiology and intensive and emergency care [4]. However, there are many barriers hindering full integration in the German healthcare systems, not least because of the complexity of the extensive and detailed healthcare sector. The main obstacles are unanswered issues regarding draft laws and legislation [9,10,11,12] in terms of the financing of the different services and tasks in telemedicine, IT security, and data access, as well as transparency, the enhancement of medical guidelines with digital aspects, responsibilities for the development of innovation, and the legal responsibilities of healthcare professionals (HCPs) [13]. There is no nationwide telemedicine infrastructure in Germany, and the current implementation of telemedicine shows several isolated single solutions limited by time, region, and financial support from insurance companies and industry [14].

Alongside systems and services maintained by hospitals or doctor’s offices, solutions that are integrated with telemedicine centers are conceivable [14]. This structure for the involvement of telemedicine centers is the focus of the research in this study, which concentrates on telemonitoring care in Germany. The starting point is a potential telemonitoring service system (TSS). Telemedicine means a healthcare service provided at distance using information and communication technology (ICT). Telemonitoring is defined as the control of a patient by the treating physician and a telemedicine center. The parameters that are relevant indicators are measured constantly and transferred to the center to be recorded and analyzed for diagnosis, treatment and prevention [15,16]. This system only works with patients who are remote from the physician as well as from the healthcare professionals in their interaction with the telemedicine center. In this article, interaction means the communication with the system by the patient himself, the treating physician or therapist, and the healthcare professional working in the telemedicine center as a service provider. Here, an interaction platform is defined by Ihlenburg [17] as a restricted, virtual, internet-based room offering all participants different services so that they can exchange targeted and suitable information for location- and time-independent communication. In this working scheme, acceptance by the healthcare professionals is an essential factor in the implementation of a successful program [18]

Theoretical foundations: Measurement of technology acceptance and transfer to medicine

In the literature there are many, mostly interdisciplinary, approaches to defining the term “acceptance”. Overall, there is a consensus that acceptance has different dimensions, including attitude and behavioral results [19,20,21,22]. Acceptance presents a latent construct, meaning that it cannot be measured directly and needs to be operationalized. Acceptance models describe concepts that try to shape which determinants influence acceptance and which elements are the constituents of acceptance [23]. Technology acceptance characterizes the individual’s voluntary and intentional adoption of the technology [24]. Technology acceptance research is a broad field and looks at the area of information systems. The gold standard for evaluating technology acceptance is the technology acceptance model (TAM) of Davis [23]. Davis claimed that the factors *perceived usefulness (PU)* and *perceived ease of use (PEOU)* determine attitude, and that this again influences *behavioral intention (BI)*. Further, PEOU affects PU, and PU independently affects BI [24]. The term BI describes what leads to actual use and can be understood to account for acceptance [24]. Later, during the evolution of the TAM, the model was extended in TAM 2, which removed attitude but added a variable covering social influence, with the factor known as subjective norms (SN) that directly influences PU and

BI [25,26,27,28] Venkatesh et al. [28] later investigated the unification of acceptance studies and developed the Unified Theory of Acceptance and Use of Technology (UTAUT). The most critical step was adding the *facilitating conditions* coming from the general research into IT acceptance as one determinant of BI [26,29]. The TAM has reached the gold standard, as reviews of this widely-used model have shown that the TAM is a reliable model for analyzing acceptance by individuals [25,26,30], not least because of its simplicity and clarity [31,32,33]. However, several revisions to the TAM have been proposed, and the model has been questioned; in addition, many other determinants influencing the core constructs have been tested in the past [26]. It is certainly the case that the results for the factors, relationships and effects differ by system types and users [31,34]. Looking at healthcare technology, the TAM has been the most commonly used model to study acceptance [18,35] and validated through questionnaires that are able to explain the reasons why a particular technology is used [36].

Methods

For the questionnaire construction, a literature review was conducted to collect the factors that build and influence acceptance. A frequency analysis identified the most common confirmed factors, and these were then clustered. After reviewing the content of the factor clusters, an item collection was performed to adapt and build the constructs for the German interactive healthcare context. The constructs were operationalized in statements, and the questionnaire was formed. A test of the questionnaire was conducted, and an item revision analysis checked the reliability of the constructs.

Literature search strategy

A manual literature review was performed to capture the constructs to explain the factors influencing acceptance of an interactive telemedicine structure and to check the existing studies on technology acceptance of the German healthcare system. International studies published between January 2000 and January 2020 were selected from PubMed by keywords. To ensure that the papers were of high quality, only studies that had been peer-reviewed were included. The search keywords were *telemedicine* OR *telehealth* AND *technology acceptance model*. Studies in languages other than German and English, as well as studies that did not have open access or full text availability, were not included. The review approach and findings are illustrated in Fig. 1, which follows the PRISMA guidelines for reviews [37].

Study exclusion criteria for the literature review

The following exclusions were made to produce a clear filtered pool of factors. After manually reviewing the clinical trials, qualitative research (e.g. interviews, pure literature reviews, and research on technology assessment (e.g. effectiveness and feasibility)) was excluded. Analyses of patient acceptance or acceptance by other non-healthcare target groups were not considered. Most importantly, research on the assessment of healthcare IT and on programs without interactive telemedicine aspects (by which we mean communication with a telemedicine center and/or the patient) such as documentation software, single devices, electronical patient records or general technology or information technology, was taken out. Only studies that used the TAM, UTAUT or the extension variables were considered, to remain with the core constructs and make a similar basis for the item creation, to ensure compatibility. Moderating factors, especially in terms of socio-demographics, were excluded. Out of 253 records, 17 studies were filtered out and passed the eligibility test.

Figure 1: Flow chart to show the selection criteria for the systematic literature review

Frequency analysis and clustering of acceptance factors for studies in the review

Fifty-eight different construct relationships could be identified in these 17 studies [34,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54] Only those constructs that were supported more than twice in a construct relationship were picked out. Clearly, the review shows that the core constructs from the original models, like behavioral intention (BI), impacted by attitude (ATT), and influenced by perceived ease of use (PEOU) and perceived usefulness (PU), were also identified in these studies as essential variables. Further analysis of the external variables showed that they can be clustered into five contexts [55], as set out below.

The technological context explains the handling of the system, including PEOU, and the performance impact, including PU. Next, the organizational context is covered by the facilitator variable, which describes whether there are suitable resources and a suitable environment for the clinical task and the system implementation, as well as the compatibility variable, which describes the fit to the current tasks. The facilitator factor is influenced on the behavioral level by the variable of perceived behavioral control, and these can be merged. The individual context describes the confidence and competence in handling a system, using the variable habit (HAB). The social context is covered by the subjective norms (SN) variable, which describes the influence on the user of other people. Another finding is the influence of market-related factors. The review showed that there were economic variables that were focused on financing, such as rewards in terms of financial support or compensation for medical fees [38,39,42]. Another market factor is the regulatory or legal context. In this area the perceived importance of data security (IOD) stands out as an influence on the behavioral intention [40,45,48]. However, for a comprehensive review there were several gaps. First, a view on the interaction framework and the service context variables was missing. Secondly, investigations focusing on the German market were absent. Therefore, the variables needed to be analyzed and equivalent indicator dimensions built. It was necessary to build the missing dimensions by an idea collection of items. A sufficient item pool for each construct was created. Table 1 shows the origin of the items and the definition of each construct, as derived from the analyzed studies.

Table 1
Results of operationalization: Construct definitions and scales of item dimensions

Construct	Definition	Item	Dimensions of added items from idea collection	Items and their operationalization in a questionnaire	Origin of idea for statement
Attitude	The HCP's individual positive or negative feelings about using TSS [73].	ATT1		I think positively about TSS.	[73]
		ATT2		Using TSS in patient care and management is a good idea.	[73]
		ATT3	General attitude to telemedicine	I endorse the establishment and expansion of telemedicine systems.	Idea collection of present study
		ATT4	General attitude to digitalization	Digitalization is an important topic for patient treatment in future.	Idea collection of present study
Behavioral Intention	The HCP's willingness to use the system [27].	BI1		Assuming I have access to TSS, I intend to use it.	[28,74]
		BI2		I intend to use TSS regularly.	[24, 74]
		BI3		I consider referring my clients to TSS.	[34]
		BI4		I actively integrate TSS in my patient care.	[74]
Perceived Usefulness	The degree to which the HCP believes using TSS would enhance his / her patient care and management (performance/service) [75].	PU1		Using TSS in my job enables me to accomplish tasks more quickly.	[24]
		PU2		Using TSS improves my patient care and management.	[27,74]
		PU3		Using TSS in my job increases my productivity.	[27,74,76]
		PU4		Using TSS in my job enhances my effectiveness on the job.	[27,74,76]
		PU5		Using TSS makes it easier to do my job.	[76]
		PU6		I find TSS useful in my job.	[27,74,76]
Perceived Ease of Use	The degree to which the HCP believes that using TSS is free of efforts / TSS is difficult to use [34,75].	PEOU1		Learning to operate TSS is easy for me.	[76]
		PEOU2		I find TSS easy to use.	[27,74,76]
		PEOU3		I think using TSS is easy for my patients.	[76]
		PEOU4		I find TSS to be flexible when I interact with it.	[76]
		PEOU5		My interaction with TSS is clear and understandable.	[27,74,76]
Facilitators	The degree to which the HCP believes that organizational and technical resources and environment exist to support the implementation and use of the system [28,74].	FAC1		I have the necessary resources to use the system.	[74]
		FAC2		I will use TSS if I receive appropriate training.	[45]
		FAC3		I will use TSS if I receive the necessary technical assistance.	[45]
		FAC4		Given the resources, opportunities and knowledge it takes to use the system, it is easy for me to use the system.	[74]

Abbreviations: ATT = Attitude, BI = Behavioral Intention, COMP = Compatibility, FAC = Facilitators, HAB = Habit, IOD = Importance of Data Security, PEOU = Perceived Ease of Use, PU = Perceived Usefulness, REL = Relationship to patient, SN = Subjective norms, TRU = Trust in Telemedicine Center

Construct	Definition	Item	Dimensions of added items from idea collection	Items and their operationalization in a questionnaire	Origin of idea for statement
Compatibility	The degree to which TSS is perceived as being consistent with the existing needs, values and past experiences of the HCP, who is a potential adopter of the system [76].	COMP1		Using the TSS is compatible with all aspects of my work.	[28]
		COMP2		I think that using the system fits well with the way I like to work.	[28]
		COMP3		Using the system fits into my work style.	[28]
		COMP4		The use of TSS implies major changes in my clinical practice.	[41,45, 50]
		COMP5		The use of TSS promotes my clinical practice.	[50]
Subjective Norms	The HCP's perception that most people who are important to him / her think he / she should or should not perform the behavior in question [73].	SN1		People who influence my behavior think that I should use the system.	[27, 74]
		SN2		People who are important to me think that I should use the system.	[27, 74]
		SN3		Patients welcome me using TSS.	[50]
		SN4		Other colleagues welcome me using TSS.	[50]
Habit	Degree of IT affinity and perceived competence according to the routine handling of IT [45,47].	HAB1		I have used telemedicine in the past.	[45]
		HAB2		I already use telemedicine technologies.	[45]
		HAB3		I feel comfortable with information and communication technology.	[45,47]
		HAB4		I feel comfortable with using and consulting technology for my patients in my daily business.	[45,47]
Importance of Data Security	Degree of perceived importance of security of patient data without loss of therapy quality, of ethical considerations and of transparency of information [45].	IOD1		Technical standards for the handling of patients' medical data are necessary.	[40]
		IOD2		Committing to standards for the handling of patients' medical data is necessary for my practice.	[40]
		IOD3		It is important to me to be able to inform my patients in detail about the use of their medical data.	[40]
		IOD4	Digital treatment quality	Quality definitions need to be transferred from the analog treatment into the digital world.	Idea collection
		IOD5	Legal, ethical and scientific framework	Expert associations must consider legal and ethical questions when it comes to data security, and clarify the usage of data for research.	Idea collection
Financing	Degree of monetary motivation and attitude to the responsibility of financing of TSS in the healthcare systems for patients [38,39,42].	FIN1		Incentives for physicians need to be offered for continuous and frequent use.	[42]
		FIN2	Bonus	I should get additionally rewarded for using TSS.	[42]

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Construct	Definition	Item	Dimensions of added items from idea collection	Items and their operationalization in a questionnaire	Origin of idea for statement
		FIN3	Financial evaluation of digital service	Digital services via TSS must be evaluated and paid for differently from the analog service.	Idea collection
		FIN4	Funding	The usage of TSS is particularly worthy of support in regards to funding.	Idea collection
		FIN5	Reimbursement	It is important that the cost of TSS is reimbursed for my patients.	Idea collection
		FIN6	Standard financing	TSS needs to be managed with a selective agreement (non-standard care).	Idea collection
		FIN7	Private payment	It is acceptable for patients to pay for the service privately.	Idea collection
		FIN8	Incentives	Whether TSS is paid for privately or is reimbursed via insurance should depend on the treatment.	Idea collection
		FIN9	Investment	For additional services, the cost of the initial equipment should be paid for as an investment by the doctor's office.	Idea collection
Importance of Standardization	Degree of perceived importance of conducting and recording the treatment in a standardized way without loss of quality [40].	STAN1		I am in favor of standardized documentation for medical practices.	[40]
		STAN2		In the case of standardized treatment processes, the administrative effort exceeds the medical benefits.	[40]
		STAN3		Daily work in medical practice is too heterogeneous for important processes to be standardized.	[40]
		STAN4	Evidence basis	The TSS needs to analyze data based on the evidence and to show that transparently.	Idea collection
Relationship to Patient	Degree of fear of losing contact and relationship with the patient because of changes in the means of communication and involvement of telemedicine experts.	REL1	Loss of patient	I fear losing patients as a result of TSS, because they will not need me anymore.	Idea collection
		REL2	Shift of reference point / contact loss	With TSS my patients need less help, because many things can be clarified with the center.	Idea collection
		REL3	Loss of treatment path	I fear losing control over the treatment pathway, because I will not be the first to be involved anymore.	Idea collection
		REL4	Intensity of patient relationship	The relationship with my patients will be more intensive because of the extensive support.	Idea collection
		REL5	Treatment mixture effect	The treatment mix of analog and digital will strengthen the patient–physician relationship.	Idea collection
		REL6	Compliance	The treatment adherence of my patients will increase.	Idea collection
Abbreviations: ATT = Attitude, BI = Behavioral Intention, COMP = Compatibility, FAC = Facilitators, HAB = Habit, IOD = Importance of Data Security, PEOU = Perceived Ease of Use, PU = Perceived Usefulness, REL = Relationship to patient, SN = Subjective norms, TRU = Trust in Telemedicine Center					

Construct	Definition	Item	Dimensions of added items from idea collection	Items and their operationalization in a questionnaire	Origin of idea for statement
		REL7	Accessibility of patients	With TSS I will have better contact with all my patients, no matter how far away they are.	Idea collection
		REL8	Reachability of patients	I will have a better connection to patients who visit me rarely.	Idea collection
Trust in Telemedicine Center	Degree of personal trust in the contact person at the telemedicine center as well as organizational trust that the center itself will treat the HCP's patients as required and in accordance with the standards [66,67]	TRU1	General trust	Generally, I can trust other people.	[67]
		TRU2	Certification of service center	I trust a certified service center that consults my patients.	Idea collection
		TRU3	Trust in other HCPs	I feel good about patients being monitored / treated by another therapist / physician.	Idea collection
		TRU4	Constancy in contact	It is important to me to have a fixed contact person at the center.	Idea collection
		TRU5	Personal contact	It is important to me to have personal contact with the experts providing the treatment, in advance.	Idea collection
		TRU6	Loss of treatment control	I fear that a colleague would treat a patient differently.	Idea collection
		TRU7	Information asymmetry	I fear that I will not be able to provide all the information to my patient in time.	Idea collection
		TRU8	Standard processes	I like to be informed beforehand about standard processes and algorithms.	Idea collection
Abbreviations: ATT = Attitude, BI = Behavioral Intention, COMP = Compatibility, FAC = Facilitators, HAB = Habit, IOD = Importance of Data Security, PEOU = Perceived Ease of Use, PU = Perceived Usefulness, REL = Relationship to patient, SN = Subjective norms, TRU = Trust in Telemedicine Center					

Adapting variables in the context of the German healthcare environment

Diseases like cardiovascular disorders (which take the biggest share of medical expenses and have the highest mortality) and pulmonary disease, as well as diabetes (which has the highest increase in prevalence) impact heavily on the German healthcare system [56,57]. Thus, a crucial influence when choosing the relevant item dimensions to fit the German context were the statements on telemedicine and digitalization made by the German diabetes association (DDG) [58], the German association of cardiology (DGK) [14], and the German association of pneumology (DGP) [59]. These position papers are addressed to the political situation and are considered in the legislative procedure. All the parties involved are working intensively on telemedicine topics.

Taking these statements into account, a call for clarity on the financing of treatments was noted throughout [14,58,59,60]. For this reason, the ideas of Hwang et al. (2014) were extended by further items. It was assumed that the financial evaluation of a digital service compared to an analog service (see item FIN3) is an influencing factor (Ickarth 2018). Specific to German healthcare is the question of including the service in the standard financing of care (see item FIN6). The payment scheme (see item FIN5) for patients is also unclear: the scheme needs either to be paid for privately (see item FIN7) or to be covered by reimbursement from insurance (see item FIN8) [61]. Lastly, the funding (see item FIN4) for the specific cost of implementation in a medical facility (see item FIN9) could possibly be an influencing factor [58]. One other field for action mentioned in those position papers is the importance of developing digital standards to ensure high-quality patient care [14,58,59,60]. The items concerning the importance of standardization were oriented using the ideas of Dünnebeil et al. [40]. One item regarding the development of evidence-based standards (see item STAN4) was added. Along with the requirements for technical standards and for transparency towards patients in relation to data handling, the mandatory adherence to the principles of data management was consistently mentioned. In this context two other items were added to the section on the importance of data security, to cover assurance of the treatment quality (see item IOD3) in the digital environment and the responsibility of associations to discuss the legal, ethical and scientific framework for the data (see item IOD4) in such service systems [58].

Adding new variables in the context of the interactive telemedicine structure

When it comes to an interactive system, with the patient and the healthcare professionals in the telemedicine center as additional players, fewer studies have concentrated on this new mode of communication, which might be a determinant of the behavioral intention of a physician. On the one side, the change in communication might mean that the relationship to the patient changes and the responsibilities for the treatment decisions and pathway need to be adapted. This becomes important because patients become better informed and the physician-patient relationship changes accordingly [58]. On the other side, new methods of communication with medical colleagues in the telemedicine center can be seen. Looking into the literature, aspects of this digital collaboration

emerge that are similar to those for eConsult platforms (exchange of knowledge about patient cases between HCPs via a digital platform). These aspects were considered for the development of this dimension [62,63]. When dealing with interactions between people, trust is an important form of social capital [64,65,66]. Consequently, two new constructs – “relationship to patient” and “trust in the telemedicine center” – were built. It is assumed that the perceived change in the patient relationship is determined either by the fear of losing the patient and losing control of the clinical treatment pathway (see items REL1 and REL3) because of the involvement of another healthcare professional at the center (see item REL2), or by the hope of strengthening the patient relationship (see item REL4) because of increasing contact points in the mixed analog and digital communication (see item REL5). The quick monitoring of inaccessible (see item REL7) and immobile patients (see item REL8) can be seen as an advantage for the patient–physician relationship. The goal would be to increase the treatment adherence (compliance) of a patient (see item REL6) [58,62].

Trust in the telemedicine center is assumed to be regulated by general trust (see item TRU1), following the model originally proposed by Yamagashi and Yamagashi [67]. Trust can also be created by certification (see item TRU2) and standard processes (see item TRU8), as well as by fixed and stable personal contacts (see item TRU4) with the HCPs involved (see item TRU5), which can be described as institutional trust (see item TRU3) [65]. Also, distrust can appear when there is the fear of losing control of the treatment (see item TRU6) or of not getting sufficient information when passing on responsibility to colleagues (see item TRU7) [62,63].

Thus, for the completely new variables TRU and REL, more than eight items were developed in order to produce a set that could undergo item revision after the field testing. The operationalization was framed by the wordings from the original TAMs that had already been established and validated, and from the most commonly used scales in the reviewed studies, to pick out formulations for the medical context [68]. A minimum of four items were defined as the indicators for each construct. The construct for attitude was therefore extended to cover the aspects of the generic attitudes to general telemedicine (see item ATT3) and digitalization (see item ATT4).

The corresponding statements were then translated into German (see Additional File 1). The field test assessed possible distortions or difficulties in comprehension, and the German wording for BI, PEOU, PU and SN was aligned with the corresponding proposals [69]. The participants were asked to rate the statements on a 5-point Likert scale from strongly agree (5) to strongly disagree (1), as in the original TAM approach [24]. Before the respondents were asked to undertake the rating and were given instructions for the questionnaire, a TSS was described in general terms to give them an idea of the functionality and method of interaction with such a TSS system and service offering (see Additional File 2). At the end of the survey the respondents were asked for personal data.

Table 1 Results of operationalization: Construct definitions and scales of item dimensions

Test of questionnaire and construct analysis

The test period started in the second week of March and lasted for four weeks; it thus happened during the first weeks of the growing outbreak of the Sars-CoV2 epidemic in Germany. The questionnaire was distributed online with the help of the market research institute Quopinon, which sent it to 62 volunteers from their database. SPSS (IBM Watson Studio Desktop & SPSS Modeler and Statistics Version 26) was used for the statistical analysis of the items to evaluate all constructs. Cronbach’s Alpha was measured to test the reliability of each construct and its internal consistency. The goal was to end up with between four and six items for each construct with an acceptable Cronbach’s Alpha above 0.7. Items were eliminated to achieve a reliability improvement higher than 0.5. In total, 40 datasets were included. The age distribution of the participants was between 21 and 63, with an average age of 40 years. 35% of the participants were male, 63% were women and one participant answered other. Most of the respondents (75%) worked in an employment relationship, with 22 working in a doctor’s office, 17 in a clinic and one in another institution. The healthcare professionals worked in different medical disciplines: most in physiotherapy or psychology, and some in general medicine with a focus on nutrition/diabetes.

Results

Table 2 shows the reliability analysis of the constructs. All the constructs except STAN showed a high reliability after necessary amendments for COMP, FIN, REL, and TRU. After removing particular items, the total reliability shows a Cronbach’s Alpha of 0.914. As a consequence of the item revision analysis, the construct of the importance of standardization was removed, because the internal consistency was lower than 0.7. A separate analysis for the more experienced participants (those aged above 30 years) also showed only a slightly higher reliability of 0.386.

Table 2
Reliability analysis after the test: Item elimination for Cronbach's Alpha amendment of each construct

Construct	Cronbach's Alpha of the construct before item revision	Items eliminated	Cronbach's Alpha of the construct after item revision	Items remaining	Cronbach's Alpha of construct if item were deleted
Attitude	0.784	None	0.784	ATT1	0.682
				ATT2	0.653
				ATT3	0.757
				ATT4	0.799
Behavioral Intention	0.783	None	0.783	BI1	0.704
				BI2	0.648
				BI3	0.836
				BI4	0.685
Perceived Usefulness	0.875	None	0.875	PU1	0.843
				PU2	0.857
				PU3	0.851
				PU4	0.829
				PU5	0.885
				PU6	0.856
Perceived Ease of Use	0.806	None	0.806	PEOU1	0.764
				PEOU2	0.723
				PEOU3	0.779
				PEOU4	0.789
				PEOU5	0.780
Facilitators	0.751	None	0.751	FAC1	0.852
				FAC2	0.646
				FAC3	0.661
				FAC4	0.633
Compatibility	0.346	COMP5 removed	0.751	COMP1	0.771
				COMP2	0.559
				COMP3	0.666
				COMP4	0.742
Subjective Norms	0.760	None	0.760	SN1	0.756
				SN2	0.627
				SN3	0.736
				SN4	0.687
Habit	0.731	None	0.731	HAB1	0.672
				HAB2	0.655
				HAB3	0.698
				HAB4	0.633
				HAB5	0.742
				HAB	0.735
Importance of Data Security	0.713	IOD4 removed, as improvement is > 0.5	0.763	IOD1	0.637

Abbreviations: ATT = Attitude, BI = Behavioral Intention, COMP = Compatibility, FAC = Facilitators, HAB = Habit, IOD = Importance of Data Security, PEOU = Perceived Ease of Use, PU = Perceived Usefulness, REL = Relationship to patient, SN = Subjective norms, TRU = Trust in Telemedicine Center

Construct	Cronbach's Alpha of the construct before item revision	Items eliminated	Cronbach's Alpha of the construct after item revision	Items remaining	Cronbach's Alpha of construct if item were deleted
				IOD2	0.667
				IOD3	0.764
				IOD5	0.761
				FIN1	0.680
				FIN2	0.637
Financing	0.466	FIN5, FIN1, FIN4, FIN2 removed	0.691	FIN3	0.637
				FIN4	0.603
				FIN5	0.637
				STAN 1–4	none
				REL4	0.728
Importance of Standardization	0.345	No improvement possible	eliminated	REL5	0.580
				REL6	0.699
				REL7	0.663
				REL8	0.724
				TRU4	0.516
Relationship to Patient	0.432	REL1, REL2, REL3 removed	0.729	TRU5	0.666
				TRU6	0.650
				TRU7	0.696
Trust in Telemedicine Center	0.565	TRU3, TRU2, TRU1 removed	0.700		
Abbreviations: ATT = Attitude, BI = Behavioral Intention, COMP = Compatibility, FAC = Facilitators, HAB = Habit, IOD = Importance of Data Security, PEOU = Perceived Ease of Use, PU = Perceived Usefulness, REL = Relationship to patient, SN = Subjective norms, TRU = Trust in Telemedicine Center					

Table 2 Reliability analysis after the test: Item elimination for Cronbach's Alpha amendment of each construct

Discussion

The difficulty in the implementation of telemedicine is the consideration of the complexity of all mandatory settings. All the named burdens and drivers may influence the acceptance of this possible user group. Many studies have investigated patient acceptance [70], which seems insufficient on its own for this system interaction, as only a little is known about HCPs' acceptance. In this context, the treating healthcare professional is the initiator of the treatment and has the main responsibility for the medical care. Thus, it is critical to analyze the attitude of the treating HCP, who is the gatekeeper to the TSS [71]. Therefore, a glance at the technology acceptance research was needed to identify the relevant determinants for acceptance. The literature review shows the constructs of the external variables, covering the technical, organizational, social, legal, and individual context, that have been frequently supported, but only one study focused on the German healthcare market [40]. This made it necessary to adapt the constructs to the regional conditions in terms of the financial and legal aspects. Additionally, the literature review identified a gap in the consideration of the aspect of the interaction and cooperation with telemedicine centers and the active involvement of the patient, so that two new constructs, "trust in the telemedicine center" and "relationship to patient", were necessary to map out these structures. The test analysis confirmed the robust quality of ten acceptance constructs and a high reliability in total. Nevertheless, the proof of reliability needs to be replicated in further investigations and the variable STAN needs to be explored again. Several test participants mentioned in the free text option that the acceptance also depends on the opinion and ability of the patients. There needs to be an investigation into whether the attitude of the patients is also an important factor affecting the behavioral intention to use a TSS.

Since the focus on the healthcare professional and the required interactivity was missing from the literature, as was a German setting, this should be a special point in future research.

Limitations

There are several restrictions to the generalization of the findings. The literature review shows a high heterogeneity in studies of healthcare settings and disciplines regarding data analysis as well as the medical and regional focus. Nationwide studies focusing on single settings and areas need to be conducted to check on possible commonalities and differences. The review was limited to PubMed, so this research could only validate the reliability of the constructs for this selected variable set, but it drew a first picture of the relevant factors. Different data collection techniques and exploratory approaches to sharpen the factors are recommended. The new constructs have not yet been tested regarding their possible relationships with other variables and their significance for a TSS setting, and this requires exploratory factor analysis.

Further, the test only included a limited set of treating HCPs, who might also have been influenced in their health area and profession by the Covid-19 situation, which made changes to communication with patients necessary.

The test described an example TSS which leads to a prognosis issue; subsequent research on the dynamic time measurement of technology acceptance is needed [19,54].

Conclusion

Understanding the complexity of the factors influencing the acceptance by HCPs of the German telemonitoring market is crucial. This study developed a conceptual framework by identifying and designing multifaceted variables and operationalizing them in the validated questionnaire. This delivers a robust foundation that can be transferred into specific medical disciplines and professions in which telemonitoring systems with an involvement of telemedicine centers are considered. Furthermore, the factors of “relationship to patient” and “trust in telemedicine center” are a new basis for capturing the interaction of such TSS infrastructures. The adapted and new constructs were optimized through the testing and reached an acceptable reliability for further research. However, the results need to be combined with the attitudinal perspective of patients to pick up all relevant players in the system.

There is a great need for further research on German HCP acceptance in telemedicine, to provide evidence to identify the barriers and the potential, which will lead to a statement of the requirements of technology, legislation and financing of telemedicine structures in Germany for providers and policy, especially from the professional society view. This understanding is essential to develop the appropriate conditions for such complex programs and to close the existing gaps. Last but not least, the Covid-19 crisis and the first reaction to ease telehealth financing in Germany [72] shows the urgency and relevance of this topic.

Abbreviations

ATT

Attitude

BI

Behavioral Intention

COMP

Compatibility

DDG

Deutsche Diabetes Gesellschaft (German diabetes association)

DGP

Deutsche Gesellschaft für Pneumologie (German association of pneumology)

DGK

Deutschen Gesellschaft für Kardiologie (German association of cardiology)

FAC

Facilitators

HAB

Habit

HCP

Healthcare professional

ICT

Information and communication technology

IT

Information technology

IOD

Importance of Data Security

PEOU

Perceived Ease of Use

PU

Perceived Usefulness

REL

Relationship to patient

SN

Subjective norms

TAM

Technology acceptance model

TRU

Trust in Telemedicine Center

TSS

Telemonitoring service system

UTAUT

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The author declares that she has no competing interests.

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Authors' contributions

This study is a research part of the PhD dissertation of the author, who wrote the paper on her own.

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81. Additional file 1 Text. Introductory text for the questionnaire, in English.
82. Additional file 2 Table. German translation of the items used in the questionnaire for the field test.

Figures

Figure 1

Flow chart to show the selection criteria used in the systematic literature review

Supplementary Files

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- [SupplementaryMaterial1Text.docx](#)