Trust in Ambient Assisted Living (AAL) - A Systematic Review of Trust in Automation and Assistance Systems

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***Abstract*—The aim of the study was the investigation of the existing literature dealing with trust in Ambient Assisted Living (AAL). Additionally, a definition of trust in AAL was derived. For that purpose, a numeric analysis of articles considering the factor trust in automation, as well as assistive technologies for older people was carried out. A systematic literature review with a total of 150 dissimilar keyword-combinations, based on three different descriptors in three bibliographic online databases, was performed. This review revealed that 18 articles deal with trust in healthcare or assistance systems, but several of them only superficially. Despite the increasing market relevance in the last decade, none of the identified studies focused explicitly on trust in AAL. As can be seen from the results, older people as a target group for qualitative and quantitative research in this field are detected, but only partially examined. For obtaining access to older persons' trust in automation in general and AAL in particular, further research is needed. To identify influencing factors on trust in AAL, a broader survey and experiments with persons over the age of 60 years should be conducted.**

Keywords-AAL; Ambient Assisted Living; Assistance Systems; Elderly People; Trust

I. INTRODUCTION

As a result of demographic change, the number of people in advanced age, who want to spend a self-determined, independent life at home, is growing. Unfortunately, not all elderly people are able to reach this goal without assistance. This often leads to conflicting goals. An age-related decline in physical fitness, as well as physical limitations in consequence of diseases or accidents, mean that the elderly need support in realizing their desire to live in their familiar surroundings. This results in tension between the affordability of traditional personal care and specific individual support, as well as novel technical support. As seen in [1] the concept of trust in Ambient Assisted Living (hereinafter AAL) should be ascribed greater importance.

On one hand, human assistance in activities of daily living (ADL) like taking a bath, preparing meal or going for a walk is a great relief for people with health restrictions. On the other hand, science has, for several decades, dealt with research into new technologies to support people in their own home [2]. Meanwhile, innovations in the home environment offer numerous opportunities for technology-supported systems. Researchers have developed a plurality of services combined with technical support for elderly people. Terms as 'Smart House' [3], 'Smart Home' [4], 'Assistive Technology (AT)' [5] or 'Ambient Assisted Living (AAL)' [6] are just a few of the frequently used terms in this context.

In the present article the importance of trust in AAL for elderly people is the focal point of interest. In order to take advantage of AAL technology, which assists an impaired person in everyday life [7], the user must have trust in this assistance system. Since, in case of an emergency, this assistance can save lives, it is obvious that the concept of trust has fundamental importance to the consideration of development, purchase and use of AAL. The fact that older people have typically grown up without technologies like personal computers, smart phones or the Internet, which are often integrated in AAL [8], implies special demands towards the design of these devices.

The present study is structured as follows: Firstly, the background section explains the development of AAL as a result of demographic change. Next, the importance of trust as an influencing factor in this research context will be highlighted and a definition for trust in AAL derived. In the third section the literature review as research framework is described in detail. The acquired data is then analyzed in its entirety and moreover, studies regarding trust in healthcare and assistance systems are considered separately. Finally, a discussion of the observed results and an overview about further research activities is provided. The design of the present study is oriented to answer the research question: *Why is the investigation of trust in AAL necessary, and what is the current state of research into it?*

II. BACKGROUND

This section contains the background information about the development of AAL as a reaction to demographic change, as well as the importance of the concept of trust as an influencing factor for AAL. In conclusion, the development of a definition of trust in AAL is detailed.

A. Development of AAL as Reaction to the Demographic Change

According to the United Nations Department of Economic and Social Affairs (UNDESA), as compared to the total population, the proportion of people over the age of 60 years is constantly increasing [9]. The number of people over the age of 60 is predicted to grow from more than 700 million in 2009, to 2 billion in the year 2050. Worldwide this would correspond to a tripling of the cohort in a period of 40 years. The annual growth rate of 'generation 60plus' amounts 2.6 percent. This increase eclipses the overall population's growth rate of 1.2 percent per annum. At the present time, over a fifth of the population in the more developed regions is 60 years of age or over. Projections indicate that nearly one third of the total population will belong to that age group by 2050 [9]. Based on this development, health care expenditure, for example within the European Union and Norway, will change dramatically [10].

Additionally, it should be mentioned that age is not readily defined in reference only to the date of birth. Although the chronological age of two persons could be equal, the biological, psychological or social age may differ [11]. Also the cohort effect may influence differences in persons' age [12]. As defined by the World Health Organization "there is no United Nations standard numerical criterion, but the UN agreed cut-off is 60+ years to refer to the older population [11]." The terminology 'older person' or 'elderly person' is used interchangeably; therefore, these terms are similarly used in the current study for people over the age of 60. The above presented facts, in combination with the existing older persons' purchasing power, accentuate the enormous importance of the elderly for science and economy.

Moreover, technological progress and a high degree of information technology are factors that are gaining more and more relevance in everyday life. The beginning of research into the field of Assistive Technology (AT) can be traced back to the early 1970's. Then, so called "phone-chains" used the standard telephone system and were organized by a network of elderly-persons and professionals [2]. Mutual telephone calls were used to monitor the group, and if a member did not respond, their doctor or relatives were notified. This can be regarded as the first electronic emergency system for elderly persons.

The next step was the development of home emergency call systems. One of the most famous was the HTS831, which had two different buttons: one red, and one green. This system consisted of a wireless transmitter, which the user was able to wear around their neck. In case of emergency the user could either push the button on the transmitter or the red button at the station, to contact the emergency center. As a security and monitoring function, the user had to press the green button once a day [2]. In the middle of the 1990's, the first video conference system for private homes was offered. TV-top boxes, or a separate video telephone, functioned as the user interface. Additionally, this system contained functions for personal discussions and organization of, for example, nursing, medical or entertainment services [13]. In summary, efforts to develop useful and coherent life assistance services, which aid older persons to live longer in their home, have existed for several decades.

In the last few years, due to awareness of the growing distribution of older people, and technological progress, the development of AAL has significantly increased in its importance. Many national and international Non-Governmental Organizations (NGOs) and research projects have been focusing on this topic. As a result, different concepts have entered the market [8][14][15][16]. For instance, through the use of sensory floor mats - which register movements in living areas and react by automatically turning the lights on - the risk of falling can be reduced [17]. Another example of AAL can be found in the combination of personal and technological support offered by the Fraunhofer Institute [8]. By means of summarizing and demand-oriented analysis of sensor data, an individualization of care, as well as nursing services is possible. From a technological perspective it must be noted that most of the described systems are still in their early phase of innovation. Only a few AAL systems are currently marketable [18]. The German Federal Ministry of Education and Research (BMBF) launched the funding program "age-appropriate assistance systems for a healthy and independent life – AAL", which sponsored 18 research projects in the field of AAL with a total amount of € 45 million [19].

Giesecke et al. (2005) have first defined AAL "as the use of AmI [Ambient Intelligence] in everyday life. Assisted means assistance, by technical devices as well as by technical or human services [6]." In 2007, a more elaborate definition of AAL is found in [7]. Hereafter, AAL denotes "living in a smart technology supported environment that reacts sensitively and adaptively to the presence of people and objects and thus provides various services to the human. The aim is to preserve, enlarge and extend the personal freedom and autonomy, by promoting and supporting personal independence [7; translated by the authors]." Although AAL does not explicitly target the elderly and can be implemented in a huge variety of living situations for people with impairments, in practice most of the projects, which carry out research are concerned with the elderly [20]. The definition by Kung and Bart (2010) focuses particularly on enabling older people to experience of a higher quality of life. AAL refers to "intelligent systems that will assist elderly individuals for a better, healthier and safer life in the preferred living environment and covers concepts, products and services that interlink and improve new technologies and the social environment [21]."

AAL cannot be seen as a single technology but as a network of interacting systems or agents, for instance companies from different areas of society. The aim of AAL

is to combine those various agents in one holistic system adapted to diverse customer needs. As seen in [18] four different scopes for application for AAL systems called "health and care", "household and supply", "security and privacy" and "communication and social environment" exist. Due to this diversity, AAL systems should integrate in a modular design and be flexible for the customer's individual needs; lifestyle and health condition [22].

In terms of the German Association for Electrical, Electronic & Information Technologies, AAL is defined as follows: "Assistant systems for the constitution of intelligent environments [aiming] to compensate predominantly age-related functional limitations of different target groups – through technological information and communication support in everyday life [23]." This definition emphasizes the role of information and communication technology in particular.

In contrast to home automation [24] or the smart house [3], AAL is not limited to only life in relation to housing, but extends to all areas of life. AAL focuses on the assistance functions of an adaptive overall system while home automation deals mainly with automation and networking of devices. AAL focuses on maintaining, increasing and extending the user's personal freedom and autonomy. In summary, AAL systems are intended for people with health impairments who require security in their environments and support in communication to prevent loneliness. The present European research focuses on these overall requirements of elderly persons. Since the concept of AAL is concerned with these holistic requirements, the importance of trust in AAL needs to be more understood for permanent usage.

B. The Concept Trust as Influencing Factor for the Usage of AAL

"There are multiple definitions of trust and a single, simple definition is insufficient to capture the essence of the concept [25]." This definition shows the plurality of the concept of trust. As seen in [26] the conception of trust arises in many disciplines like social psychology, philosophy, economics, law, marketing and others. These diverse disciplines also have different basic requirements about trust. The economists have a rational and calculative vision of trust, which contrasts with the attitudinal and ethical view of the philosophers. Social psychology emphasizes the reliability of the word and the fulfillment of obligations [27]. On the other hand, economics perceives trust as an answer to expected future behavior and suggests the usage of hostages to warrant rational behavior [28]. Furthermore, philosophy and social psychology emphasize the personal and interpersonal aspects, while law economics and marketing stress inter organizational trust. The fact that trust depends on additional situational and cultural elements, together with existence of diverse synonyms, highlights the multidimensional view of the concept and demonstrates why there is no uniform definition of the term [26].

Castaldo et al. (2010) used a quantitative approach to illustrate and handle the heterogeneity of trust by means of a content analysis. By application of 36 definitions of the term "trust", a frequency analysis was conducted. The numbers in co-occurrences show that attitude and behavior were used in most of the cases to explain trust [29].

To emphasize the diversity of the construct trust there are added numerous 'trust relationships'. Personal trust, as self-confidence, and interpersonal trust that comprises a human's trust with another human [27][30][31] can be mentioned. [32] put their research focus on close relationships and stated that trust is not present from the beginning. It has to be built up through increasing experience with the other person. Moreover, social trust characterizes trust with a system or an institution [26], while trust in automation denotes a human's trust with a technology or a device [33][34][35].

"Uncertainty, vulnerability and the possibility of avoiding risk or of making a choice based on judgment, are seen as necessary conditions for the existence of trust" [26]. The enhanced uncertainty and complexity that has stimulated the latest interest in trust in various fields of research corresponds with the increased relevance of healthcare and trust in assistance systems and automation in general. Trust in technology induces reliance when the complexness makes a thorough understanding impossible.

Turing (1950) was the first who analyzed trust between humans and machines in an experiment where a human had to differentiate between a human advisor and a computer simulating a human. 95 percent of the participants did not notice the difference and supposed that the advisor was a human. With the 'Turing Effect' the discussion about human trust in information given by automation compared to another human, was born [36].

New and innovative technologies become increasingly complicated and humans cannot manage the full degree of complexity. Humans cannot fully understand the processes behind the automation. They have to rely on automation to use it in an adequate manner. Therefore, trust can be seen as a mediator between humans and automation by guiding reliance: "Trust can be defined as the attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability" [37]. The agent is described as automation or as a person, which cooperates with the surrounding of the person [37].

As seen in different studies, people have the tendency to rely on technology they have trust in and to reject technology they do not trust [33]. When people trust automation, the usage is often influenced positively [38][39]. But also negative examples exist due to inappropriate calibration of user trust. In one notable example, the cruise ship Royal Majesty ran aground because the crew did not realize that the navigation system did not work correctly. The system lost the GPS signal and the alarm did not inform the crew. Although it was obvious to see that the water became too shallow, the disaster was not averted. A subsequent report confirmed that the crew was overly reliant on the automated position display [40]. Another tragic example of distrust towards automation led to an airplane crash where 71 people lost their lives [41]. The collision near Überlingen at Bodensee in 2002 can be attributed to the ignorance towards the Traffic Collision and Alerting System (TCAS). Two airplanes were flying in the same height and the TCAS warned both about the imminent accident. It advised the

Tupolew to ascend and the Boeing to descend but a human air traffic controller was not aware of the other airplane's position. He gave the conflicting advice to the Tupolew to descend. The Tupolew pilots' followed the human's advice and thus the collision was caused. This case represents a typical dilemma of human advisory conflicting with automation advisory. These examples show the importance and impacts of trust towards technology. If trust is not calibrated to the true capacity of the system, users may over rely (misuse) or under rely/ reject (disuse) on the automation [42].

These considerations relating to trust in technology can also have impact in the area of healthcare and AAL. As seen in [43], trust in medical technology is empirically different from trust in other technology. Based on [35], which deal with patients and healthcare providers in obstetric work systems, important implications for trust in healthcare systems and AAL-Technology emerge. The study demonstrates that trust building in medical technology transpires not only in a relationship between doctor and patient or patient and technology. There is a complex network of relationships, which ultimately forms a 'network of trust' in technology use. [44] has already observed a network of trust in supervisory control systems. In addition to the sys-tem she included a system designer, operators, management and society as other actors. Trust as a factor attributed to AAL systems, is also affected by a significant amount of implicit trust in the network around the use of the actual technology. Following the 'Actor Network Theory' [45][46], the reliance on the network located around the AAL system, is equally important for the usage of assistive technology. As an example, for [47] the use of a defibrillator implies not only trust in the product and its functions but also in the network around this product. This network includes the product designer, the organization, which implements the product and the coaches, explaining the technology to the inexperienced users [47]. It follows that distrust in a health care provider can also lead to patients' distrust in medical technology or the hospital per se [48]. Therefore, consideration of the social or work system [49], which encapsulates the technology, is necessary for an understanding of trust. Reference [35] clarified that in the case of complex medical or assistance technology, building trust in automation is more accurately building trust in a work system. Furthermore, during the use of the same system the perspectives of multiple user groups (end user, relatives, and health care provider) vary [35].

In summary, it can be seen that there are a lot of factors, which differ in the formation of trust and, which have to be considered in the development and application of AAL. Due to the importance of the concept of trust it is necessary to develop a working definition as a basis for further research activities in AAL. The following definition based on the above mentioned definitions of AAL [6][21][23] and the definition by [37] in context with automation.

Trust in Ambient Assisted Living (AAL) can be de-fined as the attitude that an assistive technology supports an impaired person within their social environment in an uncertain and vulnerable situation.

AAL also offers holistic support for persons with disabilities, not only to those over the age of 60 years. The combination of human and technical services by modular and customized technology generates various possibilities. Since users will not completely understand the technology and processes of AAL, the attitude trust helps to influence the usage of AAL.

III. RESEARCH FRAMEWORK

A literature review was conducted to explore the relevant scientific approaches in the context of trust in AAL, healthcare assistance systems and other automation. By means of this research method, information about how extensively the issue has been previously addressed in the research can be ascertained. To increase the precision of the literature review in this innovative and fast moving research field, relevant articles were identified by means of computerized search in the online bibliographic databases 'Web of Science' [50] 'PubMed' [51] and 'PsycINFO' [52] starting in November 2010 up to a publication date of January 2011. The three database searches are carried out with filter. In 'Web of Science' key search terms are filtered by topic, in 'PubMed' by MeSH Terms and in 'PsycINFO' by keywords. These three different terminologies represent the generic terms for the search algorithm in the respective database.

For investigation in the three databases, 150 dissimilar search term combinations are performed in each setting. The used key search terms are presented in Table I. The first search requests always contain a term of the categories 'Attributes' and 'Auxiliaries'. At first, the term trust has been set and was queried alternatively with the keywords of the descriptor 'Auxiliaries'. After carrying out these searches, the term reliance was set and also requested with those from the second category. Then, the already carried out 30 search combinations have been linked sequentially to the concepts of the third descriptor 'Population'. By extending the research with these four search terms and consideration of the abbreviations AAL and ATS, ultimately 150 searches per database were performed.

Due to the large number of search combinations and potentially relevant studies, the search results are already reviewed for further availability during the database search. For this, both title and abstract are considered. Afterwards, to identify the relevant full text articles a set of exclusion criteria are selected. For inclusion in the literature review articles had to fulfill the following criteria:

TABLE I. KEY SEARCH TERMS

Attributes	Auxiliaries	Population
Reliance	Ambient Assisted Living/ AAL	Adult
Trust	Assist* System/ Technology	Age*
	Assistive Technology Service/ ATS	Elder*
	Automation	Old*
	Healthcare	
	Intelligent/ Interactive Home	
	Medical Technology	
	Smart Home/ House/ Living	
	Technology	

*Search included stated terms and derivates (e.g., age, aging, aged).

(1) The study described explicitly the connection between trust and automation or assistive technology, whereby trust is seen as an influence factor for the interaction with the system

(2) The article was published in a journal or presented at an international conference

(3) Studies, which were first presented at a conference and afterwards published with identical findings as a journal article, were only taken into consideration with the journal release

(4) The publication was written in English

(5) Due to the database research date, studies are included up until January 2011.

A data form was used to remove the important information for each relevant article. After structuring the articles and integrating the data in the fact sheet, a detailed data analysis was undertaken.

IV. DATA ANALYSIS

The previously described 150 search term combinations in each database initially identified 8,498 potentially relevant articles for the literature review. By means of the structural query, the database 'Web of Science' offered 4,401 publications. The database 'PubMed' yielded 3,855 results and the search requests in 'PsycINFO' provided 242 studies. Owing to the consideration of the above described five exclusion criteria and after analyzing titles and abstracts of the 8,498 studies, 164 publications are used in the next part of the review. In this step, the full text of these 164 articles was reviewed. After analysis of the full text versions, 92 articles were included for the further literature analysis. With regard to the exclusion criteria, a total of 72 of the filtered studies were excluded, leaving 56 percent of the original 164 articles. Fig. 1 gives a numerical overview about the structural sequence of the literature research.

Because of the five exclusion criteria shown above, 72 articles (44 percent) were excluded after the full text review.

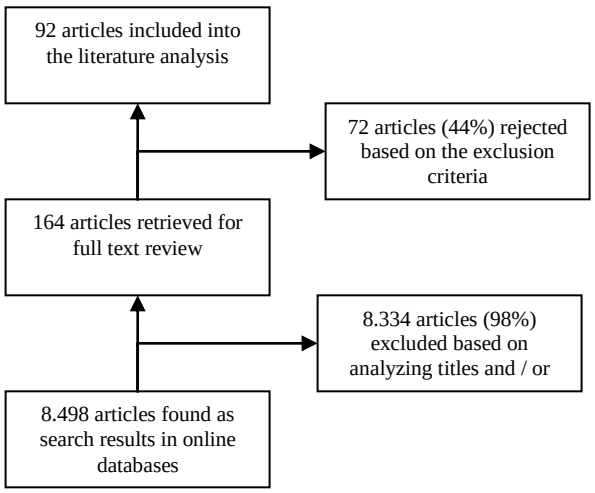

Figure 1. Literature research sequence diagram (authors design).

Most of the studies (48 articles) are not relevant due to the wrong topic focus. 15 of these studies had focused on trust in websites/ online platforms as well as trust in e-commerce applications and are not followed up owing to the exclusion criterion. A further 17 studies are eliminated since they were not published at a conference or in a journal. The last seven excluded articles were published once in a journal and additionally published at a conference with almost identical results. These studies are only considered one time with the more current journal article in our results. Thus, in the end, 92 articles were analyzed in detail in the literature review.

These articles covered the topics trust in automotive [53][54][55][56][56][57], aviation [40][58][59][60][61][62][63][64][65], combat identification [66][67][68][69][70], general design advancement [33][71][72][73][74], supervisory control systems [38][39][75][76][77][78], healthcare and assistance systems [79][80][81][82][83][84] and others [85][86].

As can be seen in Fig. 2, with a total of 18 articles the cluster 'Healthcare and Assistance Systems' has the largest number of relevant studies. This fact can be explained due to the specific key search terms in the descriptor 'Auxiliaries' (e.g., 'Healthcare', 'Assistance/Assistive System/ Technology', or 'Medical Technology') in the first step of the literature search. These articles will be analyzed with special regard in the further course of the study. Firstly, the other six clusters with focus on measuring and analyzing trust in technology will be briefly addressed.

Diverse computerized trials and experiments relating to trust in automation and assistance by means of transportation 'Aviation' (16 articles) or 'Automotive' (11 articles) were performed. In the consideration of the articles in the cluster 'Aviation', the focus is on research in air traffic control (e.g., [62][63][65] and multitask flight simulation [40][59][58]. The background of this field of research is that pilots' trust in alarms or cues within cockpit automation has impact on the usage of autopilot systems. Recent results can be found in [60][61][64].

In the cluster 'Automotive', reliance in automotive

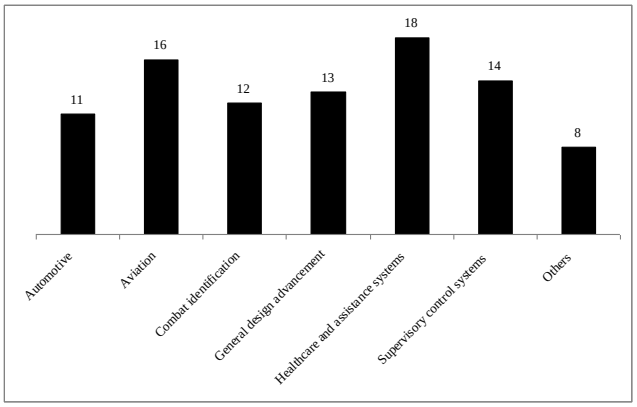

Figure 2. Numerical division of the literature review results by topic (alphabetical order) (authors design).

adaptive cruise control systems [57][87], advanced traveler information systems [55] and particular automotive collision warning systems (e.g., [53][54]) play an important role in research. These computer-assisted experiments aim to analyze trust in different alarm types as false alarm (FA) or unnecessary alarms (UA) in simulated driving situations [56].

Furthermore, in the last decade the military has integrated the factor of trust in 'Combat Identification' in its research projects [66][70]. The literature research included 12 studies on this military subject. The authors in this cluster examined the effects of trust and human responses to automation alerts and false alerts. Participants, who are performing simulated combat tasks, often have to analyze aerial photographs for the presence of enemy targets. Research developments can be seen in [67][68][69].

In addition, 13 articles, among eight former literature reviews, observe trust in 'General Design Advancement' [33][37][73][74]. Jian, Bisantz, and Drury (2000), the only quantitative study in this cluster, developed a trust questionnaire in human-machine interaction, which today is used for measuring trust in various automated systems [71].

Further 14 articles deal with reliance on different 'Supervisory Control Systems'. Monitoring of luggage screening [76], pumping [37][39][78] and central heating systems [77] have been considered in this category. Moreover, Bahner, Hueper, and Manzey (2008) have regarded a process control system and the influence of complacency and automation bias in interacting with a decision aid in this context [75]. Finally, a cluster called 'Others' was created for including all studies, which cannot be integrated in one of the before mentioned sub items. These articles concentrate for example on trust in tele-operation systems [88], automation etiquette [86] or trust in an automated counting and circle estimation task [85].

A. Data analyses of overall results

In the next step, the data sheet with the overall studies has been analyzed (A) and compared with the results from the topic trust in healthcare and assistance systems (B).

(1) Publication date

Between 1987 and 1991 only two studies were published in this context [33][34]. The first experiment of trust in a human-machine supervisory control system was realized by [38]. Whereas, up until 1999, 15 studies were published in total, from 2000 to 2010, 77 articles with regard to trust in technology and assistance systems can be found. Since 2003, every year six studies or more are indicated. In 2008, a maximum of 11 relevant articles are found.

(2) Type of study

In a next step, the distinction between conceptual and empirical/experimental articles is examined. From the overall 92 reviewed studies, 22 consider conceptual and 70 empirical methods for their research. These conceptual articles comprise former summaries and literature reviews (12 articles) as well as articles with the focus on framework, model or questionnaire development (10 articles). The 70 empirical articles can be differentiated into quantitative and qualitative research methods. Since 1987, in total 62 quantitative studies (including experiments, online, postal or paper standardized questionings or a combination of experiment and questioning) were identified. It can be observed, that only five studies include questionnaires only. In contrast, 57 studies used experiments or a combination of experiments and questionnaires for measuring trust. By comparison, eight articles with qualitative methods as qualitative interviews, workshops and focus group interviews were considered.

(3) Participants characteristics

In a next step, the participants' age distribution is considered. In order to receive a better understanding of the participants in experiments or surveys, a clustering into five age groups was conducted. These groups were subdivided into 'participants younger than 30 years' 'participants from 30 to 60 years', as well as 'participants older than 60 years'. Moreover, one age group comprised a combination of younger (< 30 years) as well as older (> 60 years) participants. Further studies performed experiments or interviews without age differentiation.

Regarding the 70 empirical studies, in 22 of the studies or 31 percent, there was no age differentiation declared. In 35 surveys participants were younger than 30 years and in five surveys they were between the ages of 30 and 60 years. In only eight surveys (16 percent of overall) were participants older than 60 years. In five articles the participants exclusively belonged to the age group over 60 years. In three further studies both younger participants (< 30 years) and people over the age of 60 were examined.

Participation rates range from an experiment with six [89] or a qualitative interview with nine participants [90] to a postal survey with 1187 participants [91]. In total, in 43 of the articles (61 percent) less than 50 participants took part in the surveys on trust in automation or assistance systems. In eight studies between 51 and 100 and in 16 studies between 101 and 500 participants were involved. Reference [91] was the only study with more than 500 participants. In two articles there was no participant number specified. Moreover, only three out of the surveys contained a limitation with regard to the gender. One study by [82] questioned 24 women, or rather 24 mothers who had recently given birth. In two other articles only male participants, former pilots [92] and students [93], were surveyed. In 38 surveys both gender were examined and 29 surveys did not make an explicit distinction.

(4) Publication type

Another study detail can be carried out by the differentiation between 'conference vs. journal publication'. Among the 92 examined articles, 18 articles (20 percent) were presented at a corresponding conference and 74 articles published in a journal. The journal with the most publications and major interest in the research of trust and automation was 'Human Factors' with a total of 21 articles (23 percent). The journal 'Ergonomic', with eight relevant articles, the 'International Journal of Industrial Ergonomics', with four and several journals with three studies follow.

B. Data analysis of studies regarding trust in healthcare and assistance systems'

This rising relevance of the concept of trust, which can be found in the different research topics, is also evident by the large number of relevant articles in trust and 'healthcare and assistance systems'. In this field of research interest has been increasing in the last decade.

(1) Publication date

The first published paper relating to trust in healthcare automation was presented in 2002. The conference paper by [86] was the first article that emphasized the factor trust. From this point on until January 2011, 18 articles can be found. These articles deal with reliance on healthcare, medical or household assistance systems. In the years 2003, 2004 and 2006 no publications within this context can be found, whereas since 2007, every year articles are considered. 2010 revealed the largest number of studies in field, with five published. Fig. 3 gives a detailed overview about the annual distribution of the studies in the cluster 'healthcare and assistance systems' in comparison to the other topics. As can be seen, the importance of a conscious handling and perception of the concept of trust in combination with automation and, particularly, healthcare and assistance systems has been increasing in recent years. The first study with regard to trust in automation and human-machine interaction was published in 1987 [33]. In contrast, the first publication regarding trust as a variable for developing healthcare systems for older persons was presented in 2002 [81].

(2) Type of study

Four of the 18 articles in this cluster used conceptual methodologies. Three articles focused on framework or model development [79][81][83] and one study summarized the relevance of training in technology used by tele-home care nurses [84]. Moreover, 14 articles included empirical research–seven used quantitative and seven qualitative methods. The publications with quantitative methodologies are divided into three studies with a combination of questionnaire and experimental design, two studies with exclusive questionnaire surveys and two with experiments. The qualitative research exclusively consists of articles with qualitative interviews.

In comparison, within the other topics quantitative studies dominate with 55 studies. In particular, in new research areas qualitative surveys are utilized to get a detailed understanding of the topic. For this purpose, the focus is set on qualitative interviews, as has occurred in the research area of trust in healthcare and assistance systems. Seven of the overall 18 studies (39 percent) included qualitative interviews with individuals or workshop and focus group discussions. In 2010, four studies used qualitative interviews, which show that researchers are still in the process of developing a detailed understanding. Given that general research on trust in human-machine interaction started in 1987 [33] and to this day ambiguities in this context exist [60][61][94] it is understandable that qualitative interviews are still used in this research area.

(3) Participants characteristics

For the 14 empirical articles an age group differentiation was performed. In three of the studies, participants were younger than 30 years and in one study they are between 30 and 60 years. Moreover, five of the articles consider participants over the age of 60 years. Further two studies consider a combination of younger and older participants, while three surveys give no information about age differentiation. Where the work system is in healthcare and assistance systems such as AAL, the end user is mostly over the age of 60. Therefore, it is of immense relevance that this target group will be considered in the research. Fig. 4 displays the previous study numbers, in which participants over 60 years were involved.

As can be seen, in the other clusters the target group of people over the age of 60 plays only a subordinate role. Only one author has considered elderly persons' trust in a human-decision aid system and compared the results to people younger than 30 years [85].

In contrast, in the healthcare sector researchers have focused more on the age group over 60 years. Of the total of

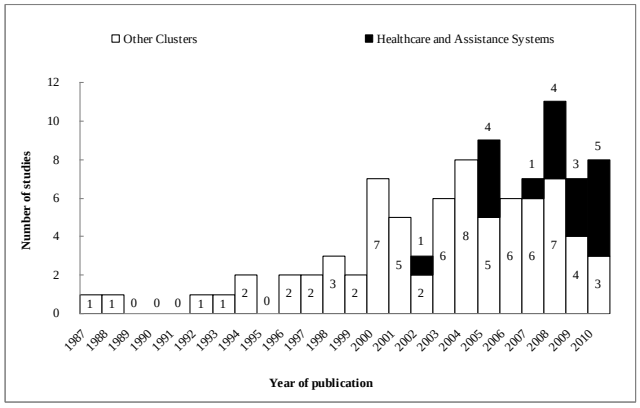

Figure 3. Year distribution of studies in 'healthcare and assistance systems' vs. other topics (authors design).

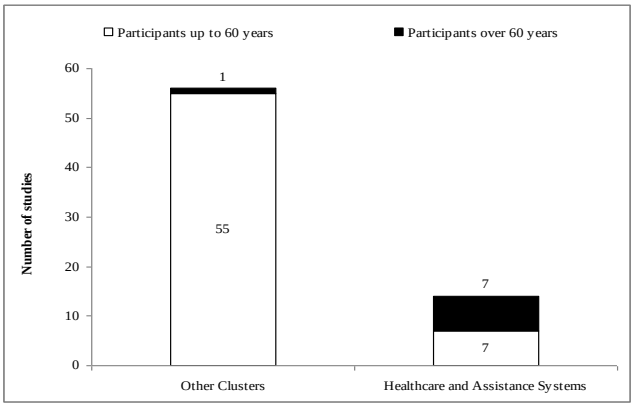

Figure 4. Age differences of study participants in the different clusters (authors design).

eight studies that have dealt with participants over 60 years, seven studies (88 percent) are located in this cluster. Two studies have taken a differentiation of younger and elderly persons into account [80][95]. Moreover, five articles have exclusively focused on people over 60 years [90][96][97][98][99]. In 50 percent of the overall studies, which analyze the factor of trust in healthcare and assistance systems by experiments or surveys, the age group over 60 years is strongly represented.

Concerning the number of participants in the topic 'healthcare and assistance systems', in nine of the studies the participant rate amounted to less than 50 participants. In two studies the participant rate ranged from 51 to 100 persons and three articles took more than 100 participants into account. These articles also include the reference [91] with a postal questionnaire of 1187 people. With reference to the participant rate it can be highlighted that the study with the most participants [91] as well as one of the studies with the least participants (n=9) [90] belong to the topic trust in healthcare and assistance systems.

Regarding the gender distinction within the different methodological designs, 12 articles have regarded both sexes; one article made no differentiation and one study [82] viewed only female participants. This study with solely female participants interviewed 24 women who had recently given birth. They were questioned in a qualitative interview to analyze trust in medical technology and obstetrics work system [82]. For the observation of this complex work system additional interviews with care providers were conducted [35]. Furthermore, it can be said that healthcare and technical support for elderly persons are themes, which concern men and women equally. Therefore, it seems logical that most of the studies deal with both genders.

(4) Publication type

Moreover, among the 18 studies, six articles (33 percent) are presented as conference papers and 12 articles (67 percent) were published in journals. The journal 'Ergonomics' with two publications was the only one, which was represented several times. The author Enid Montague with four research studies since 2009 has taken a pioneering role in context of trust and healthcare technology [35][43][82][83]. Additionally, Coughlin et al. (2007, 2009) and Ho et al. (2005a, 2005b) are listed with two articles [79][80][96][100].

Due to the topical nature of the research field, the distribution of articles presented at conferences and published in journals can be explained. From the overall 18 studies in the healthcare cluster, 12 were published in journals and six studies were presented at conferences. By comparison, from 74 articles within the other topics, 62 were published in journals and 12 studies, thus 16 percent, were presented at conferences.

V. CONCLUSION AND FUTURE WORK

The significant increase of elderly persons due to demographic change and the resulting rise in purchasing power is affecting the development of reliable AAL systems [101]. Since 2005 the European and national sponsoring programs for AAL have steadily increased the relevance of supported living in a home environment, which enlarges and promotes personal independence. Moreover, it is difficult to understand why AAL has had absolutely no consideration in combination with measuring trust in the research literature. The search combinations 'reliance or trust' and 'Ambient Assisted Living/ AAL' yielded no results in the current literature study. There was no study explicitly examining trust in AAL systems. Moreover, the relevance of measuring trust in healthcare technology and assistance systems is not prominent within the research results. It can be seen that the consideration of trust in connection with healthcare, medical technology or assistance systems is still in a nascent stage. A few studies considered trust in intelligent home systems [100], smart home [96], telemedicine systems [98], as well as automation [95] or technology [90] at home. Furthermore, it must be noted, that there is no consistent terminology for assistance systems for elderly persons. No systematic approach and documentation or a uniform technology and understanding exist in research, which complicated measuring trust in this context.

On one hand, these results could imply that the topic has not been viewed as a relevant scholarly topic. On the other hand, due to the increasing number of studies in the last decade, this suggestion seems not to be supported. Analyzing the publication date shows that all relevant articles were composed in this period. It is evident that the research field has gained in importance in the last decade.

Another interesting fact can be found in the different frequency distribution of quantitative and qualitative studies. In the analysis of the type of study it can be highlighted that researchers who are examining trust in healthcare and assistance systems use qualitative as well as quantitative methodologies. The fact that trust in healthcare and assistance systems do not singularly depend on technology but rather on a complex work system [35][47], underlines the relevance of more substantial research into this topic.

Moreover, researchers have recognized that the characteristics of elderly participants have been taken into account. An analysis of trust in this sector can only be realized by the integration of people over the age of 60. Seven articles in the last decade consider older participants' trust in healthcare and home assistance systems. The increasing demand and importance of AAL due to the higher life expectancy and demographic shift clarify a considerable backlog demand in measuring elderly persons' trust in AAL. More research into this age group is required to fill the gap left by the few studies and quantitative results. Finally, it can be surmised that by reason of the novelty of the research of measuring trust as an influencing factor for using healthcare and assistance systems, the exact influence of trust cannot be quantified. Only 18 articles, which cover that topic, were found owing to the literature review. Initial developments reveal that trust in healthcare and medical technology differs from reliance on other technologies [43].

Both, qualitative and quantitative research is required to cope with increasing demands in the coming years. Furthermore, more elderly participants must be taken into account for measuring and conceiving trust in an AAL system. In order to ascertain trust the elderly have in AAL, a

deeper understanding of their needs as well as fears and worries is essential. Additionally, trust of reference persons may have influence in using AAL. For researchers and designers of AAL, recognizing the influencing factor of trust will support the development of marketable solutions.

Due to the knowledge gained by the literature review, further research in the context of elderly persons' trust in AAL will be conducted. Based on the results of the present study, the variables regarding trust in AAL have to be examined in a next step. The investigation conforms the various influence factors on trust in AAL and beyond the connection to the usage intention. For this, a scenario-based questionnaire survey and additional experiments will be performed. The experiments include mock-ups of AAL technology on tablet PCs. Different scenarios will be conducted by older test persons. The impact of personal and technical assistance within AAL will be examined and afterwards reliability of AAL technology manipulated.

LIMITATIONS

The systematic review had to contend with some limitations in the research process. First, the selection of online databases should be considered. Literature for trust in automation and healthcare can be seen as an interdisciplinary field. Therefore, three bibliographic databases were used: 'Web of Science' comprising of interdisciplinary content across 256 disciplines; the database 'PubMed' focusing on healthcare content; and 'PsycINFO', psychological literature. Due to this selection, articles, which are not integrated in these databases, are excluded for the review. Second, the information provided in the articles is very heterogenic. Some include a specific description about the experimental design, while other studies fail to provide detailed information. Third, due to the fact that only English language articles were included in the review, a distorted picture is drawn, as the studies focus on English-speaking authors. Fourth and finally, the studies included in the literature review were screened up until January 2011. Thus, articles, which were published afterwards, are not considered for this systematic review.

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