Needs, Functions, and Technologies of Technical Assistance Systems in Nursing Context: A Systematic Review

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Abstract: Due to the ageing of society, health insurers and care sectors in many Western countries are facing major challenges. Technical Assistance Systems (TAS) could have the potential to ease the situation, while at the same time promoting the independence and self-determination of care-dependent people. However, TAS have not yet been fully established in nursing. Reasons for this include an inadequate systematisation of the research and development area and the lack of uniform terminology, which leads to poor comparability and thus to missing financing models. To tackle this condition and help to select functions and technologies based on needs, we conduct a systematic review identifying needs, functions, and technologies as areas of interest addressed in 50 evaluated TAS approaches. Further, this work assesses gaps in TAS research and aims to create a uniform understanding of assistance functions.

1 INTRODUCTION

An increasing average life expectancy (Destatis, 2019), combined with an ageing population (Nowossadeck, 2013; Peters et al., 2010), are central challenges for many Western countries. The nursing rate and the care costs both increase disproportionately strong with an increasing prevalence of age-related diseases. Due to the baby boomers' retirement over the next years, a decreasing working population must face an increasing workload as well as increasing costs in the nursing sector (RKI & Destatis, 2015).

Technical Assistance Systems (TAS) are mentioned as a promising approach for coping with this trend in the 2015 health report by the *Robert Koch Institute* (RKI) and the *German Federal Statistical Office* (Destatis). TAS are expected to have great potential to strengthen the independence and self-determination of care-dependent people as well as to relieve caring relatives and caregivers (RKI & Destatis, 2015). TAS can be understood as technical aids for supporting care-dependent people at home and in inpatient care facilities regarding health-promotion, preventive, curative, rehabilitative, and palliative care (Lutze et al., 2019). However, there is no common definition for TAS, usually also referred to as *Health Smart Homes* (HSH; Wollschlaeger & Kabitzsch, 2019), *Ambient Assisted Living*- (AAL), and *Assistive Living-Technologies* (Elsbernd et al., 2012), or *Assistive Devices* (Marasinghe, 2016; Steel et al., 2009). TAS can support various aspects of care- or support-dependency (see Figure 1) in a psychological, physiological, or health-related manner, affecting care-dependent people's autonomy, participation, safety, or quality of life positively (Lutze et al., 2019). In TAS, technologies are used to provide assistance functions (hereinafter referred to as *functions*) according to user needs and requirements (Wollschlaeger & Kabitzsch, 2019). Thus, the suc-cess of TAS does not only require their availability at acceptable costs but also the selection of functions and technologies that are adapted to the needs and requirements of potential users (Karlsson et al., 2011; McCreadie & Tinker, 2005; Weiß et al., 2013).

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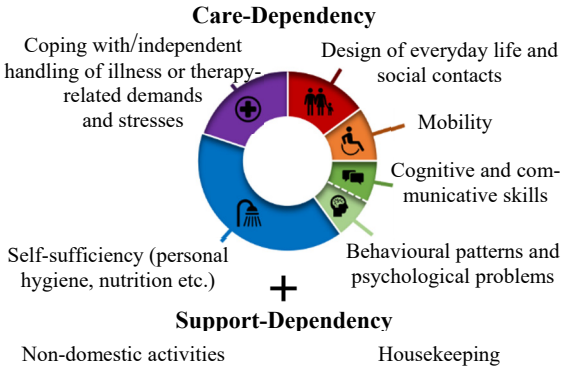

Figure 1: Aspects of care and support dependency, defined in the new assessment instrument of German social long-term care insurance from 2017 (Pick et al., 2019).

However, even though TAS are expected to have the potential for supporting activities in the nursing context, they have barely gained acceptance to date (Lutze et al., 2019). Two reasons for this are the inadequate systematisation of the broad and interdisciplinary research and development area of TAS and the lack of a uniform terminology, which leads to poor comparability. As a result, very few development projects are brought to market as mature and affordable TAS, subsidised from longterm care insurance (Kunze & König, 2017; Weiß et al., 2013).

With this paper, we intend to help innovative TAS projects to bridge the gap between being an innovation and a market-ready solution. To this end, we tackle the missing systematisation of the research and development area of TAS by conducting a systematic review identifying needs, functions, and technologies as areas of interest addressed in evaluated TAS approaches.

This paper provides the following main contributions: i) An *analysis of the current state* in TAS research concerning functions, addressed needs, and used technologies, which ii) *provides guidance* for new TAS projects to facilitate a needs-based selection of functions and technologies, and iii) an *assessment of existing gaps* in TAS research.

The remainder of the paper is organised as follows: The next section introduces the method and section 3 the findings of the literature review. Subsequently, section 4 discusses the results in the context of related research. Section 5 concludes the paper with a summary and potential further research.

2 METHOD

Three aspects represent the core of this article, assistive technologies, their functions, and needs related to them. To identify all three aspects, a systematic literature review was conducted. We searched across the three databases PubMed/Medline, Academic Search Elite (EBSCOhost), and Web of Science, the former covering studies in the medical field, the latter two – as these are interdisciplinary databases – covering diverse fields not included in PubMed. Relevant search terms were identified and combined; synonyms were tested for results. The final search string combines a search for requirements (incl. synonyms such as "need") of assistive technologies (incl. synonyms such as AAL, HSH) with a care (and relevant synonyms) context. Applying the search string in the three databases in July 2020 yielded 1,559 results.

After removing duplicates, titles and abstracts of 1,218 records were screened. During the screening, those records were included, where hardware components of the technology were described, the system reported was already validated and the target group were adults. Records were further excluded if no needs or functions were named, or the study described an assistance system that was already described more comprehensively in other studies included. Only peer-reviewed journal papers in English or German language were included. No time restrictions were applied. After excluding 1,025 records, which did not meet the inclusion criteria, 193 records were further assessed regarding their eligibility by reading the full-text articles. The inclusion criteria reported above were again applied.

Finally, 50 studies were included for qualitative content analysis according to Mayring (2015). The goal was to extract information about the assistive technologies, their functions, and needs related to them. For identifying assistive technologies and their functions, no pre-defined categories were applied, but categories were built inductively. The needs of people involved were initially categorised deductively, i.e. based on pre-defined categories, namely the aspects of care and support-dependency, defined in the new assessment instrument of German social long-term care insurance from 2017 (Pick et al., 2019), and described above (see Figure 1). The existing categories were further refined by additional inductive categories. Also, superior categories were identified to further cluster the results of all three aspects.

3 RESULTS

3.1 Target Groups

The analysis of the 50 articles showed that TAS are being developed for many different target groups (see

Table 1), mainly older people (26 out of 50) or people with typical age-associated diseases, such as Parkinson's (2 out of 50), or Dementia and/or mild cognitive impairment (MCI; 14 out of 50).

Table 1: Quantity of target groups, addressed in the research and development process of TAS in the articles examined.

Target Group	Quantity
Elderly	26
Cognitive Disordered (mainly Dementia and MCI)	15
Third Parties	11
Movement Disordered	4
Cognitive and Movement Disordered (e.g. Parkinson's)	3
Increased Risk for Diseases	2
Visually Impaired	2
Verbal and Communication Impaired	1

3.2 Functions

The TAS functions presented in the 50 articles can be divided into six inductively formed categories (F1 – F6; see Table 2). These include the *manual emergency call*, which is consciously triggered by the user's action and serves to call for help, as well as the *status monitoring* function, which enables self- or external monitoring of a condition (indoor/outdoor position, health, sleep) and, if necessary, the triggering of an automatic emergency call. *Activity monitoring* includes TAS that monitor the user's activities to map daily activities, detect anomalies (falls, behaviour disruption, wandering, seizures). The *environmental monitoring* function describes the ability of a TAS to monitor the user's surroundings to identify emergencies or sources of danger. Both, the activity, and the environmental monitoring can, if necessary, trigger follow-up actions. *Therapy*/*activation*-functions aim to positively influence people's behaviour or their mental and physical health, e.g. by supporting therapies or providing targeted information and recommendations. TAS supporting users in their everyday life were subsumed under the *Assistance* function.

Note that a TAS can have several functions, which can be assigned to either one or more categories.

3.3 Functions and Technologies

In addition to the functions of the TAS, the technologies used to implement these functions were identified and divided into inductively formed categories (T1 – T4): *mobile security alarm*, *sensors*, *interfaces*, and *robots*. Again, multiple technologies can be used in a single TAS to implement one or more functions.

As illustrated in Table 2, sensors were by far the most frequently used technology, followed by interfaces. The most common sensors (mainly used for monitoring) are environmental sensors, while the most common interfaces are tablets and smartphones. Interfaces are primarily used for therapy/activation and assistance functions. In case of therapy/activation they are often combined with environmental sensors or cameras, e.g. for monitoring the execution of exercises, providing feedback, or monitoring progress (Pastorino et al., 2014). Although, robots were rarely applied, they can be used for realising functions from nearly all categories.

3.4 Functions and Needs

The need categories (N1 – N12) include the aspects of care- and support-dependency mentioned before (see Figure 1) as well as the inductively built categories *safety*, *autonomy*, *health,* and *third-party needs* (see Table 2). The satisfaction of safety, autonomy, and health needs are by far the most common goals of TAS. In contrast, only a few TAS address housekeeping, self-sufficiency, behavioural and psychological problems, or activities outside the home.

TAS with activity monitoring often additionally address the needs of third parties, as they allow the detection of various anomalies, such as behavioural disorders, and thus facilitate care work (Corno et al., 2017) or bring peace of mind to relatives (Mitchell et al., 2020). TAS with therapy/activation functions, in addition, often address the need for coping with illness and/or therapy-related burdens.

Cognitive and communicative needs are almost exclusively focused on by TAS with therapy/activation functions. The main aim here is to influence care-dependents' clarity and memory (e.g. Kerssens et al., 2015) or to give them the ability to communicate their needs (Bozomitu et al., 2019). Behavioural and psychological problems are only addressed by functions from the field of therapy/activation which aim to positively influence the behaviour of the person in need of care and thus create a system to support emotional self-regulation (Torrado et al., 2017) or to prevent falls (Paul et al., 2017). Needs from the area of self-sufficiency are only addressed by two TAS, which are designed to support independent food intake (by using reminders, Borelli et al., 2019) or automatic climate regulation (Hudec & Smutny, 2017).

Table 2: Mapping between functions and the addressed needs of care-dependent people and the technologies used. *Legend: If a value is greater than 1.5 times the mean value of a column, i.e. that a function was implemented particularly frequently in combination with a certain technology, it is highlighted in green. Values greater than 1.5 times the mean value of a row, i.e. the corresponding technology is used particularly frequently for a special function, are highlighted in blue. If both are true, the value is highlighted in grey. The highlighting was also provided for the technologies' sub-categories (lighter colours, which represent the same colour scheme). Since a single TAS can have several functions, combine several technologies and address multiple needs, the column and row totals do not match the total number of TAS per category.*

			Functions					
			F1	**F2**	**F3**	**F4**	**F5**	**F6**
			Manual Emergency Call	Status Monitoring	Activity Monitoring	Environmental Monitoring	Therapy/ Activation	Assistance
			7	**18**	**25**	**8**	**18**	**13**
Technologies								
T1	**Mobile security alarm**	**1**	1	1				
T2	**Sensors**	**42**	3	15	24	6	11	4
T2.1	*Environmental sensors*	*24*	*1*	*7*	*1*	*5*	*4*	*3*
T2.2	*Smart objects*	*12*	*1*	*3*	*7*	*1*	*1*	*1*
T2.3	*Smartphone sensors*	*5*		*2*	*2*		*3*	
T2.4	*Audio sensor*	*3*				*1*	*1*	*1*
T2.5	*Camera*	*9*	*2*		*3*		*5*	*2*
T2.6	*Smart wear*	*4*		*3*	*2*			
T2.7	*Medical measuring device*	*5*		*5*			*1*	
T2.8	*Smartwatch sensors*	*3*			*1*		*2*	
T3	**Interfaces**	**24**	4	3	2		15	9
T3.1	*Computer*	*5*	*1*				*5*	*1*
T3.2	*Smartwatch*	*5*	*2*				*3*	
T3.3	*Smartphone*	*6*	*2*	*2*			*3*	
T3.4	*Sound player*	*5*			*2*		*2*	*2*
T3.5	*Tablet*	*6*	*2*	*1*			*3*	*5*
T3.6	*SmartTV*	*2*					*2*	*1*
T3.7	*Braille*	*1*						*1*
T3.8	*Telephone*	*1*					*1*	*1*
T3.9	*Haptic actuator*	*1*					*1*	
T4	**Robots**	**4**		1	1	1	2	3
Needs								
N1	**Mobility**	**8**	1	1		1	4	3
N2	**Cognitive and communicative**	**8**	1		2	1	5	2
N3	**Behavioural and psychological problems**	**2**					2	
N4	**Self-sufficiency**	**2**						2
N5	**Coping with illness and/or therapy-related burdens**	**10**			2		7	2
N6	**Everyday life and social contacts**	**9**	1	2	2		3	4
N7	**Activities outside the home**	**3**	1	1	2			1
N8	**Housekeeping**	**1**			1	1		
N9	**Safety**	**22**	5	10	15	5	3	5
N10	**Autonomy**	**21**	4	10	10	4	8	5
N11	**Health**	**24**	2	10	8	1	10	7
N12	**Third-party needs**	**11**	1	4	8	1	1	1

4 DISCUSSION

4.1 Focus on Potential Users

The majority of the TAS is aimed at the elderly or people with age-related diseases. This means that functions from the monitoring areas predominate as they are preferred to enable older people to live as autonomously as possible in their own homes. On the contrary, functions from the assistance area are underrepresented as they are preferably aimed at other target groups, such as communication support systems for people with communication problems (Hudec & Smutny, 2017) or systems for self-regulation for autistic people (Torrado et al., 2017). This implicates that the spectrum of functions that are typically used in connection to older people, their needs, and the technologies necessary for implementation, is significantly more representative than for other target groups and the TAS in these categories are over-represented. Since (caring) relatives and medical or nursing specialists are often the main users of the TAS, and not the care-dependent people themselves, the needs of these third parties also need to be considered.

4.2 Standardisation of Functions

To assess the pervasion of TAS functions from research to practice, we compared the functions identified in this review with categories of functions already included in standardisation. A taxonomy of standardised functions, which has been collated in Wollschlaeger & Kabitzsch (2019), is depicted in Figure 2. The TAS functions identified in this work have been mapped with the categories of the taxonomy as indicated by colour[1] in Figure 2. It is apparent that, in research, the TAS functions mainly focus on the safety and security aspects, esp. on the category "Protection of Health" (F1 – F4, F6). Another area of emphasis can be found in the categories "Communication & Multimedia" (some aspects of F5) as well as "Fire and Average Protection" (F4). Interestingly, most TAS functions for exercise and for influencing behaviour (F5) are not represented in the taxonomy. This might be due to them being quite recently developed use cases that have not yet been established and introduced in the standardisation process.

Aspects such as "Usability" and "Intrusion Protection" are covered by standardisation, but are mostly not in the focus of research as well as many functions from the "Smart Home" category. An explanation for this might be that research papers that focus on these aspects might have been excluded due to missing validation. However, the differences between TAS research and standardisation indicate that for successful TAS in practice, a more holistic view is required, including re-use of existing technical equipment and functionality.

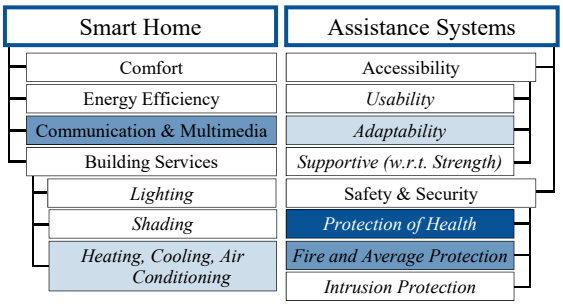

Figure 2: Taxonomy of functionality categories contained in standardisation, adapted from Wollschlaeger & Kabitzsch (2019). The categories found in the systematic review are indicated by colour.

4.3 Meeting User Needs

The results of our review suggest that all needs derived from the new assessment instrument of German social long-term care insurance were addressed by the functions of TAS in the examined papers. The focus of the investigated TAS seems to be the safety-, autonomy- and health-related user needs. Our study shows that there is a lot of catching up that has to do with TAS, which address behavioural and psychological problems or support self-care, activities outside the home, and housekeeping for care- or support-dependent people.

To put our results about user needs into perspective, they can be compared with the coverage of needs identified by Lutze et al. (2019) in their literature review on TAS-users' benefits. In contrast to us, Lutze et al. (2019) define autonomy as a super-category for the modules of the new assessment instrument. Both Lutze et al. (2019) and we have included safety as an additional category. In total, a trend similar to ours regarding the relative frequency of needs is emerging. Lutze et al.'s (2019) results also confirm that few TAS are developed, which address behavioural and psychological problems or support self-care, activities outside the home, and house-keeping.

In their comparison of the requirements for TAS for cognitively impaired people with current research approaches, based on a scoping review, Blackman et

[1] darker colour represents TAS functions being mapped more frequently to a category

al. (2016) criticise the often-prevailing understanding of "need", which leads to a failure of the actual purpose of TAS. According to Blackman et al. (2016), many TAS focus on physiological needs with the goal of relieving medical and social resources, and needs are often misunderstood as deficits, illnesses, or dependencies. Thus, the aim of TAS to assist the elderly in living an autonomous and dignified life and to remain included in the society is often neglected. This contradicts this work's results, which found that most of the examined studies feature TAS with a focus on the autonomous life of older people in the home environment or on maintaining a social life.

Furthermore, Blackman et al. (2016) criticise that the majority of the publications analysed lack theoretical underpinnings of TAS. Since we had to exclude 37 articles due to missing information on the addressed user needs, we can partially confirm this criticism. A lack of references to needs in the research and development of TAS has also been frequently reported in previous research (Biniok & Lettkemann, 2017; Choi et al., 2019; Nagapuri et al., 2019). This is another barrier for the adoption of TAS in practice, as the focus on user needs is important for TAS to be accepted by potential users and thus prevail on the market (McCreadie & Tinker, 2005).

4.4 Technology Requirements

Requirements (additional to the needs) for the TAS should be determined and matched with technologies that meet these requirements best regarding the target group or the individual. Elderly people e.g. often have problems in operating smartphones (Costa et al., 2015) due to the small displays (Paul et al., 2017). User acceptance of TAS that record video or sound is often low (Gerka et al., 2019; Tunca et al., 2014) as users feel restricted in their privacy and are concerned about personal data. This is also reflected in the low number of TAS using cameras for monitoring purposes. For sufficiently high reliability of activity, environment, or status monitoring systems, a larger number of sensors is often necessary, which in turn increases the costs and the energy consumption of the TAS, and potentially harms the privacy of the users (Grgurić et al., 2019). In general, TAS and the technologies used should, among other things, be characterised by aspects such as reliability, robustness, the protection of privacy, the security of private data, a low environmental impact, and low costs (Borelli et al., 2019; Grgurić et al., 2019; Nazemzadeh et al., 2015; Tunca et al., 2014). This is especially challenging when using sensor networks or modern internet and cloud-based services (see Addante et al., 2019).

Similar to the area of functions, the technical perspective and the increasing importance of a person's home for health care (Haux et al., 2016) advocates for an additional, more holistic perspective on HSH. Maeder and Williams (2017) view HSHs as systems-of-systems and capable of becoming part of a health services continuum. To this end, they encourage to also shift the development strategy from a bottom-up manner to an overarching approach. Considering HSHs as systems of systems will most likely become more relevant in the future as technology becomes more mature and available as off-the-shelf components so that utilising the existing residential infrastructure or devices (such as entertainment or home automation appliances) for health benefits seems promising. In this context, the importance of integration and interoperability standards as open challenges for HSHs are underlined by researchers such as Memon (2014), Haux et al. (2016), or Maeder and Williams (2017). This is in line with our observations that a more holistic view of TAS is required for them to be used in practice.

4.5 Limitations

Conducting a systematic literature review is always limited by a certain subjectivity of the process. Applying other search strings or using other databases could have led to different results. The in- and exclusion process is subjective as well as the qualitative content analysis. Furthermore, the process of selecting relevant literature was only carried out by one author. Thus, no statement can be made on the reliability of the results, as provided by Mayring (2015) in the form of calculating intercoder reliability.

No quality assessment of the articles analysed took place. Rather, the selection of the TAS should depend on the functional efficiency of the TAS.

The number of TAS presented in the literature reviewed varies greatly across the various categories for functions, needs, and technologies, so that the frequencies presented in this work should be interpreted carefully. Since, e.g., monitoring functions were most frequently integrated into the investigated TAS, needs addressed by these functions may be overrepresented.

5 CONCLUSION

The purpose of this paper was to summarise the situation in the broad and interdisciplinary research area of TAS to overcome their missing systematisation. Therefore, we conducted a systematic literature re-

view of 50 mature TAS and created a mapping between functions, implementation technologies and addressed user needs. The focus of the examined TAS lies on assistance systems that are intended to enable elderly people or people with dementia to live an autonomous and dignified life in their home environment. To this end, sensor technologies are the most common technology used. The large variety of addressed needs implies that individual TAS will often be used in combination with other TAS or appliances.

Our results support the demand for a more holistic view of TAS as meaningfully networked technologies to create an interoperating system for a specific context instead of many individual systems. Therefore, the interoperability and integrability of technologies must be considered, while simultaneously examining user requirements. Future work should adopt a view on requirements based on a resource-focused mind set (e.g. WHO ICF classification of Functioning, Disability and Health[2]), rather than a deficit-oriented perspective. To overcome the confusion in this research field, it is furthermore important to strive for a uniform understanding of assistance functions in future work. By offering an analysis of the current state and guidance for further research and development projects, this paper contributes to this understanding.

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