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Validation of Housing Standards Addressing Accessibility - Exploration of an Activity-Based Approach

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Abstract

The aim was to explore the use of an activity-based approach to determine the validity of a set of housing standards addressing accessibility. This included examination of the frequency and the extent of accessibility problems among older people with physical functional limitations who used no mobility device (n=10) or who used a wheelchair (n=10) or a rollator (n=10). The setting was a kitchen designed according to current housing standards. The participants prepared lunch in the kitchen Accessibility problems were assessed by observation and self-report. Differences between the three participant groups were examined. Performing well-known kitchen activities was associated with accessibility problems for all three participant groups, in particular those using a wheelchair. The overall validity of the housing standards examined was poor. Observing older people interacting with realistic environments while performing real everyday activities seems to be an appropriate method for assessing accessibility problems.

Keywords: Functional limitations, housing design, person-environment fit, older people, occupational therapy.

Introduction

The growing size of the ageing population raises a societal challenge to design accessible housing meeting this population's requirements. The pertinence of this problem is underscored by the fact that the frequency and severity of functional limitations increases with age and that the majority of persons experiencing functional limitations are older (Crews and Zavotka, 2006). Stineman et al. (2007) found that housing accessibility, especially the use of mobility devices, was associated with an increased probability of encountering difficulties in performing everyday activities. Moreover, accessible housing has been shown to critically support older persons' ability to maintain health (Fänge and Dahlin Ivanoff, 2009) and independence (Wahl et al., 2009), and perceived behavioral control is important to determining expectations of senior housing (Huan, 2012). Since older persons generally spend most of the day at home (Heyl et al., 2005), the design of accessible housing is central to healthy aging.

Housing standards play an important role for the provision of accessible housing as they are intended to accommodate people with functional limitations (Preiser and Ostroff, 2001). The present study focused on standards that specify housing accessibility, defined in metrics, hereafter referred to as standard definitions. Architects use standard definitions to steer by during the design process (Nickpour and Dong, 2009). It is therefore crucial that these standards are valid in the sense that they are defined to enable environmental interaction so that people with functional limitations are able to perform everyday activities. However, a review of research with a potential to inform housing standard definitions addressing accessibility shows that accessibility research is sparse and has hitherto mainly addressed isolated aspects such as reach, seat height, and space requirement. Moreover, such research has primarily addressed industrial work station design rather than housing design and the research has been conducted in laboratory like environments (Helle et al., 2011). Studies performed in non-realistic environments that do not involve real human activity may not be valid for establishing housing standard definitions. However, to the best of our knowledge, the validity of housing standard definitions has not recently been investigated in a manner that mirrors real life situations, although this intuitively would seem to be appropriate.

Most previous accessibility research has been concerned with the fulfillment of existing standards (Steinfeld and Danford, 1999) and has therefore focused on the environment rather than on the interaction between environment and person (Thapar et al., 2004). Based on the notion of person-environment fit (p-e fit), as expressed by Lawton and Nahemow (1973) and

Lawton and Simon (1968), Iwarsson and Ståhl (2003) suggested that accessibility should be deployed as a relative concept that addresses a person-environment fit (p-e fit) relationship. Yet, there is a need to operationalize this relationship and to explore methodological approaches useful for the investigation of the p-e fit. Occupational therapy models serve to describe person-environment-activity-transaction and aim to increase our understanding of what limits or restricts activity performance (e.g. Townsend and Polatajko, 2007). It would accordingly seem relevant both to investigate p-e fit and to explore the potential of using an activity-based approach to examine the extent to which housing standard are defined to enable individuals with functional limitations to perform everyday activities such as the ability to force a threshold, enter a room, move around in the room, reach for objects in wall cupboards, etc.

The prevailing definition of accessibility (Preiser and Ostroff, 2001) does not take user perceptions into account, which has been criticized among others by (Thapar et al., 2004). It has been argued that observation and self-report provide distinct, complementary information, and a combination of both methods is therefore recommended (Wæhrens, 2010; Bean et al., 2011). To establish the validity of housing standards, it is important to obtain knowledge that furthers our understanding of both p-e fit and activity performance. A further critique of current accessibility research is that it usually emphasizes the requirements of those using a wheelchair over those of other groups of users (Thapar et al, 2004), even if such groups, e.g. those using a rollator, a wheeled walker, are often much larger (Kaye et al., 2000). It is therefore important to investigate accessibility problems in different groups. To the best of our knowledge, differences in accessibility problems among diverse user groups are largely unexplored.

The overarching aim of this study was to contribute to the methodological advancement needed for the establishment of valid housing standard definitions. The specific aims were to explore the use of an activity-based approach to investigate the validity of a set of housing standard definitions addressing accessibility. This was done by examining the frequency and extent of accessibility problems among groups of older people with different physical functional limitations when they performed real activities in a realistic housing environment. This included examination of differences in accessibility problems among those not using mobility devices, those using a rollator, and those using a wheelchair. Another aim was to examine differences in data on accessibility problems collected by observation and self-report.

Methods and materials

Setting

The study was conducted within an ordinary kitchen that was designed according to current housing standards addressing accessibility, defined in metrics and operationalized by means of 12 items of the environmental component of the Nordic Housing Enabler (Iwarsson and Slaug, 2008) (see Table I).

Table I in here

An ordinary kitchen was used because it is a delimited environment in which a series of well-known everyday activities are performed. The kitchen was furnished along one side of the room and consisted of a kitchen counter with a workstation with leg room beneath the table suitable for sitting work, a wash basin, a refrigerator, a dishwasher, an induction stove, a coffee machine, a kettle, wall cupboards, and base units. An ordinary side-hinged door with threshold opened up into the kitchen. Participants were requested to perform a standardized activity defined as: open the door and enter the kitchen, cook an egg, prepare an open-faced sandwich and make a cup of coffee, clean the dishes, leave the kitchen and close the door behind. This included e.g. taking objects from the wall cupboards and base units and loading the dishwasher. The kitchen equipment was strategically arranged to ensure that participants had to interact with each of the 12 design features under investigation several times during the activity. Objects placed in the wall cupboards and base units were positioned at the very front of the shelves. Glasses and cups were not stacked, while plates and cutting boards were piled three and three. It should be noted that not all 12 design features that referred to the standard definitions under investigation were of relevance to all participants. For example, standards for floor space and door width were not considered relevant to those not using mobility devices, and the standard definition targeting legroom beneath the kitchen counter was only relevant to those who were seated during the activity.

Sampling

Municipality health professionals, i.e. activity center staff, community nurses, and occupational therapists were contacted by telephone and asked for assistance in identifying potential participants. If the professionals agreed, they were informed verbally and in writing about the study aims and provided with material necessary for the identification of potential participants. Purposive sampling techniques complemented by snowballing sampling among participants were employed (DePoy and Gitlin, 2011). The following inclusion and exclusion criteria were applied: 60 years of

age or older; living in ordinary housing; regularly prepare lunch and coffee and clean the dishes at least twice a week; having primarily physical functional limitations and being cognitively well-functioning. Individuals with severe hearing or visual functional limitations were excluded. The target sample was 30 participants who were assigned to one of three groups according to their mobility device use: using no mobility devices (n=10), using a rollator (n=10), or using a manual or powered wheelchair (n=10). Participants using a mobility device were excluded if they did not use it during the kitchen activity.

The professionals were instructed to verbally inform potential participants and to hand out information sheets that described the study aims and the participants' role in the data collection. According to the professionals, a few of the potential participants declined to participate for reasons such as lack of time or because they felt uncomfortable about participating in research. The professionals collected contact information, which was sent to the first author (TH) in agreement with the potential participants. She contacted them by phone to check that the inclusion and exclusion criteria were met. At this stage, another two participants backed out for the same reasons as those reported by the professionals.

Study participants

The participants' average age was 75 years (range 60-93, standard deviation (SD) = 9.11); 26 were single-living. Those using a wheelchair were the younger than those using a rollator or no mobility device. The group of participants using a rollator included nine women; only six women participated in the other two groups. The participants had different degrees of physical functional limitations, but they all had problems in the form of reduced spine and/or lower extremity function. Limitations of stamina and reduced upper extremity function were reported by 23 participants (Table II).

Table II in here.

Ethics

Individual appointments were made if participants gave verbal consent by telephone to participate in the study. Written consent was obtained immediately prior to the data collection. Participants were informed that they could withdraw from the study at any time without any consequences, and that data would be anonymized and treated confidentially. The study was

approved by the Danish Data Protection Agency. Formal ethical approval was not required for this kind of research in Denmark.

Instrumentation

The participants' physical functional limitations and use of mobility devices were assessed dichotomously by the personal component of the Housing Enabler (Iwarsson and Slaug, 2001). In a Swedish context, the Housing Enabler has demonstrated content validity (Iwarsson and Slaug, 2000), construct validity (Fänge and Iwarsson, 2003), and good inter-rater reliability (Iwarsson and Isacsson, 1996). The Nordic version of the Housing Enabler (environmental component) (Iwarsson & Slaug, 2008) is considered sufficiently reliable for use in Nordic contexts (Helle et al., 2010). Additional participant characteristics (age, sex, height, and weight) were registered as displayed in Table II.

Data on accessibility problems were collected by means of a study-specific structured observation scheme and a study-specific structured interview questionnaire. These instruments were developed based on textbooks on psychometrics, observation schemes, questionnaire methodology, and traditional usability tests (see e.g. Streiner and Norman, 2008; Schaeffer & Pressers, 2003; Jordan, 2001). An accessibility problem was defined as the degree of effectiveness and efficiency with which participants interacted with the environment when performing a specific activity.

The observation scheme and the interview questionnaire each consisted of 12 identical items. These items referred to the 12 kitchen design features for which the validity of the standard definitions was examined. The researchers observed the participants' accessibility problems during the activity, and the participants were asked to self-report their perception of the extent to which each of the 12 design features caused accessibility problems. In both protocols, the accessibility problems were rated on an ordinal scale ranging from no problem, minor problem, and severe problem to impossible (Table III). The development of the ordinal scale used in the observation scheme and interview questionnaire was inspired by the scoring system of the Enabler Concept (Steinfeld et al., 1979) and the Housing Enabler (Iwarsson and Slaug, 2000; 2010). In addition, the observation scheme allowed the researchers to record notes on any additional accessibility problems evolving during the performance of the activity. The interview questionnaire included two additional items: one allowing the participants to comment on any additional accessibility problems

evolving during the performance of the activity, and another item summarizing his/her perception of the overall accessibility of the kitchen.

Table III in here.

Prior to the data collection, the two protocols were piloted, and basic psychometric properties such as face and content validity were investigated. As a first step, this involved expert discussions among authors and colleagues concerning item definitions. Next, to improve the face and content validity of the items of the interview questionnaire (Streiner and Norman, 2008), cognitive interviews (Willis, 2005) were performed with five older people who did not take part in the study, but who were otherwise similar to the participants. The observation scheme and the questionnaire were subsequently piloted with an individual who did not use a mobility device and was not included in the sample, but who fulfilled the inclusion and exclusion criteria. Finally, to test inter-rater reliability (Streiner and Norman, 2008), the observation scheme was piloted with one person using a wheelchair and another person using a rollator. The observation scheme was administered while a camera technician videotaped the standardized activity performance sessions. Five raters (the first and third author, a research assistant, and two Housing Enabler instructors) trained for administration of the observation scheme watched the two videos and rated their observations independently from each other. Weighted kappa statistics (Streiner & Normann, 2008) were calculated and demonstrated good to very good reliability (mean k=0.78 for the person using a wheelchair, mean k=0.86 for the person using a rollator) (Altman, 1999). To investigate reliability during the subsequent observations (N=30), two researchers completed the data collection independently. Using the same measures, a mean reliability of k=0.80 was demonstrated, i.e. very good reliability (Altman, 1999).

Procedures

Individual data collection sessions lasted for about 1.5 hours and were administered by the first author. First, the personal component of the Nordic Housing Enabler instrument was administered (Iwarsson and Slaug, 2008) and data on participant characteristics were collected (see Table II). Next, participants were introduced to the kitchen and the standardized activity. The observation scheme was administered while the study participant performed the activity. The interview questionnaire was administered immediately after the activity had been performed.

Data analysis

All entered data were proof-read to ensure correctness of data entry. Descriptive statistics and graphs were used to examine and display the distribution of the observation and interview data. The Mann-Whitney U-test (Kirkwood and Sterne, 2003) was used to investigate whether there were significant differences regarding the accessibility problems among participants not using mobility devices, those using a rollator, and participants using a wheelchair. The Sign test (Kirkwood and Sterne, 2003) was used to investigate whether there were significant differences between the observation and interview data. P-values ≤ 0.05 were considered statistically significant.

A classical content analysis technique (Kohlbacher, 2006) was used to categorize and analyze the observation notes and participant comments. The number of occurrences per category was counted and presented if considered to be substantial (Kohlbacher, 2006). Based upon observed distributions, we report comments that occurred ≥8 times, i.e. >25% of the total sample. The statistical analyses were performed using SPSS version 20. Graphics were produced by means of Microsoft Excel, version 2010

Results

The design features that caused the most frequent and severe observed and self-reported accessibility problems across the three groups of participants were the wall cupboards' upper shelves and the base units' lower shelves. Participants who used no mobility device had the least frequent and least severe accessibility problems. Design features referring to standard definitions relevant to this group of participants caused minor to severe observed and self-reported accessibility problems (see Figure 1). For those using a rollator, all 12 design features caused accessibility problems. Design features causing the most frequent and severe observed and self-reported problems were: the base units' lower shelves, the wall cupboards' upper shelves, the threshold and the floor space by domestic appliances (see Figure 2). As to those using a wheelchair, accessibility problems were found for at least five participants for each of the 12 design features. One exception was door width, which was only reported to cause accessibility problems by four participants. The design features that caused the most frequent and severe observed and self-reported accessibility problems to those using a wheelchair were: the wall cupboards' upper shelves, the base units' lower shelves, the thresholds, the floor space in general and the wall cupboards' upper shelves (see Figure 3).

Figure 1, 2 and 3 in here.

Significant differences between accessibility problems of those not using a mobility device and participants using a rollator were observed for three design features and self-reported for five. Significant differences between participants using a wheelchair and participants using a rollator were observed for six design features and self-reported for four. .Significant differences between participants using no mobility device and those who used a wheelchair were observed for 10 design features and self-reported for all 12 features (see Table IV).

Table IV in here

Overall, no significant differences between data collected by observation and self-report were observed. Observation notes showed that the mobility devices were used for transportation purposes, such as for bringing objects from one end of the kitchen to the other. Moreover, rollators were used for sitting during the activity performance. More than 25% of the participants used the physical environment to compensate for their functional limitations, e.g. by holding on to the door frame while walking through the door or leaning against the kitchen counter during kitchen work and when walking along it. Three participants stood in front of the dish washer and the refrigerator while the rest used them laterally. Finally, it was noted that those who used mobility devices closed the side-hinged door by squeezing their fingers in between the door leaf and the door frame, giving the door a push.

Table V in here

Discussion

To the best of our knowledge, the results of the present study provide new insights into accessibility problems encountered by older people with different kinds and degrees of physical functional limitations. A striking aspect of the results is that the study participants encountered many accessibility problems while performing well-known everyday activities although the study setting (a kitchen) had been designed according to current housing standard definitions intended to ensure accessibility. The study contributes to the methodological advancement needed to nurture the establishment of valid housing standard definitions. Based on these encouraging results, we suggest that activity-based approaches should be applied to serve this purpose.

The present study demonstrates that the overall validity of the 12 housing standards definitions is poor. This finding supports recent research proposing revisions of standards addressing accessibility (Steinfeld et al., 2010; Blanck et al, 2010), particularly those purporting to accommodate those using a wheelchair (see Figure 3). However, for specific design features such as the base units' lower shelves, those using a rollator had the most frequent and severe accessibility problems. Hence, we cannot take for granted the widespread reasoning that if environments are accessible to those using a wheelchair they will also be so to others. The study demonstrates the importance of examining accessibility problems and the validity of housing standard definitions in a sample representing the broad spectrum of those people whose needs the standards are intended to meet (Keates and Clarkson, 2004). Still, most previous studies have investigated accessibility in a homogeneous sample.

In ergonomics and anthropometry the unit of analysis is often single accessibility issues such as reach investigated in relation to for instance body position (seated versus standing) or sex (see e.g. Kozey and Das, 2004; Pacquet and Feathers, 2004). In line with Kirvesoja et al. (2000), the results of the present study show that knowledge on human body size alone is not sufficient for designing environments accessible for older people with functional limitations. It is therefore difficult and maybe inappropriate to apply models of ergonomics and anthropometry with static standardized measures for the establishment of valid housing standard definitions addressing accessibility. The activity-based approach applied in the present study shows that accessibility problems arise as a result of the interaction between the individual, the mobility device, the environment, and the activity. Interestingly, we found that the environment is not only a barrier but also a facilitator (see Table V). We also found that mobility devices were used for transportation of e.g. a cup of coffee placed on the rollator or in the lap of those using a wheelchair. Forcing a threshold with a cup of coffee differs substantially from forcing it without, because the coffee will most likely topple. In addition, half of those using a rollator sat on the device during parts of the activity performance. The finding that mobility devices are integrated into the activity performance is in line with previous research (Löfqvist et al., 2009) and has implication for environmental demands such as threshold heights and space for legroom under the kitchen counter. Thus, the results demonstrate the importance of including mobility devices in the investigation of the validity of housing standard definitions and the value of examining accessibility problems in realistic environments during actual activity performance.

As demonstrated, some standards are not defined in a manner that duly enhances accessibility because the definitions do not cater for the way older people with mobility devices actually interact with the environment. One example is the standard definition for floor space positing 130 cm in front of the domestic appliances, which the study participants did not use. Instead, an accessibility problem appeared in terms of lack of legroom beneath or next to the domestic appliances (sees Table V). We also found that there is a need for additional standards (see Table V). Based on these results, we argue that standard definitions not anchored in reality seem to be of poor relevance and may have poor validity. In line with others, we suggest a revision of current standard definitions addressing accessibility (Steinfeld et al., 2010) and, moreover, identification of potentially lacking standards using an activity-based approach.

The disparity between our results and those of others as concerns the value of combining methods, e.g. observation and self-report, to obtain a full picture of the investigated phenomenon (Bean et al., 2011; Wæhrens, 2010) may be due to the definition of accessibility we applied (Iwarsson and Ståhl, 2003). In the present study, accessibility problems only addressed physical aspects of p-e fit without taking aspects such as satisfaction into consideration. Since the strength of self-report lies in its ability to capture experiences of a more subjective character, this may explain our findings. Moreover, older people may adapt to the environment as argued by Lawton (1975) and may thus not notice accessibility problems that are obvious to observers. For instance, only the observers noticed the participants' elevated shoulder while working by the kitchen counter. Based on the results of the present study, that observation seems to be a valid method for identifying accessibility problems.

Cross-sectional designs are useful for explorative purposes, but single snapshots of a complex reality do not necessarily reflect the actual situation. Moreover, we are aware that non-probability sampling techniques are expected to generate samples of participants that may be more resourceful than the population to which they belong (DePoy and Gitlin, 2011). The results of this study should therefore be interpreted with caution. However, if we assume that the study participants were the resourceful ones, the frequency and extent of accessibility problems identified would probably not be less in a random sample. It should also be noted that the three groups of participants were not comparable with respect to characteristics such as sex, age, and height. Another aspect important to consider is the study setting. Although it was an ordinary, real kitchen, it was a contrived setting created to study a specific situation. Hence, it may be relevant to address

whether or not the data collected truly reflect real life activity performance. Our results may have turned out differently if the study had been conducted in the participants' own kitchens. However, for the examination of the validity of standard definitions, it is necessary to use a standardized setting.

For the exploration and exemplification purposes of this study, the target group was limited to older people with physical functional limitations. Accessibility problems of people across a lifespan with other functional limitations such as cognition, hearing, and vision limitations should also be investigated in order to create the knowledge base for the establishment of valid standard definitions for the entire population that standards are intended to accommodate (Keates and Clarkson, 2004). Also, the use of study-specific instruments for data collection in studies of accessibility is a recurring issue within accessibility research (Steinfeld et al., 2010; Preiser and Ostroff, 2001). We therefore made an effort to test the basic psychometric properties of the study-specific protocols used in this study. With satisfactory inter-rater reliability results and an interview questionnaire that was easily understood and well-accepted by the participants, we consider the results sufficiently reliable for the purpose of the present study. However, more robust instruments with established validity and reliability should be designed for future investigation of the validity of housing standards.

Conclusions

Based on the encouraging methodological experiences gained in this study, we propose an activity-based approach to investigate whether standard definitions actually accommodate the needs of older people with functional limitations. The study showed that the overall validity of the housing standards examined is poor, and it hence supports the need for a research-based revision of these standards. A revision may benefit older people using wheelchair in particular, but also those using a rollator and even those who do not use mobility devices may benefit from such research. Consequently, there is a need for a critical review of the validity of the current housing standard definitions addressing accessibility and for identifying potentially lacking standards. Since different design features generate accessibility problems to a different extent depending on the functional capacity and type of mobility device in question, it is recommended to include people across a broad spectrum of functional limitations. For the investigation of accessibility problems based on the notion on p-e fit, observation seems to be a valid method.

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Table I. Design features investigated. All designed according to the Nordic version of the Housing Enabler standard definitions[1].

	Design feature	**Standard definition**
Space[2]	Door width	85 cm
	Legroom beneath kitchen counter[3]	60 cm depth, 80 cm width, 72cm height
	Floor space (whole kitchen)	130 cm
	Floor space where turning is necessary	130 cm
	Floor space in front of domestic appliances	120 cm
Height	Threshold	2.5 cm
	Kitchen counter height	
	- for those using a wheelchair	84 cm
	- for those not using a device	85 cm
Reach	Kitchen counter depth	60 cm
	Wall cupboards' upper shelves	30 cm depth 165 cm above the floor
	Wall cupboards' lower shelves	30 cm depth, 140 cm above the floor
	Base units' upper shelves	30 cm depth, 42 cm above the floor
	Base units' lower shelves	30 cm depth, 2.5 cm above the floor

[1]An instrument assessing housing accessibility (Iwarsson and Slaug, 2008).

[2]Only relevant for those using mobility devices.

[3]Relevant only for those using a wheelchair and half of those using a rollator who were seated during the activity.

Table II. Sample characteristics (N=30).

Characteristic	**No use of mobility devices** n=10	**Use of rollator** n=10	**Use of wheelchair** n=10	**Total** N=30
Age, years				
- mean (SD)	79.1 (9.13)	79.0 (6.11)	66.8 (5.96)	74.97 (9.11)
- range	62-93	69-88	60-77	60-93
Sex				
- men	4	1	4	9 (30%)
- women	6	9	6	21 (70%)
Height				
- mean (SD)	163.7 (11.81)	164.0 (8.42)	171.4 (7.7)	166.37 (9.84)
- range	148-181	149-183	158-183	148-183
Weight				
- mean (SD)	72.1 (13.97)	76.5 (19.8)	82.0 (21.33)	76.87 (18.45)
- range	56-90	54-115	55-125	54-125
Functional limitations[1]				
- reduced spine/lower extremity function	10	10	10	30 (100%)
- limitations of stamina	8	9	6	23 (77%)
- reduced upper extremity function	7	9	7	23 (77%)
- poor balance	7	8	7	22 (73%)
- difficulty in moving head	6	5	1	12 (40%)
- reduced fine motor skills	2	3	6	11 (37%)
- incoordination	1	3	4	8 (27%)
- loss of lower extremity function	0	1	3	4 (13%)

[1]Assessed by means of the personal component of the Nordic Housing Enabler (Iwarsson and Slaug, 2008).

Table III. Definitions and operationalizations of response categories used for study-specific observation scheme and interview questionnaire.

Response category	**Response category definition**	**Additional specification of definition**
No problem	Activity completed with ease and no extra effort was required	The activity was performed easily and successfully
Minor problem	Activity completed with ease but little extra effort was required	The participant[1] had to retry to perform the activity ***one time*** (re-reaching for, re-maneuvering, retry to force the threshold, etc.), the participant bumped into the environment with the mobility device ***one time***, or if the participant visually/auditorily[2] expressed the use of a small extra effort (panting by exertion/strenuous looking)
Severe problem	Activity completed but with the use of extra effort	The participant[1] had to retry to perform the activity ***more than once*** (re-reaching for, re-maneuvering, retry to force the threshold, etc.), the participant bumped into the environment with the mobility device ***more than once***, or if the participant visually/auditorily[2] expressed the use of extra effort (panting by exertion/strenuous looking)
Impossible	Activity was not completed and participant gave up	It was not possible to perform the activity

[1]In the questionnaire "participant" was replaced by "you."

[2]In the questionnaire “visually/auditorily” was replaced by “perceived.”

Table IV. Statistical significance of differences in accessibility problems between the three samples observed by researchers and self-reported by participants for each design feature compared across groups (N=30).

Design feature	Not using/using rollator		Using rollator/wheelchair		Using wheelchair/not using	
	Observation p-value	Self-reporting p-value	Observation p-value	Self-reporting p-value	Observation p-value	Self-reporting p-value
Thresholds	.000	.000	.040	.629	.000	.002
Door width	.146	.317	.056	.100	.005	.030
Kitchen counter height	.661	.374	.002	.042	.005	.012
Kitchen counter depth	.259	.067	.208	.280	.048	.012
Floor space	.317	.012	.845	.313	.002	.001
Floor space turning	.317	.146	.010	.052	.000	.001
Floor space at domestic appliances	.005	.002	.000	.016	.001	.001
Wall cupboards' upper shelves	.191	.488	.478	.690	.000	.000
Wall cupboards' lower shelves	1.00	.549	.011	.011	.001	.019
Base units' upper shelves	.189	.022	.001	.077	.374	.049
Base units' lower shelves	.014	.048	.661	.933	.084	.022
Legroom beneath kitchen counter	-	-	.256	.412	-	-
Summary of self-reporting	-	.067	-	.001	-	.000

P-values ≤ 0.05 were considered to be statistically significant and are marked in the Table.

Table V. Observation notes and participant comments about design features investigated.

Design feature	Observation notes	Participant comments
Wall cupboards	Slowly reaching, looked concentrated and sounded slightly exhausted when reaching for objects. Stood on toes/difficult to reach when seated.	I could only reach objects placed at the two lower shelves and only if objects were placed at the very front.
Domestic appliances (stove, refrigerator and dish washer)	The stove was used frontally by standing participants. Other domestic appliances were mostly used laterally. The lack of legroom beneath or beside the domestic appliances forced those using mobility devices to sit laterally.	I had to sit sideward and use the domestic appliances laterally, because there was no leg room/space for my rollator/wheelchair.
Floor space	Limited floor space necessitated opening and closing doors. Placing themselves to obtain a good working position required re-maneuverings.	Although I could get about in the kitchen, I felt scantly of space.
Floor space turning	No participants turned around 180 or 360 degrees during the activity. When requested, turning required much precision, several maneuverings. Moreover, participants bumped into the base units and walls.	
Base units	Slowly reaching, looked concentrated and sounded slightly exhausted to reach for objects. Participants bumped into the base units.	I could only reach objects placed at the very front of the shelves.
Door	Closed the door by squeezing the fingers in between the door leaf and	

	door frame to push it to close, trying to avoid squeezing the fingers.	
Door frame	Grabbed hold on the door frame to lean against and to take-off by it, while forcing the threshold and walking through the door.	
Threshold	Participants bumped into the threshold when forcing it or they were not able to push the device over it. It was not possible to force the threshold with objects on the rollator or in the lab without the objects toppling.	I could not bring my coffee and lunch over the threshold, because this will topple.
Legroom beneath the kitchen counter	Those using rollator/wheelchair bumped into the sides of the legroom and/or placing one-self to obtain a good working position required re-maneuverings	
Kitchen counter depth	Slowly reaching, looked concentrated and sounded slightly exhausted to reach for objects placed rearmost of the kitchen counter	
Kitchen counter height	Elevated shoulders during kitchen work by the kitchen counter. Slightly bending to reach down to the work surface	
Kitchen counter	Leaned against the kitchen counter during kitchen work and when walking along the kitchen counter.	

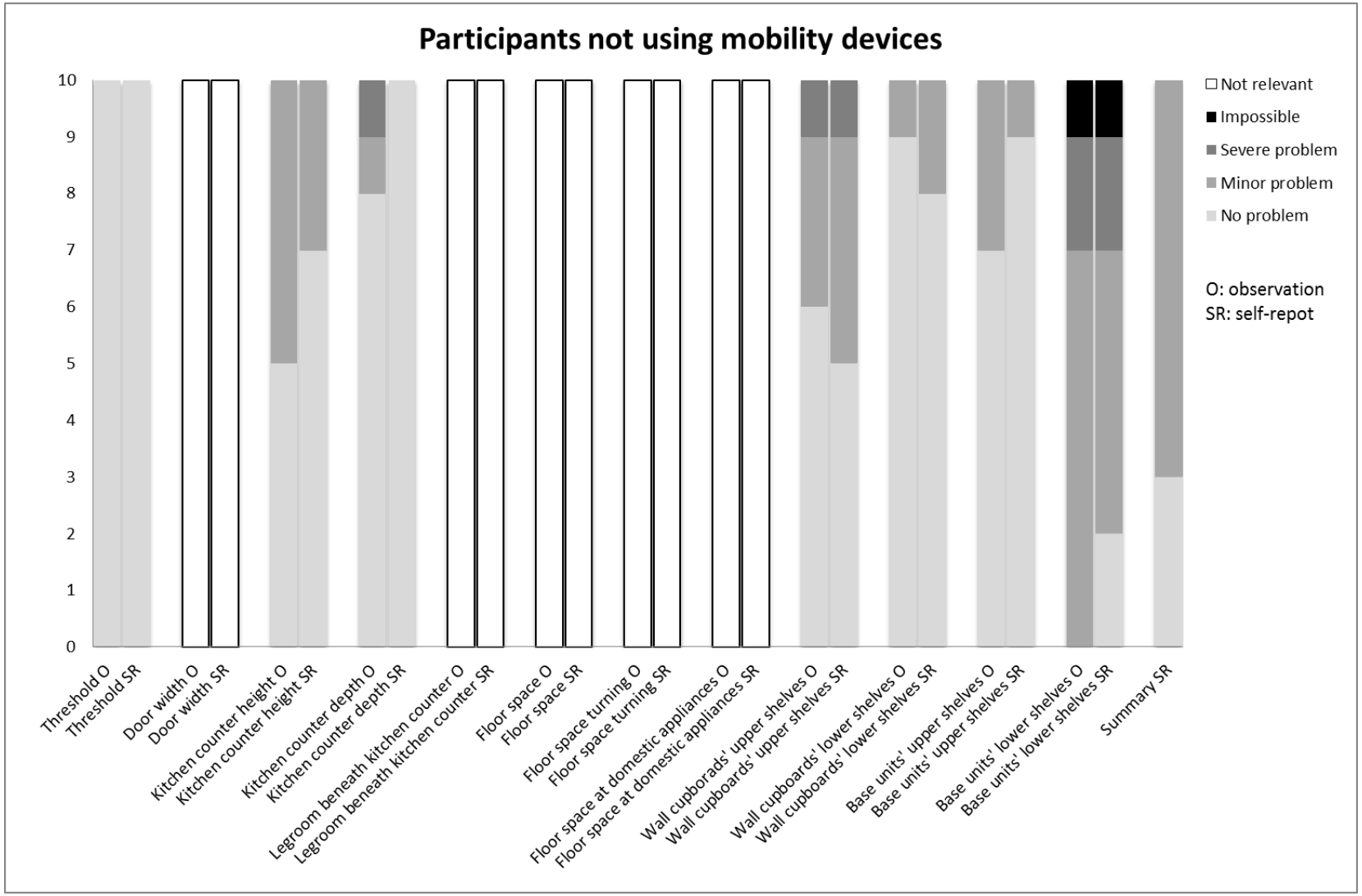

Figure 1. Number of times each of the 12 investigated design features was assessed as *no problem, minor problem* and *severe problem* or *impossible* by means of observation and self-reporting among participants not using mobility devices (n=10).

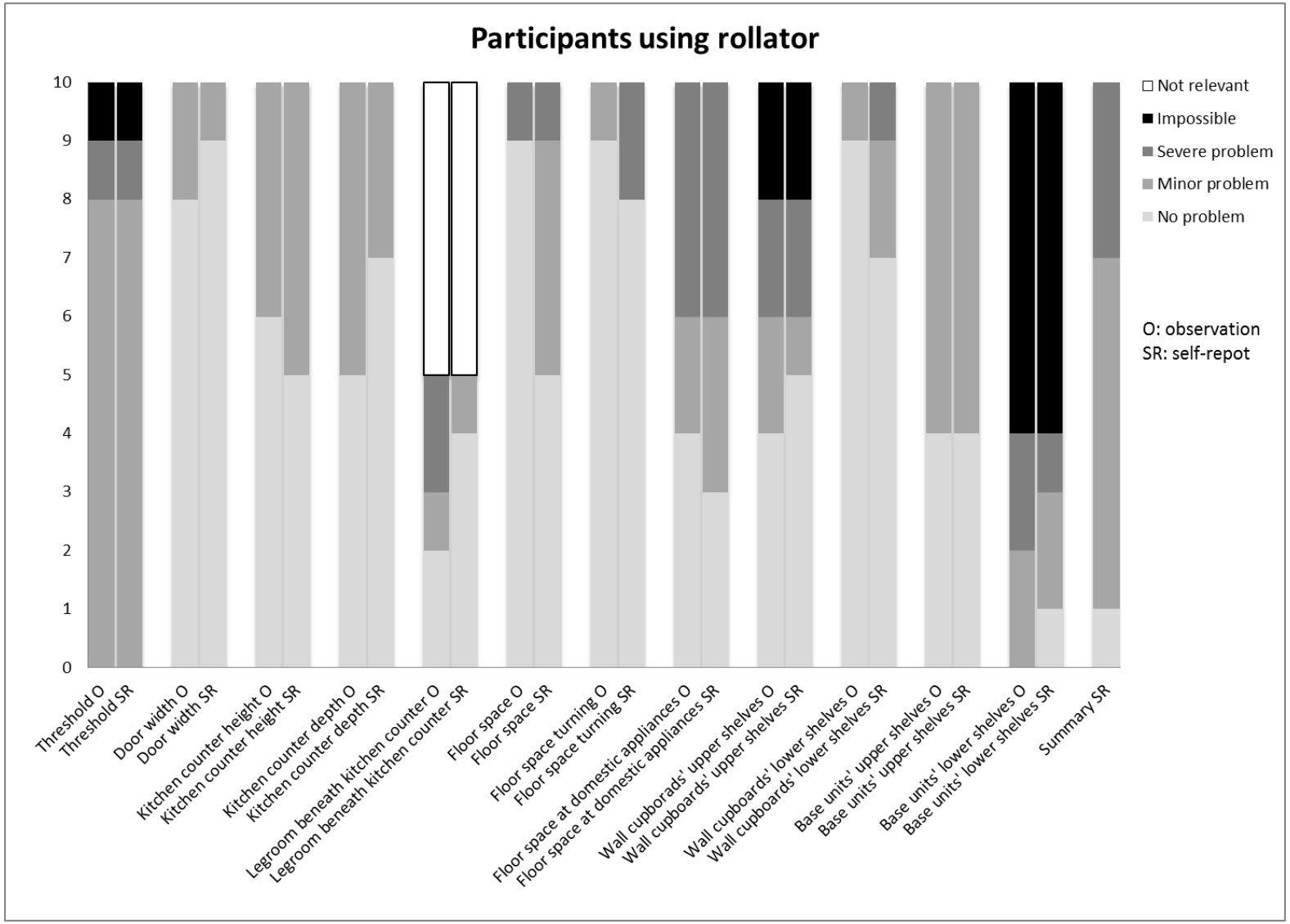

Figure 2. Number of times each of the 12 investigated design features was assessed as *no problem, minor problem* and *severe problem* or *impossible* by means of observation and self-reporting among participants using a rollator (n=10).

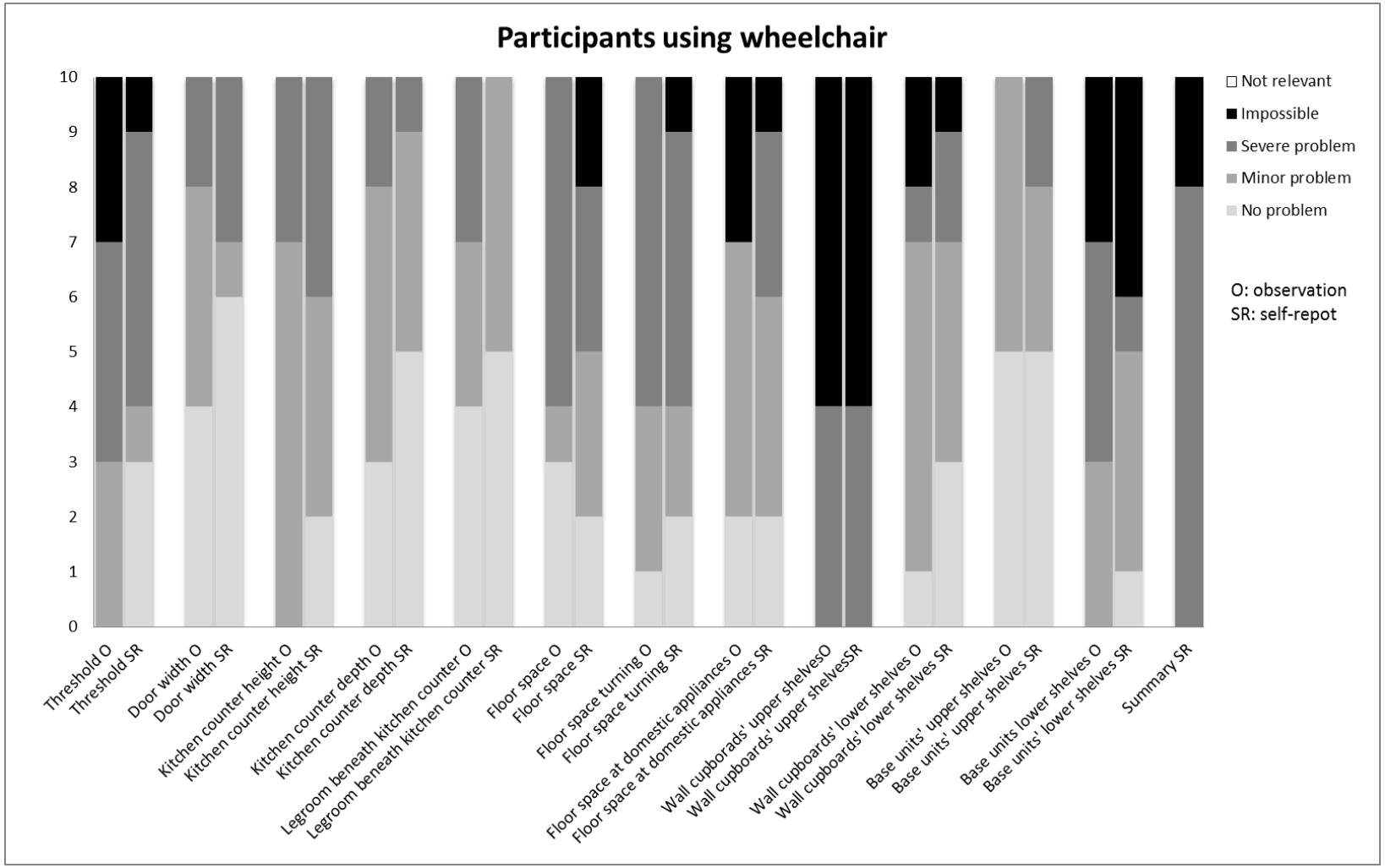

Figure 3. Number of times each of the 12 investigated design features was assessed as *no problem, minor problem* and *severe problem* or *impossible* by means of observation and self-reporting among participants using a wheelchair (n=10).