

Smart@Home – Supporting safety and mobility of elderly and care dependent people in their own homes through the use of technical assistance systems and conventional mobility supporting tools: A cross-sectional survey

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Abstract

BACKGROUND: The use of technical solutions and conventional mobility aids can support the independence of people into old age in their own homes. However, we found relatively few empirical investigations on the effects and costs of these systems.

METHODS: The aim of the study was to investigate usability, user satisfaction and the correlation between costs and benefits of different built-in smart home solutions and conventional mobility supporting tools in the home of elderly, partially care-dependent tenants (>65 years). A cross-sectional survey was conducted from February to March 2018 with tenants of a housing association in apartments equipped with smart home technology and conventional mobility supporting tools. The response rate in the intervention group was n=37 persons (out of 46 tenants with installed smart home and conventional solutions) and in the control group n=64 persons (out of 100 tenants without built-in smart home and conventional solutions). Data were collected by a written questionnaire regarding usability and satisfaction of the tenants with the built-in smart home solutions and conventional mobility supporting tools. In addition, both the intervention and the control group were asked general questions about communication, safety and how to deal with the need for long-term care in their own living environment.

RESULTS: Results showed that with regard to usability, satisfaction and price performance ratio of the installed smart home solutions, the installation of the corresponding solutions with an overall score of 1.41 was mostly positively evaluated by the tenants. Overall, users rated the installed smart home solutions better than the conventional mobility supporting tools (mobility aids, such as handholds and increased balcony floor level).

CONCLUSIONS: Analysis of the price performance ratio showed that smart home solutions are generally more expensive than conventional tools, but also contribute significantly to an increased security of the tenants, and thus may enable longer living in a familiar environment. We recommend modularized offers consisting of various components of smart home solutions, since this significantly reduces installation costs and allows for an individual composition according to requirements. Moreover, smart home solutions should be considered to be listed as medical aids.

Background

Information and communication technologies are becoming increasingly important in the care of the elderly and persons in need of care [1, 2]. These technologies include the so-called smart home, which by definition is an information and sensor technology upgraded home that is networked within itself and externally [3]. Certain technical solutions can promote or maintain the independence of people into old age [4]. In the meantime, more and more technical solutions are available for easy-to-use, barrier-free and age-appropriate care at home [5, 6]. The need for such applications becomes essential in particular due to socio-demographic changes, the lack of skilled nursing staff, an increase in single and childless households as well as increasing mobility and growing distances between (care-receiving) parents and

adult children. These changes in population and care structure are creating new demands and specific challenges for the entire health care system [7, 8].

The expected increase in the number of people in need of long-term care from 2.5 million in 2013 to up to 3.5 million in 2030 [9] is also expected to result in a growing proportion of old and very old people living in their own homes and/or receiving care there. Currently, about three quarters of all care recipients in Germany are cared for at home [10]. This corresponds to the desire of most people in need of long-term care to be cared for in their own homes [11] and also follows the guiding principle of the reform of the social long-term care insurance of "outpatient before inpatient" [12, 13].

With regard to the outpatient sector, intelligent living environments (smart home solutions) can provide important and necessary support for people in need of help and/or care in coping with their everyday life, maintaining their state of health and autonomy, social participation and increasing their security. In order to meet the desire of most people to be able to live as long and safely as possible in their own homes [14, 15], technical solutions and aids must meet special requirements [16]. They should be reliable, user-friendly, suitable for everyday use and robust, and also provide various expandable functions, such as fall detection sensors with integrated emergency call function and intelligent light strips for a safe orientation at night [17].

The present study was conducted to determine the extent to which smart home solutions and conventional mobility supporting tools can contribute to promoting and maintaining the independence of older and old people and to increase safety in their own homes. The following research questions were addressed in the investigation:

1.
How do residents evaluate the effective use of smart home solutions and conventional tools in their own homes?
2.
What is the price and quality performance ratio of the smart home solutions and conventional tools, taking into account the resulting benefit (efficiency) for the tenants?

Methods

Study Design

The present study was conducted from February to March 2018 in a district with an above-average number of elderly people. As part of a cross-sectional survey, tenants in need of care and without aged 65 to 90 + were interviewed by means of questionnaires. In their apartments, individual smart home solutions and other conventional aids such as grab handles, service sockets and balcony elevations for easy entry and exit were previously installed. The survey focused primarily on the aspects of the need for care, communication/social contacts and security. The questionnaire was pre-tested for comprehensibility and legibility, and modified accordingly.

Sample

The written survey was conducted by means of questionnaires with an enclosed stamped envelope. The survey included all tenants aged 65 to 90 + years of a housing association, in whose apartments smart home solutions and/or conventional aids to support mobility had been installed. As a control group, a random selection of 100 additional tenants with the same age structure was available, in whose apartments no smart home solutions or conventional mobility aids had been installed so far. In order to ensure the highest possible response rate, the tenants had the opportunity to complete the questionnaire at home. The tenants could either return the completed questionnaire directly by mail in a stamped envelope or in a sealed envelope to the housing association.

Data Collection

Tenants with installed smart home and conventional solutions were provided with information on the study and the course of the investigation at an information event. Afterwards they had the opportunity to fill in the 2-page questionnaire directly on site or to take it home and return it afterwards. Tenants of the control group received a letter from the research group by internal mail from their housing association with explanations of the survey and a 1-page questionnaire with a stamped envelope. The data collection was carried out according to the medical-ethical principles of the Ethics Committee of the State of Berlin.

The questionnaire consisted of three parts in total. In the first part, demographic data was collected. In the second part of the questionnaire, the participants were asked to give an assessment of various aspects of their individual housing situation in order to be able to compare the intervention and control group with regard to need for care, communication/social contacts and security in combination with smart home solutions (Table 1). The respondents were able to indicate whether and to what extent the statements on the questionnaire were applicable using a 5-level scale (1 = "fully applicable"; 2 = "rather applicable"; 3 = "partly applicable"; 4 = "rather not applicable"; 5 = "not applicable"). In the third part of the questionnaire, tenants with built-in solutions were asked about their satisfaction with the smart home solutions which had been installed as well as other built-in conventional mobility supporting aids, such as service sockets, handrails and adapted balcony exit/elevation (Table 2). In order to assess user satisfaction with the installed solutions, the participants in the intervention group were given a scale of 1 (very good) to 6 (unsatisfactory) using a German school grading system.

Table 1
Comparison of the living situation with and without smart home solutions

Statements on housing situation:	Tenants with installed smart home solutions from GESOBAU			Control group without smart home solutions			
	n	Mean	SD	n	Mean	SD	p
I would like to live in my apartment even if the need for care arises.	36	1.31	0.75	64	1.44	0.69	0.375
Even with increasing need for care (up to bedriddenness) I want to live in my apartment.	37	1.89	1.24	62	2.15	1.13	0.301
Smart home solutions (e.g. orientation light on the ground, fall detection sensor) enable me to live longer in my own home.	33	1.97	1.38	53	2.15	1.31	0.542
I have a reference person with whom I am in regular contact to report that I am doing well.	37	1.08	0.36	63	1.70	1.27	0.001
I know who I can inform immediately in a possible emergency.	35	1.09	0.28	61	1.34	0.79	0.024
I leave my apartment regularly to maintain social contacts.	36	1.50	1.00	61	1.74	0.98	0.255
I feel safe in my apartment.	37	1.22	0.53	61	1.30	0.59	0.507
The installed smart home solutions make me feel safer in my home.	31	1.55	0.81	26	2.38	1.39	0.010
Smart home solutions in my home lead to more security.	31	1.71	0.97	49	2.02	0.99	0.172
I can move independently in my apartment.	37	1.38	0.79	63	1.48	0.78	0.549
I can orientate myself well in my apartment even in the dark.	36	1.61	1.10	63	1.79	0.94	0.384
I am afraid of forgetting to switch off electronic devices and thus causing fire damage.	33	3.58	1.30	63	3.30	1.32	0.333
I am afraid of forgetting to switch off electronic devices and causing water damage.	33	3.73	1.15	61	3.33	1.29	0.140
I am comfortable in my apartment.	37	1.24	0.76	64	1.31	0.75	0.658

Table 2
Tenant satisfaction with installed smart home solutions

Installed modules of the smart home solutions:	Indication of satisfaction on a scale from 1 (very good) to 6 (insufficient) in %.						n	Mean
	1	2	3	4	5	6		
Tablet	50.0	33.3	11.1	0	0	5.6	18	1.83
Stove safety	78.9	21.1	0	0	0	0	19	1.21
Orientation light	85.0	15.0	0	0	0	0	20	1.15
Lighting control	53.8	38.5	7.7	0	0	0	13	1.54
LED strip (corridor)	66.7	33.3	0	0	0	0	3	1.33
Visual doorbell	93.3	6.7	0	0	0	0	15	1.07
Door detector	75.0	25.0	0	0	0	0	8	1.25
Automatic switch	50.0	50.0	0	0	0	0	8	1.50
Inactivity detector	50.0	50.0	0	0	0	0	4	1.50
Fall detection bath + toilet	72.7	27.3	0	0	0	0	11	1.27
All-off control	83.3	16.7	0	0	0	0	6	1.17
Home emergency call	100.0	0	0	0	0	0	5	1.00
Heating control	33.3	66.7	0	0	0	0	3	1.67
Installed conventional aids:								
Service socket	57.1	35.7	7.1	0	0	0	14	1.50
Object socket	33.3	66.7	0	0	0	0	6	1.67
Handles bathroom	58.3	33.3	8.3	0	0	0	24	1.50
Handles toilet	40.0	40.0	20.0	0	0	0	10	1.80
Handles balcony	100.0	0	0	0	0	0	8	1.00
Handles corridor	66.7	0	33.3	0	0	0	3	1.67
Balcony exit	81.8	0	9.1	9.1	0	0	11	1.45
Balcony elevation	69.2	23.1	0	0	0	7.7	13	1.62
Overall satisfaction	63.0	33.3	3.7	0	0	0	27	1.41

Data Analysis

Data were screened prior to analysis for any anomalies (eg, missing data, outliers, and nonnormality). Data were analyzed using SPSS Statistics for Windows, Version 24 (Statistical Package for the Social Sciences, Chicago, Illinois). Data analysis was primarily descriptive. Scales used were interpreted pseudo metrically resulting in an analysis with mean values (standard deviations), since the use of medians did not allow for sufficient discrimination. Statistical significance was tested by means of Student's t-test, even though the prerequisites (especially with regard to data distribution) were only partly fulfilled. To verify the results, all significance tests were checked with appropriate nonparametric tests.

Results

Quantitative analysis of the written survey by questionnaire

The response rate was above average in both groups surveyed. A total of 37 of the 46 tenants with installed smart home solutions and/or mobility aids submitted the completed questionnaire, which corresponds to a response rate of 80.4%. In the control group, 64 questionnaires were returned from a total of 100 questionnaires sent out, which corresponds to a response rate of 64%.

The first part of the questionnaire was used to collect general personal data. Information on participant's age was available from 35 persons in the intervention group. Almost three quarters (74.3%) were between 65 and 80 years old, 25.7% were over 80 years old. Among the tenants in the control group, 63 persons indicated their age, 58.7% of whom were between 65 and 80 years old and 41.3% over 80 years old. In both groups, more than three quarters of the respondents were female. With regard to their housing situation, 42.9% of the tenants with installed smart home solutions stated that they were living alone, which was true for a significantly larger proportion of tenants in the control group, namely 61.7% in total. 43.8% of the tenants in the intervention group were in need of care. In the control group, on the other hand, this was true for a significantly lower proportion, namely 13.6% of the tenants surveyed (Fig. 1). Of the 37 tenants in the intervention group, a total of 15 persons (40.5%) were in need of long-term care, with care degrees 1 and 2 (care degrees (Pflegegrade) in Germany range from 1 = minor impairment of independence or skills to 5 = severe impairments of independence or abilities that are associated with special demands on nursing care) being the most frequently represented with a share of 33.3% each. None of the tenants in this group had the highest degree of care (care degree 5) (Fig. 2). Among the tenants from the control group, 8 out of 64 people surveyed required nursing care, which corresponded to 12.5% of the residents. Care degree 2 was most frequently represented (50%). Care degrees 4 and 5 did not occur in this group (Fig. 3). The most frequent physical complaints were mobility limitations, both in the intervention group (59.5%) and in the control group (43.8%) (Fig. 4).

The second part of the questionnaire was intended to provide insights into various aspects related to smart home solutions. With regard to the aspects of care, communication/social contacts and safety in connection with smart home solutions, the mean values of the tenants' answers with installed smart home solutions were on a scale of 1 to 5 between 1.08 and 3.73, in the control group between 1.3 and 3.33. Significant results were available for aspects of communication/social contacts and safety. For example,

the survey showed that both, tenants from the intervention group and tenants from the control group, were fully satisfied that they had regular contact with a reference person in order to report that they were doing well (Table 1 mean 1.08; n = 37 and mean 1.70; n = 63). In addition, the participants in the study stated that they felt safer in their homes thanks to smart home solutions. This was fully true for tenants from the intervention group (mean 1.55; n = 31), and nearly equally true for tenants from the control group (mean 2.38; n = 26). Finally, the participants of both groups said that it was fully true for them to know whom to inform immediately in the case of an emergency (mean 1.09; n = 35 and mean 1.34; n = 61, respectively).

Table 2 shows the mean values of user satisfaction among tenants with installed smart home solutions, highlighting the three best rated technical and conventional solutions. On a scale of 1 (very good) to 6 (unsatisfactory), the tenants' assessments of the smart home solutions and conventional aids installed in their homes were in the range from very good to good. The technical solutions were rated with average mean values between 1.00 and 1.83, while the ratings for conventional aids ranged between mean values from 1.00 to 1.80.

The highest rated component of the installed smart home solutions was the "home emergency call" (mean 1.00) which, for example in the event of falling, forwards an emergency call to the corresponding emergency call centre. The "visual doorbell" which signals the ringing of the doorbell to tenants with impaired hearing both acoustically and visually by means of a wireless bell was rated second best (mean 1.07). In third place was the "orientation light" (mean 1.15), which activates a glare-free floor lighting at night when leaving the bed. The "tablet", which is used to operate the automated modules, such as the "light control", received the lowest rates (mean 1.83). Regarding the installed conventional mobility supporting aids, the item "balcony handrails" was rated "very good" (mean 1.00), followed by the "balcony exit/elevation" (mean 1.45) and the components "service socket" and "bathroom handrails" (mean 1.50). The lowest rating was given to the "toilet handrails" (mean 1.80). Overall, the tenants' satisfaction with all installed smart home solutions and conventional aids was rated "very good" (mean 1.41).

Cost-benefit analysis of the installed smart home solutions

The cost-benefit analysis focused on quality, price and performance. Price performance ratio and the quality of the installed solutions – smart home solutions and conventional aids – were analysed and evaluated accordingly. In determining the best price performance, the price of the installed solutions was compared with the tenants' evaluation of the installed solution, while quality performance was determined exclusively on the basis of the tenants' evaluation. Prices of the smart home solutions and conventional aids are displayed separately.

Price Performance

In a first step, acquisition costs were categorized in order to divide the conventional mobility supporting aids into two price categories (price category 1: 1 to 70 euros, price category 2: 71 to 140 euros) and the smart home solutions into four price categories (price category 1: up to 200 euros, price category 2: 201 to 250 euros, price category 3: 251 to 1000 euros, price category 4: over 1000 euros). The corresponding results are shown in Table 3 for the conventional aids and in Table 4 for the smart home solutions.

Table 3
Price-performance conventional mobility supporting aids

Installed solution	Number of tenants with correspondingly installed solution	Scale (1–6)	Costs in Euro
Service socket	14	1.5	36
Object socket	6	1.67	36
Handles bathroom	8	1	60
Handles toilet	13	1.62	125
Handles balcony	24	1.5	135
Handles corridor	3	1.67	135
Balcony exit	10	1.8	135
Service socket	11	1.45	136

Table 4
Price-performance smart home solutions

Installed solution	Number of tenants with correspondingly installed solution	Scale (1–6)	Costs in Euro (single installation)	Costs in Euro in combination with another solution	Costs in Euro in combination with two other solutions	Costs in Euro in combination with three other solutions
Home emergency call	5	1	176			
Automatic switch	8	1.5	192			
LED strip (corridor)	3	1.33	207			
Tablet	18	1.83	214			
Visual doorbell	15	1.07	217			
Orientation light	20	1.15	248			
Stove safety	19	1.21	473			
Door detector	8	1.25	843			
Heating control	3	1.67	1651			
All-off control	6	1.17	1001	744	658	625
Inactivity detector	4	1.5	1230	973	887	884
Fall detection bath + toilet	11	1.27	1389	1132	1046	1003
Lighting control	13	1.54	2630	2373	2287	2244

With regard to price performance, the best result among the conventional aids (Table 3) was achieved by "balcony handrails" (grade 1.0 = "very good"), which also belonged to price category 1 with low acquisition costs. Comparable results were also achieved for the "balcony exit/elevation" (grade 1.45 = "very good") as

well as for the "bathroom handrails" and the "service socket" (each grade 1.5 = "very good"), of which only the service socket was in price category 1. None of the installed conventional aids was rated below 1.8 (grade 2 = "good") or had acquisition costs (including installation) of more than 140 euros. Among the smart home solutions (Table 4), the "home emergency call" and the "visual doorbell" achieved best price performances with a rating of 1.0 ("very good") and 1.07 ("very good") respectively. Comparable results were achieved for "orientation light" (1.15), "all-off control" (1.17), "stove safety" (1.21), "door detector" (1.25) and "fall detection" (1.27). However, a closer look at the price categories shows that the "home emergency call" (176 euros), the "visual doorbell" (217 euros) and the "orientation light" (248 euros) are the most cost-effective. In contrast, the other systems rated "very good" were considerably more expensive at prices of over 1000 euros. The most expensive system to install was the "light control" at 2360 euros. In terms of the rating, none of the smart home solutions was rated below 1.8.

Quality Performance

The quality assessment of the installed solutions (Table 5) was based on the grades (1 to 6) given by the individual tenants. In a first step, ratings on the conventional aids were looked at separately from the smart home solutions, and in a second step, compared with each other. Among the conventional aids, the "balcony handrails" achieved the best grade of 1.0 ("very good"), while the "balcony exit/elevation" was rated at a similarly high quality (grade 1.45 = "very good"). All ratings ranged from 1.0 to 1.8, meaning that all installed conventional aids were rated between "very good" and "good". Best quality performance among the smart home solutions was achieved by the "home emergency call" with a grade of 1.0 ("very good"), followed by the "visual doorbell" (grade 1.07 = "very good") and the "orientation light" (grade 1.15 = "very good"). However, with one exception in each case ("tablet" – grade 1.83; "balcony handrails" – grade 1.0), the smart home solutions were overall rated better than the conventional aids (1.0 to 1.5 vs. 4.45 to 1.8).

Table 5
Quality-performance conventional mobility supporting aids and smart home solutions

Installed solution (conventional aids and smart home solutions)	Number of tenants with correspondingly installed solution	Scale (1–6)	Costs in Euro
Home emergency call	5	1	176
Handles balcony	8	1	60
Visual doorbell	15	1.07	217
Orientation light	20	1.15	248
All-off control	6	1.17	1001
Stove safety	19	1.21	473
Door detector	8	1.25	843
Fall detection bath + toilet	11	1.27	1389
LED strip (corridor)	3	1.33	207
Balcony exit	11	1.45	136
Automatic switch	8	1.5	192
Inactivity detector	4	1.5	1230
Service socket	14	1.5	36
Handles bathroom	24	1.5	135
Lighting control	13	1.54	2630
Balcony elevation	13	1.62	125
Heating control	3	1.67	1651
Object socket	6	1.67	36
Handles corridor	3	1.67	135
Handles toilet	10	1.8	135
Tablet	18	1.83	214

In summary, all conventional aids were rated at 1.53; all smart solutions at 1.34 on average. The p-value for Student's t-test was $p = 0.066$; for the nonparametric Withney U-test $p = 0.63$.

Discussion

With regard to the research questions to be examined focusing on usability, user satisfaction and price-performance ratio of the installed smart home solutions and the conventional mobility supporting aids, it can be concluded that the installation of the corresponding solutions was positively evaluated by the tenants (overall rating 1.41).

In general, the installed smart home solutions were rated better by the users than conventional aids. At this point, however, it should be pointed out that the poorer evaluation of the installed conventional aids was partly due to unfavourable structural conditions for the optimal installation of the devices. For example, bathrooms were too narrow to adequately install grab handles, and balcony elevations for easy entry and exit, which had actually been evaluated and carried out positively, created a difference in altitude between the apartment and the balcony, which had to be adjusted afterwards.

Analysis of the price-performance ratio has shown that the installed smart home solutions are basically more cost-intensive than conventional aids. However, in contrast to the less expensive built-in conventional aids, it must be taken into account that, although smart home solutions are more expensive, they also contribute significantly to an increased security for the tenants. Inactivity detectors and fall detections can, for example, be linked to different terminal devices, and the notification of the home emergency call may directly be connected to a home emergency call provider. If an emergency call is not available, the information on the event can be transmitted to the mobile devices of the caregiving relatives. Moreover, with regard to the total price it must be considered that certain solutions which have been installed separately are expensive but price competitive in combination with other components. This is especially the case for the smart home solutions, which additionally require a base station (Table 5, lines 3–6). In view of the results with an average grade of 1.83 for the tablet and 1.54 for the lighting control (Table 5), it must be taken into account that tablet training courses were being coordinated at the time of the survey and that problems with lighting control were currently being dealt with by the manufacturer. In the case of lighting control, there were occasional difficulties with the automatic switch.

Not all of the products classified at high quality by the tenants belonged to an expensive price category. Price category 1: up to 200 euros and price category 2: 201 to 250 euros include products that were rated "very good" by the tenants and can therefore be recommended both, from a nursing science and health economics point of view. These include in particular the "home emergency call", the "visual doorbell" and the "orientation light".

Overall, it is noticeable that all technologies improve communication possibilities and increase the feeling of security. Visitors are less often "overheard" by the visual doorbell, an emergency call system contributes to the sense of security from the user's point of view, and orientation lighting offers tenants the opportunity to move around safely even in the dark and thus prevent falls. Another study points to the benefits of technical innovations in the home setting [18]. These assessments are also reflected in the comparative survey between the 37 tenants with built-in solutions and the control group. The 37 tenants tended to show a better evaluation of communication and autonomy aspects in their newly created living environment. In some aspects – despite the small sample size – statistically significant differences were even found, for

example with regard to the statement that the smart home solutions enable a greater sense of security in the apartment.

In addition to the communication possibilities and the feeling of security, another important aspect is the user-friendly handling (usability) of smart home solutions. A prior examination of the usability and user-friendliness (benefit estimation) is an essential prerequisite for the purchase and subsequent integration of smart home solutions in the households of the users [19]. The assumption that older people generally have a low level of acceptance of technology cannot be supported. Although there is general uncertainty about the new technical devices, this is due to little or no previous technical experience [20, 21]. Since almost all users (96.3%) rated the smart home solutions as positive, a negative attitude of older people towards new technologies can be largely ruled out. However, trainings could contribute to reduce existing uncertainties among users.

Moreover, a focus must be placed on the financial implementation or the assumption of costs for the acquisition and installation of smart home solutions. With regard to the German legislator's target of "outpatient rather than inpatient", it is essential to create conditions to enable elderly people (in need of care) to remain in their own homes as long as possible. Higher additional payments by the health insurance funds for remedies and aids are a first step in this direction. Current questions regarding whether there should be a cost sharing by the users and, if so, how much, or whether selected smart home solutions can be included in the catalogue of assistive devices for services financed by the health insurance funds should be evaluated in the near future [2]. At the same time, the possibility of integration in households should also be examined in advance, since not all households may have connections or suitable structural conditions, and configurations may interfere with other technologies [22]. These are currently important and necessary developments, but this is not enough: With regard to demographic changes and the fact that more and more old and very old people want and "should" continue to live in their own homes, innovative solutions to improve their situation must be considered. In the future, solutions will be needed to ensure the safety of the (care-dependent) residents, which will enable them to live in their own homes until old age. Smart home solutions allow early detection and elimination of dangers, for example to avoid falls or emergencies or to be able to react appropriately and immediately in emergencies [23, 24].

A further point to be considered is the safety of the newly installed smart home solutions. Failure risks or defects of the systems should be checked precisely in advance, so that suitable measures can be taken if necessary. This means that the installed systems must be suitable for everyday use. Another important point is to ensure accessibility in order to guarantee prevention of possible care phenomena and care problems. In the future, it can be assumed that the possibilities of smart home solutions, especially with regard to networking, will be expanded, so that privacy and data protection will become increasingly important [25].

From the information available, it can be concluded that, in view of the ongoing demographic changes and the associated social changes towards a more dynamic lifestyle for older people, a special focus should be placed on the further development of smart home solutions [26].

With regard to the initial research questions in this study, it can be stated that tenants report an effective benefit in the installed smart home solutions. In addition, the study showed that smart home solutions generally have a benefit for tenants in terms of the price-performance ratio, even taking into account the more cost-intensive smart home solutions. Finally, the technical solutions were predominantly rated "very good" in terms of the price-performance ratio.

Overall, smart home solutions were rated slightly better than conventional solutions, although the significance threshold was only just missed. This can also be understood as an indication for a high degree of willingness to use technical solutions among elderly and old people.

Limitations

Three limiting methodological problems have to be considered in the study carried out: On the one hand, the small sample size was small, which is due to the fact that smart home solutions were only installed in 27 apartments of the respective housing association. On the other hand, the actual testing phase of the installed smart home solutions and conventional mobility supporting aids by the users was quite short due to the fact that the installation of the corresponding solutions was completed four weeks before the start of the survey. A third methodological problem is, as it is often the case in surveys, the social desirability of the response behaviour. Social desirability is promoted, among other things, by the adaptation to structural characteristics, in this case the installation of smart home solutions and conventional aids by the own housing association. However, socially desirable behaviour may also be promoted by the design of the survey instrument. In order to prevent this tendency as far as possible, emphasis was placed on specific questions oriented towards the individual installed solution or aid in order to reduce the willingness and also the possibilities for criticism. An additional methodological precaution against socially desirable response behaviour was the accompanying letter, in which the tenants were informed that they would participate in the survey voluntarily and anonymously.

Conclusions

The analysis of the study results leads to the conclusion that smart home solutions are a useful supplement to enable elderly people and/or people in need of care to remain in their own homes as long and safely as possible. Modularized offers consisting of different components of smart home solutions have proven to be recommendable, as costs for the installation can be reduced significantly and an individual composition according to the requirements is possible. In order to best meet the German legislator's target of "outpatient before inpatient", a stronger consideration of technical solutions in the list of aids by the National Association of Statutory Health Insurance Funds (German GKV-Spitzenverband) should be considered in the near future. At the same time, corresponding technical solutions can support the approach of the German Care Strengthening Act III (Pflegerstärkungsgesetz III), which came into force on 1 January 2017 and which, among other things, aims to develop social rooms in such a way that people in need of care can live in their familiar home and family environment for as long as possible.

Declarations

Ethics approval and consent to participate

The study was carried out according to the medical-ethical principles of the Ethics Committee of the State of Berlin.

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analysed during this study are included in this published article [and its supplementary information files].

Competing interests

The authors declare that they have no competing interests.

Funding

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Authors' contributions

DJ and SSL conceived the design of the study, coordinated and collected participant data and data analysis and drafted the manuscript. UMW supervised the study and revised it critically for important intellectual content. NAL supervised the design of the study and made substantial contributions to conception, analysis and interpretation of data. All authors read and approved the final manuscript.

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Figures

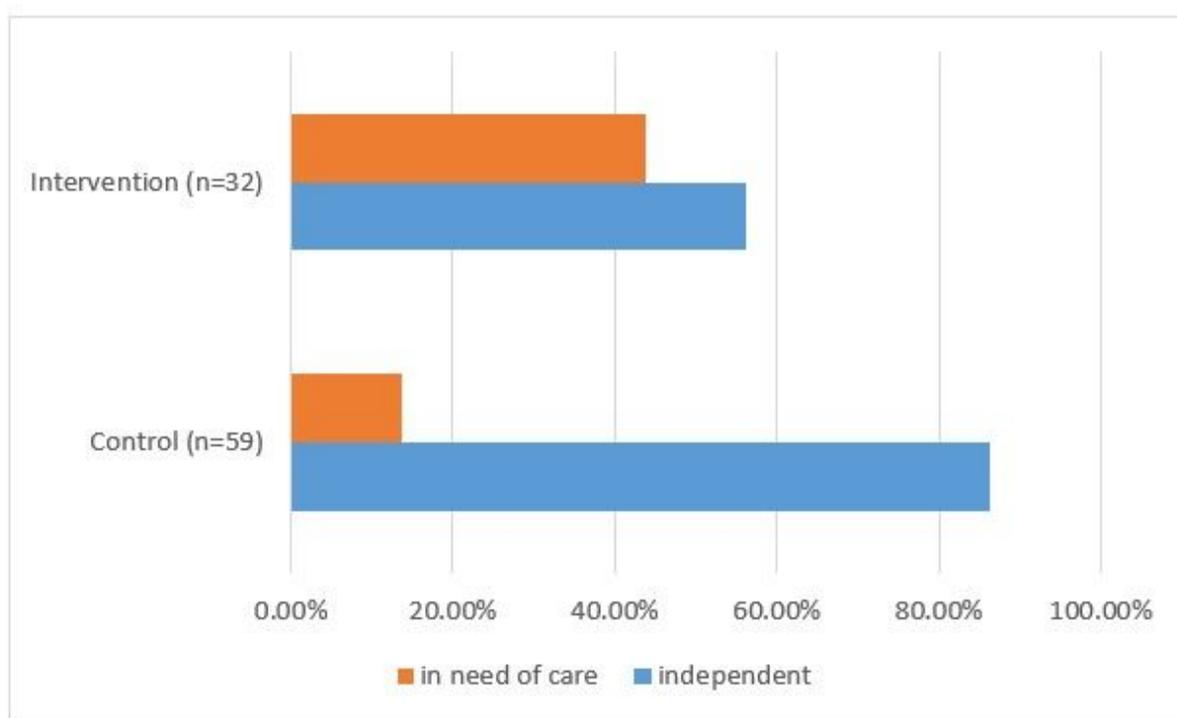


Figure 1

Sociodemographic data intervention vs. control group – need of care

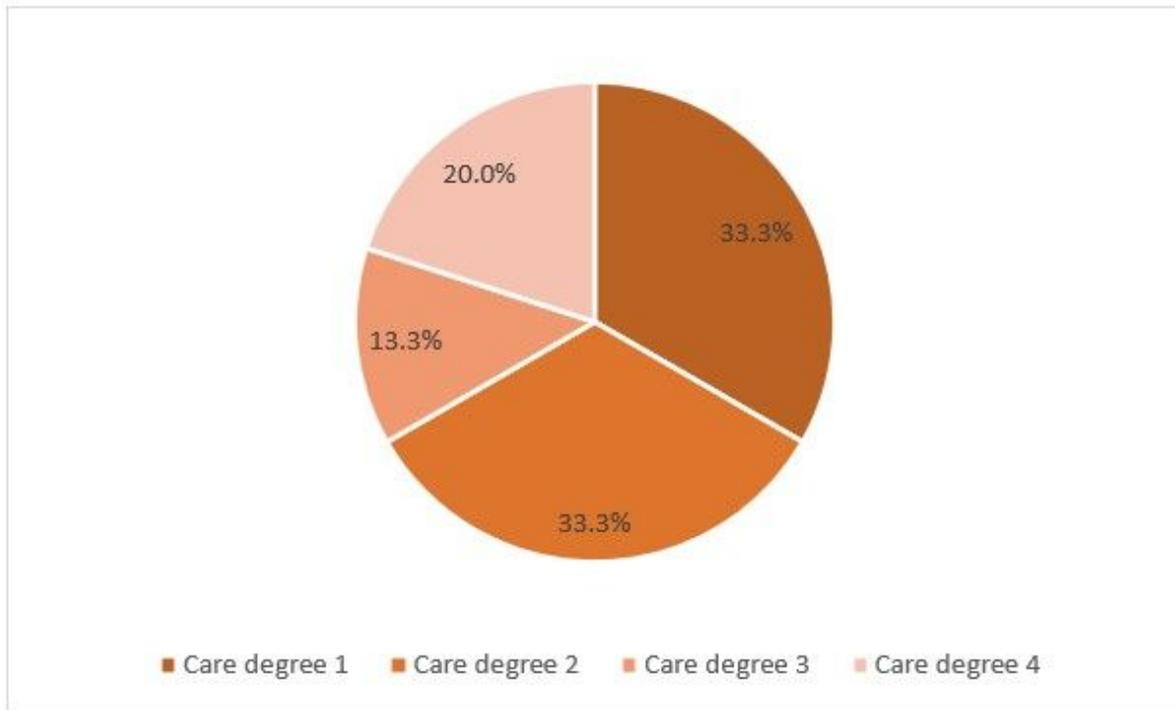


Figure 2

Sociodemographic data intervention group – care degrees (n=15)

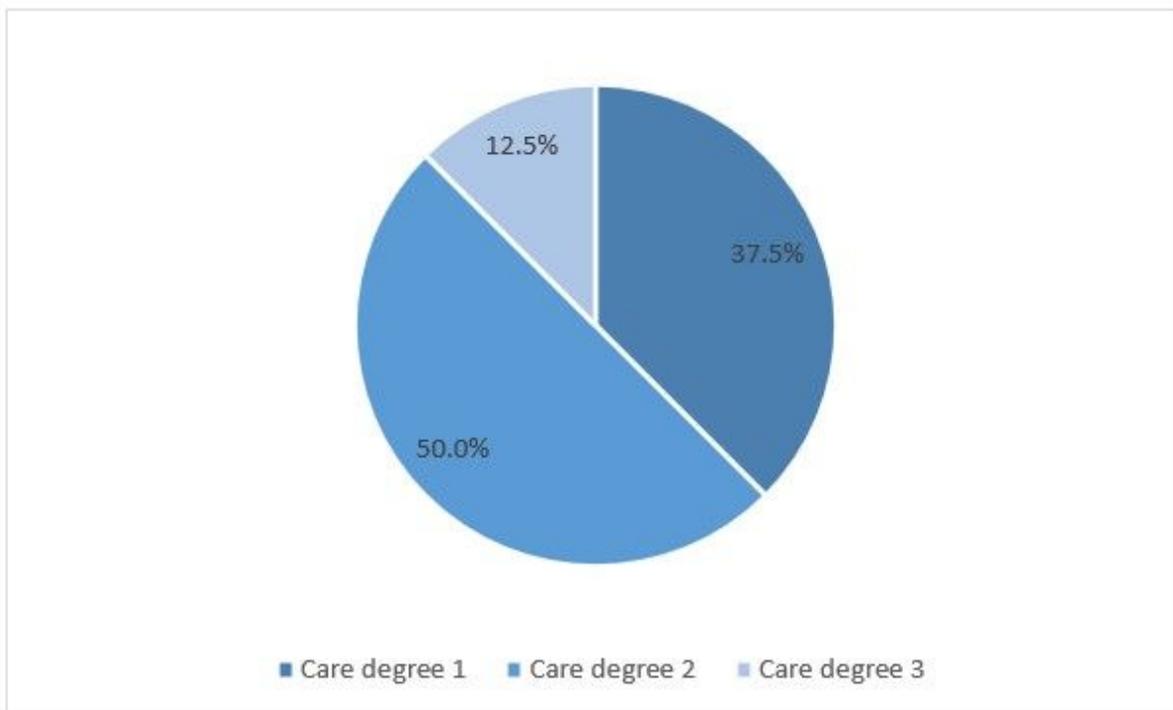


Figure 3

Sociodemographic data control group – care degrees (n=8)

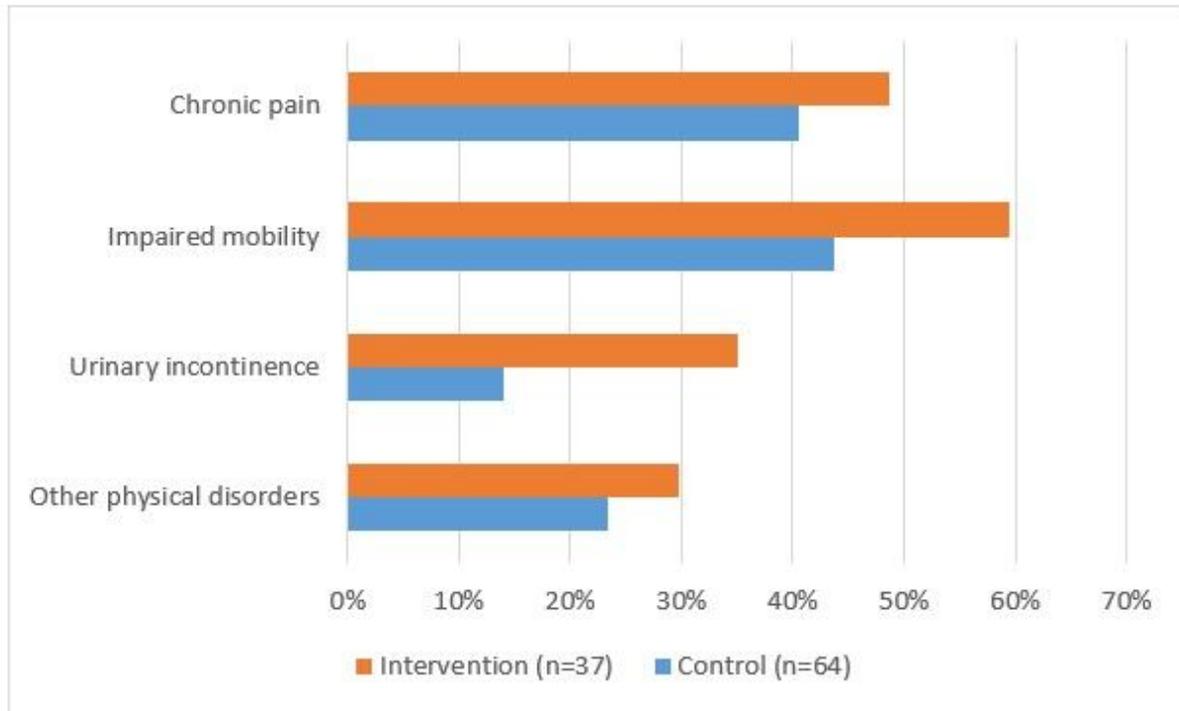


Figure 4

Sociodemographic data intervention vs. control group – physical limitations

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