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Defining profiles of functional limitations in groups of older persons: How and why?

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ABSTRACT

Objectives: Addressing the complexity of multiple health problems in the older population, the objective was to identify combinations of functional limitations for use in simulation analysis, in order to enable predictions of the potentially most severe person-environment fit (i.e. accessibility) problems among groups of older persons.

Methods: Utilising data from 1,542 persons aged 75-89 years and applying Configuration Frequency Analysis, we tested which combinations of functional limitations that occurred more or less often than expected. Significant combinations were defined as type profiles and used in simulated accessibility analyses.

Results: Eleven combinations occurred more often and eight less often than expected ($p<0.05$). Simulations with ten type profiles predicted varied patterns of accessibility problems.

Conclusions: The use of type profiles has potential to contribute to the knowledge of combinations of functional limitations among groups of older persons. Variation in predicted accessibility problems for different type profiles helps identifying priorities in societal planning.

Keywords: physical environment, p-e fit, methodology, accessibility, simulations, p-e fit

INTRODUCTION

Multiple medical and health related problems are common in the older population (Karlamanga et al., 2007). Moreover, not only prevalence of comorbidity increases with age, but also dysfunction in body systems and limitations in physical performance. Older persons generally experience a gradual decline in physical capacity (Verbrugge & Jette, 1994), manifested as functional limitations (Nagi, 1991) such as difficulties in moving, in bending and kneeling, in poor balance, reduced ability in handling and gripping, etc. Coexistence of several such conditions complicates health care related assessments, decisions and preventive measures; considering them in isolation may compromise validity. The knowledge of the prevalence of multiple conditions or combinations of conditions and how to make use of such knowledge e.g. in research on ageing and public health is still limited. Sound methodology is a basic prerequisite, but there is no standard analytical approach to study this complexity. The potential benefits of extending the knowledge in this field and at the same time finding feasible ways of analyses are considerable, as functional limitations themselves have been shown to have predictive value for various health related outcomes, including medical as well as economic aspects (Guralnik & Ferrucci, 2003).

In research on ageing, there is an increasing interest for studying person-environment relationships, of relevance for example for societal planning issues such as housing provision for senior citizens (Wahl & Iwarsson, 2007). The aspect of person-environment relationships in focus for the current study is accessibility, an outcome that has been focused both in research and political debate during recent years. Based on recent findings consistently demonstrating relationships between housing accessibility and aspects of health (see e.g. Oswald et al., 2007), it is imperative from a public health perspective to make the built environment accessible for all, regardless of functional capacities (United Nations, 2006). Underlying the concept of accessibility is Lawton and Nahemow's ecological model of ageing (Lawton & Nahemow, 1973), also referred to as the competence-press or person-environment (P-E) fit model. This model defines the person in terms of a set of competencies, and the environment in terms of its demands, called environmental press. With the addition of the docility hypothesis (Lawton, 1986), stating that those with lower personal competencies are more vulnerable to environmental press, whereas those with higher competencies can withstand greater environmental press, this has become one of the most influential P-E fit models. According to the model a balance between the individual's competence and the environmental press can be achieved by changing one or the other component, or both. A very important implication is that a person's level and range of action can be maintained or improved, even if the functional competence deteriorates, provided that the demands made by the environment are lowered at the same time. Applying the notion of P-E fit to accessibility, this means that accessibility theoretically can be achieved for all citizens, regardless of functional capacities, if the environmental demands are sufficiently reduced.

Based on the ecological model of ageing and the notion of P-E fit, a methodology for assessing accessibility problems has been established (Iwarsson & Slaug, 2001), originating from the so-called Enabler Concept (Steinfeld et al., 1979). The principal idea of this methodology is that accessibility problems can be estimated by combining data on the individual's functional limitations (personal component), with data on presence of physical barriers in the environment (environmental component). Applying this methodology in empirical research on individuals in their actual environments as well as in professional practice, extensive evidence of the validity of accessibility as a relevant variable in research on ageing, rehabilitation, and public health have been published (see e.g. Oswald et al., 2007), and the relevance for practice has been reported on (see e.g. Fänge, Risser & Iwarsson, 2007). This methodological platform constitutes the framework for this study.

However, to be able to validly capture accessibility problems on a societal level, applying a public health perspective, it is necessary to further develop this methodology for group- rather than individual-based approaches. Since the personal component is crucial for the generation of accessibility problems (Iwarsson & Ståhl, 2003), one basic condition for further methodological development is to increase the knowledge about the occurrence and interaction of combinations of functional limitations (Guralnik & Ferrucci, 2003) in different target groups. One such group of particular importance for societal planning is the older segment of the population, as we know that older people often have more than just one functional limitation.

Even though there are studies reporting the prevalence of single functional limitations (Barbotte, Guillemin, Chau & Lorhandicap group, 2001), there are few studies that explicitly focus on the combinations of functional limitations and/or methodological approaches suitable for such research. In one study, Carlsson and co-workers (2002) used cluster analysis in an attempt to explore associations within combinations of functional limitations. However, the results were not sufficiently conclusive to establish it as the methodology of choice. That is, even though the sample size was only 72 cases, cluster analysis resulted in 25 different combinations of functional limitations to consider. While several studies of combinations of diseases or medical conditions recently have been published (van den Akker, Buntinx, Roos, Knottnerus, 2001; Crisafulli et al., 2008; Karlamangla et al., 2007), the extensive literature search accomplished for the current study highlighted the lack of similar research concerning functional limitations, also confirmed by a recent review article (Alves, Leite & Machado, 2008).

Based on the notion of P-E fit, combinations of functional limitations implies a set of concerns regarding the environmental design from an accessibility point of view, where even conflicting considerations may need to be balanced and evaluated. Consequently, it would provide important information for physical planning purposes to know whether the presence of some functional limitations is associated with the presence or absence of others. For example, as loss of sight and limitations in movement taken separately calls for very different environmental design in order to prevent accessibility problems, it would be valuable to know if they are more or less likely to occur together. By not only considering how frequently different combinations occur but also the strength of their internal associations, additional information would be provided. Such information could be of particular use in situations where knowledge of the full panorama of functional limitations is limited; i.e. if the occurrence of some functional limitations is known, then the probability for other functional limitations to occur or not in combination could be estimated. Thus, there is a need to assure by means of statistical testing, that combinations appearing to indicate stronger internal associations do not merely represent chance findings. To achieve this analytical goal we have explored a statistical method not commonly used within this research field, Configurational Frequency Analyses (CFA) (Krauth & Lienert, 1982), which has been specifically developed to analyze combinations of dichotomous variables, in terms of their internal associations. Furthermore, after the identification of relevant combinations, such combinations could be used to define type profiles of functional limitations on group or population level. That is, type profiles can be regarded as representing different groups of people, characterized by their specific combinations of functional limitations.

With such knowledge at hand, in order to explore outcomes in terms of sets of priorities for improved housing accessibility for different groups of people, additional steps of methodological development are needed. One specific challenge in research on ageing and environments is that large-scale experiments are not feasible to conduct. Within research on population health and health care delivery, there has been a growing use of simulation techniques (Fone et al., 2003; Gaba, 2004). Since such techniques are especially appropriate when you want to predict the results of changing some pre-conditions, for example the characteristics of the target group, they might be useful in research based on the notion of P-E fit. Without implying any statistical simulations per se, basic analyses can be made by calculating various outcome variables for different pre-defined scenarios (Gaba, 2004).

The overall purpose of this methodological study was to generate knowledge on combinations of functional limitations and to lay the ground for further methodological development. The specific aim was to identify relevant combinations of functional limitations among groups of older persons, to define these combinations as type profiles and to use them in simulated accessibility analyses, thereby enabling predictions of the potentially most severe accessibility problems for different groups of older persons.

METHOD

Database and data collection

For this study, part of the ENABLE-AGE survey study database was utilised, comprising data on personal and environmental variables among persons aged 75-89 years, in national samples from four European countries (N=1,542). The ENABLE-AGE Project is a cross-national, interdisciplinary research project, focusing on home and health. Details of the project have been published elsewhere (see e.g. Iwarsson et al., 2007; Oswald, et al., 2007).

The national sample characteristics and sizes were: Latvia, 75-84 years (n=303), Germany, 80-89 years (n=450), Sweden, 80-89 years (n=397) and Hungary, 75-84 years (n=392). Women constituted 80% of the study sample. Basic demographic characteristics for the total sample are given in Table 1. All data of the ENABLE-AGE Survey Study were collected at home visits by raters trained for reliable administration of an extensive set of instruments.

(Table 1 in here)

The Housing Enabler instrument

One of the instruments used in the ENABLE-AGE Survey Study, in order to capture housing accessibility was the Housing Enabler (HE) (Iwarsson & Slaug, 2001). This instrument consists of an assessment of the personal component of P-E fit, i.e. presence or absence of functional limitations such as “Severe loss of hearing”, “Prevalence of poor balance”, “Difficulty in handling and fingering”, etc. (13 items), and dependence on mobility devices (2 items), and an assessment of the environmental component of P-E fit, i.e. presence or absence of physical environmental barriers (188 items). The functional limitations as well as the environmental barriers were assessed by trained raters who have acquired their expertise and knowledge through special training courses. All the functional limitations are assessed by means of a combination of observation and an interview with the participant, following detailed instructions and definitions for each item provided in a manual (Iwarsson & Slaug, 2001). The assessment of the environmental barriers follows an extensive checklist, where barriers are defined in relations to national guidelines and standard specifications. Based on the assessments of the personal and environmental components, a score representing the predicted magnitude of accessibility problems in each case can be calculated. The score is calculated by use of a matrix comprising predefined severity ratings 0-4, where the profile of functional limitations and use of mobility devices identified in each person is juxtaposed with the environmental barriers found present in the home environment; higher scores mean more accessibility problems (Iwarsson, 2005).

Content and construct validity as well as inter-rater reliability of the HE have successively been strengthened (Iwarsson & Slaug, 2001), in Swedish (Fänge & Iwarsson, 2003; Iwarsson & Isacsson, 1996) as well as in cross-national (Iwarsson, Nygren & Slaug, 2005; Helle et al., 2010) empirical studies. The instrument is being used in research on ageing and occupational therapy research (see e.g. Iwarsson, 2005) as well as in municipality practices (Fänge & Iwarsson, 2005; 2007) and for building up databases useful for housing planning and provision (Fänge et al., 2007).

Items, categories and profiles of functional limitations

To define the functional limitations of an individual in this study, we used the items that make up the personal component of the HE instrument, with the exception of the item "Extremes of size or weight", as the validity of this item has been questioned (Jensen, Iwarsson, Ståhl, 2002). It should be noted that two items in the HE instrument are treated as belonging to the personal component, though they actually concern use of mobility devices. This is based on the argument that use of mobility devices can also be seen as a manifestation of a worsening condition in a functional limitation present. Furthermore, as the ultimate aim of this study is to support societal planning, e.g. housing provision for senior citizens, use of mobility devices is particularly important as they pose extra challenges on the design of the physical environment (Brandt et al., 2008). Thus, the personal component used for this study comprised 12 items of functional limitations and two on use of mobility devices, with occurrences as presented in Table 2.

(Table 2 in here)

With 14 items of functional limitations / use of mobility devices, the number of theoretically possible combinations is 2^{14}=16,384. In order to reduce this number and to increase the likelihood of identifying relevant combinations, we decided to join single items of functional limitations into broader categories. In accordance with the aim of the study, the basic principle was to join items that contribute to the magnitude of accessibility problems in a similar manner. To arrive at a statistically manageable number of categories, we used an approach of several parallel steps, where different perspectives were considered. We tested the internal correlation of the items, both in our empirical data and in the scoring potential of the items as pre-defined in the HE instrument (Iwarsson & Slaug, 2001). We asked an experienced occupational therapist (OT) to categorise the items without any knowledge of the results of the correlation analyses and only based on her professional knowledge of which items that by experience may result in similar accessibility problems. Further, through discussions taking the outcomes of the correlation analyses into consideration, together with the OT suggestion and reviews of relevant basic concepts in the International Classification of Functioning, Disability and Health , ICF (WHO, 2001), we came up with a list where the 14 items were categorised into six broader categories (Table 3). Just as in the original items of the HE, these categories were treated as dichotomous variables in the forthcoming analyses, with the values of 1 or 0 (presence/absence of a category of functional limitations). For those categories that included more than one functional limitation item, one item present was sufficient to assign the category the value of 1. Consequently, a category with the value of 0 meant that all the functional limitation items included were absent. For an overview of the categories, see Table 3.

(Table 3 in here)

The six categories could then theoretically be combined into 64 different patterns, ranging from 0 on all to 1 on all six categories. Such patterns, combining different values of presence or absence of all these six categories, together formed what we call profiles of functional limitations. However, including only persons with at least one functional limitation in the analysis, we in fact reduced the number of profiles that theoretically could occur from 64 to 63. In Table 4, the occurrences of the profiles of functional limitations in our sample are listed in descending order.

(Table 4 in here)

Statistics

At the prospect of this study we explored a statistical method, CFA (Krauth & Lienert, 1982), which is particularly adequate for analyzing combinations of dichotomous variables, in terms of their internal associations. Basically, CFA implies statistical testing of whether the occurrence of a combination is significantly higher (overrepresented) or lower (underrepresented) than expected, relative to the individual occurrence of each functional limitation. The expected occurrence is calculated by multiplying the probabilities of the individual occurrence of each of the functional limitations. Thus, an overrepresented profile indicates stronger internal associations of the functional limitations within the combination, while an underrepresented profile indicates weaker internal associations. We ran the CFA analysis on the ENABLE-AGE Survey Study database, testing the theoretically possible combinations of functional limitations on all four national samples, together and separately. Only participants with at least one functional limitation were included in the CFA (n=1,333), as the explorative goal of this analysis was specifically to detect relevant combinations among those with the presence of functional limitations. The use of CFA is a novel, yet promising approach to achieve this analytical goal. CFA employs a rather simple and straightforward algorithm, which is not constrained by the complicacies that other alternative approaches, such as the more common methods of hierarchical cluster analysis and principal component analysis, unfold in analyzing dichotomous variables (e.g. Rencher, 2002).

From the results of the CFA analyses, we targeted those profiles of functional limitations that came out as statistically significant ($p<0.05$), either as occurring more or less frequently than expected, relative to the individual occurrence of each functional limitation. However, in order to have profiles that appear meaningful to analyze, we also limited the targeted profiles to those that occurred with a frequency of at least ~2 % of the total sample. For comparing / contrasting reasons we decided to include the significantly underrepresented profiles in the next steps of the analysis procedure as well.

Simulations

The ten targeted profiles were then explored as type profiles in simulated accessibility analyses. Simulations here only imply that instead of using the empirical data for the environmental barrier items, in the analyses the barriers were treated as they were all present. In that sense, "worst-case scenarios" were simulated. For every person we thus calculated accessibility scores for all of the 188 environmental barriers, in accordance with the type profile adherent to their actual combination of functional limitations. In the ordinary scoring procedure, the pre-defined severity ratings (0-4) in the intersections between functional limitations and environmental barriers are summed up to a total accessibility score. However, since these analyses targeted type profiles with items of functional limitations joined into broader categories, in the current study we used a modified scoring procedure. First, we calculated the average rating for each category of functional limitations, and then summed up the average ratings of the categories. This was done in order to balance the influence of the limitations within a category. For example, for the type profile “Limitations in movement and limitations in upper extremity” this means the average of ratings for functional limitations D, E, F, G, K + the average of ratings for H, I, J (see Table 2 for legends to capital letters). Thereafter, separately for each of the type profiles, the sums of these average scores were calculated for every barrier. In that way, the magnitude of accessibility problems can be predicted on environmental barrier level. Finally, environmental barriers were ranked according to the accessibility scores, thus making it possible to detect varying patterns of environmental barrier ranking among the type profiles. That is, the purpose was to theoretically predict the environmental barriers potentially causing the most severe accessibility problems for different groups of older persons, represented by the type profiles. In order to limit the length of table presentation, only items that were ranked among the top twenty items by at least one of the type profiles were included.

RESULTS

Profiles of functional limitations

Out of the 63 possible profiles, 19 came out as statistically significant ($p<0.05$) in the CFA. Eleven of the profiles occurred more often than expected (overrepresented), and eight occurred less often than expected (underrepresented). Detailed results of the CFA are given in Table 5, for five over- and five underrepresented profiles, selected since they displayed the highest observed frequencies (at least ~2%). These ten significantly over- or underrepresented profiles covered 73.0 % of the cases in our dataset. In addition, there were three non-significant but frequent profiles with an occurrence ranging from 2.3 % to 5.0 %, as shown in Table 4.

The occurrence of the ten significant profiles selected for further analyses, denoted type profiles, ranged from 1.9 % to 26.7 %. Eight of them included more than one category of functional limitations, and five of them included three or four categories. When running the analyses separately for each of the national samples, only one to four of the profiles came out as significant in each. The single largest profile in terms of occurrence (26.7 %), i.e. with limitations in movement only, was significant in three of the four national samples. As there is limited additional value in presenting the results for each national sample, Table 5 only shows results for the total sample.

(Table 5 in here)

Simulations of accessibility problems

Simulations of accessibility problems showed different patterns of barrier ranking for the ten type profiles (Table 6). When the category "Limitations in movement" was included in a type profile, there was a larger proportion of Outdoor and Entrances items among the top ranking environmental barriers, compared to type profiles with "Limitations in upper extremity" included. In the latter type profiles, the Indoor items dominated the top ranking barriers. In five type profiles "Wall-mounted cupboard/shelves placed extremely high" and "No grab bars at shower/bath" had the two top positions. In three type profiles with "Severe loss of hearing included", "No telephone with amplified sound" had the top position in two, and in the third, this item was found in position three. In two type profiles with “Loss of sight” included, environmental barrier items related to stairs and lifts held half of the top twenty positions. The type profile including only “Limitations in upper extremity” had items related to apparatus / control handling and door mechanisms in more than half of the top twenty items. Sixty-two (33 %) of the 188 environmental barrier items had at least one top twenty position, and 58 (31 %) of these had a top twenty-position among the significantly overrepresented type profiles.

(Table 6 in here)

DISCUSSION

The main contribution of this explorative study was to take further steps in building a useful and practicable methodology for identifying relevant combinations of functional limitations that can be defined as type profiles on group level, applying a public health perspective. While also extending the overall knowledge on the occurrences of combinations of functional limitations in a large sample of older people, above all this study demonstrates the potential gain of using type profiles in simulation analyses, with health related outcome variables. In this study only very basic simulations were undertaken, ranking the predicted accessibility problems generated by the combination of type profiles of functional limitations and barriers in the home environment. Theoretically, this methodology could be used for much broader purposes and deserves further development. For societal planning, when additional studies have taken advantage of and made use of this methodology, it may prove a very important achievement. While hitherto not often highlighted in public health literature, it is of vital importance for health promotion and public health efforts to create physical environments supportive for health.

Though there has been an increasing awareness of the value of assessing the functional capacity of older people from a public health perspective (Carlsson et al., 2002; Guralnik & Ferrucci, 2003), this is still a research field where knowledge is scarce and further progress is required. This study represents a methodologically innovative approach, where we explored and analysed the occurrences of specific combinations of functional limitations in a sample of older people in four European countries. The results deliver new insights as they demonstrated a high occurrence of multi-combinations, with just a few combinations that stood out as indicating stronger internal associations of the functional limitations included. In this regard our results add valuable information to the existing knowledge in this research field, although it should be kept in mind that the results have to be interpreted with caution and need to be replicated in further studies before any inferences can be made.

The choice of CFA as a method to identify relevant profiles of functional limitations was preceded by careful considerations of more conventional statistical methods. As mentioned in the introduction, cluster analyses have been undertaken earlier and pointed out as a possible pathway to follow (Carlsson et al., 2002). While that approach was found to be a more promising method than factor analyses, it failed to produce sufficiently conclusive results that could be interpreted and further explored in a meaningful way. Moreover, a weakness of cluster analyses that was discussed by Carlsson et al. is the lack of possibilities for statistical testing of the clusters. That is, cluster analysis is purely data descriptive in resting upon subjective decisions, and thus the profiles previously presented were identified only by means of qualitative comparisons of different patterns. By searching and reviewing relevant literature, the CFA was found as a particularly appropriate method for the dichotomous variables we are dealing with (von Eye, 1990; Krauth, 1993). Compared to factor and cluster analyses, interpretation of CFA results is straightforward; depending on whether it occurs more or less often than expected relative to the individual occurrence of each functional limitation, the tested combination is either overrepresented or underrepresented in the data. In the current study the statistical testing applied did not strictly follow the statistical conventions. Running a CFA on six categories implies a multiple testing situation and α-adjustment by use of the Bonferroni correction is conventionally recommended to control for the overall “experiment-wise” error rate. However, the rational of statistical hypothesis testing is not applicable in the conventional sense to an explorative analysis, not based on explicit hypotheses on statistical effects but on a heuristic search for structure in the data. Thus, we decided to consider all combinations for further examination which were significant at the 5 % level. As demonstrated by the current results, CFA can be recommended for future studies of this kind.

Although successful for the identification of significant profiles of functional limitations, a concern connected with the CFA regards the presentation of results, and the potential use of these results. As presented in the current study, we assign equal attention to the over- and underrepresented significant profiles. To some extent this should be seen in the light of the explorative nature of this study, but there are also more fundamental reasons. From a societal planning perspective it may seem obvious that the overrepresented profiles should be in focus, as they represent combinations of functional limitations with stronger internal associations. However, the underrepresented profiles also constitute interesting findings in spite of weaker internal associations. For example, though “Limitations in movement and limitations in upper extremity” was the second most frequent profile of all, it was also underrepresented, whereas the profile of these limitations in combination with “Use of mobility devices” was both frequent and overrepresented. For comparison and contrasting reasons, and in order to deepen our understanding of the interaction of functional limitations, the underrepresented profiles thus appear important to present as well. Moreover, these findings indicate that the choice of relevant type profiles in a given situation is dependent on several factors, where strong internal associations of the functional limitations may be one such factor, but high frequencies may be another. In order to come up with relevant type profiles valid for prioritisation in housing planning, many circumstances need to be considered and balanced. In this process, analyses such as CFA give important additional information, supporting decisions of priority setting. Still, while the results of the current study are promising, they only represent a first, exploratory step and more studies are required before type profiles can be validly used at population level.

One strength worth noting is the fact that the cross-national sample utilised is large and comprises data from four diverse European countries. The results of the analyses based on the four national samples indicate that when applying CFA, the importance of the size of the sample should not be underestimated. That is, since only one to four of the significantly over- or underrepresented profiles of functional limitations in the national samples reached statistical significance, the methodological approach presented can only be recommended with large samples. While useful for an exploratory methodological study of this kind, a limitation that has to be kept in mind is that the sample used is not representative of older people in the population as a whole (Iwarsson et al., 2007; Oswald, et al., 2007).

One interesting aspect of this study is that it demonstrates the usefulness of basic simulation techniques. In this research field simulations have so far not been widely used, though potential benefits are obvious as it has been shown for other public health related areas (Kuljis, Paul & Stergioulas, 2007; Eldabi, Paul & Young, 2007). By matching the type profiles with lists of possible barriers in the environment, outcomes in terms of accessibility problems may be foreseen on a detailed level, even in the form of a ranking order. The impact of combinations of functional limitations on the character and magnitude of accessibility problems is shown by the fact that environmental barriers with high ranking priority for one functional limitation may drop considerably in priority when other functional limitations are added. Besides the demonstration of the dynamics of P-E fit as described in the ecological model of ageing (Lawton & Nahemow, 1973; Lawton, 1986), in practice contexts this can serve as a support for architects and others involved in planning processes concerning housing for different groups of people. That is, already at an early designing stage such simulations have potential to identify the environmental barriers most important to avoid, depending on the group of inhabitants at target. Different architectural solutions can be compared with regard to predicted accessibility problems, and balanced with other issues under consideration, representing a novel approach that remains to be tested in practice.

In conclusion, the methodology here explored may prove a valuable contribution to research on ageing, rehabilitation and public health. The type profiles defined add to the existing knowledge of combinations of functional limitations among groups of older persons, though more studies are required to establish validity. The benefit of using computer simulations in order to predict accessibility problems for groups of people with different combinations of functional limitations deserves to be further exploited. Accessibility problems may be foreseen and taken account for already at early designing stages in the process of housing provision. Variation in predicted accessibility problems for different type profiles helps identifying different sets of priorities, and thus supports planning procedures and decisions to foster improved housing accessibility at societal level.

REFERENCES

van den Akker, M., Buntinx, F., Roos, S., Knottnerus, J. A. (2001). Problems in determining occurrence rates of multimorbidity. *Journal of Clinical Epidemiology, 54*(7), 675-679.

Alves, L.C., Leite, I.C., Machado, C.J. (2008). The concept and measurement of functional disability in the elderly population: a literature review. [Article in Portuguese] *Ciência Saúde Coletiva, 13*(4), 1199-207.

Barbotte, E., Guillemin, F., Chau, N. & Lorhandicap group. (2001). Prevalence of impairments, disabilities, handicaps and quality of life in the general population: a review of recent literature. *Bulletin of the World Health Organisation [online], 79*(11), 1047-1055.

Brandt, Å., Löfqvist, C., Jónsdottir, I., Sund, T., Salminen, A-L., Werngren-Elgström, M., & Iwarsson, S., (2008). Towards an instrument targeting mobility-related participation: Nordic cross-national reliability. *Journal of Rehabilitation Medicine, 40*(9), 767-772.

Carlsson, G., Iwarsson, S., Ståhl, A. (2002). The personal component of accessibility at group level: Exploring the complexity of functional capacity. *Scandinavian Journal of Occupational Therapy, 9*(3), 100-108.

Crisafulli, E., Costi, S., Luppi, F., Cirelli, G., Cilione, C., Coletti, O., Fabbri, L.M., Clini, E.M. (2008). Role of comorbidities in a cohort of patients with COPD undergoing pulmonary rehabilitation. *Thorax 63*(6), 487–492.

Eldabi, T., R.J. Paul, and T. Young. (2007). Simulation modelling in healthcare: reviewing legacies and investigating futures. *Journal of the Operational Research Society, 58*(2), 262-270.

von Eye, A. (1990). *Introduction to Configural Frequency Analysis: The search for types and antitypes in cross-classifications*. Cambridge, UK: Cambridge University Press.

Fone, D., Hollinghurst, S., Temple, M., Round, A., Lester, N., Weightman, A., Roberts, K., Coyle, E., Bevan, G., Palmer, S. (2004). Systematic review of the use and value of computer simulation modelling in population health and health care delivery. *Journal of Public Health Medicine, 25*(4), 325-335.

Fänge, A., Iwarsson, S. (2003). Accessibility and usability in housing – Construct validity and implications for research and practice. *Disability and Rehabilitation, 25*(23), 1316-1325.

Fänge, A., Iwarsson, S. (2005). Changes in accessibility and aspects of usability inhousing over time – An exploration of the housing adaptation process. *Occupational Therapy International, 12*(1), 44-59.

Fänge, A., Iwarsson, S. (2007). Challenges in the development of strategies for housing adaptation evaluations. *Scandinavian Journal of Occupational Therapy, 14*(3), 140-149.

Fänge, A., Risser, R., Iwarsson, S. (2007). Challenges in implementation of research methodology in community-based occupational therapy: The Housing Enabler example. *Scandinavian Journal of Occupational Therapy, 14*(1), 54-62

Gaba, D.M., (2004). The future vision of simulation in health care. *Quality and Safety in Health Care, 13*(Suppl 1), 2-10.

Guralnik, J. M., Ferrucci, L. (2003). Assessing the building blocks of function: Utilizing measures of functional limitation. *American Journal of Preventive Medicine, 25*(3 Suppl 2), 112-121.

Helle, T., Nygren, C., Slaug, B., Brandt, Å., Pikkarainen, A., Hansen. A-G., Pétersdóttir,E., Iwarsson, S. (2010). The Nordic Housing Enabler: Inter-rater reliability in cross-Nordic occupational therapy practice. *Scandinavian Journal of Occupational Therapy, 17*(4), 258-266.

Iwarsson, S. (2005). A long-term perspective on person-environment fit and ADL dependence among older Swedish adults. *Gerontologist, 45*(3), 327-36.

Iwarsson, S., Isacsson, Å. (1996). Development of a novel instrument for occupational therapy assessment of the physical environment in the home - a methodologic study on "the enabler". *Occupational Therapy Journal of Research, 16*, 227-244.

Iwarsson, S., Nygren, C., Slaug, B. (2005). Cross-national and multi-professional inter-rater reliability of the housing enabler. *Scandinavian Journal of Occupational Therapy, 12*(1), 29-39.

Iwarsson, S., Slaug, B. (2001). *The Housing Enabler: An instrument for assessing and analysing accessibility problems in housing*. Nävlinge & Staffanstorp: Veten & Skapen HB & Slaug Data Management.

Iwarsson, S., Ståhl, A. (2003). Accessibility, usability, and universal design – Positioning and definition of concepts describing person-environment relationships. *Disability and Rehabilitation, 25*(2), 57-66.

Iwarsson, S., Wahl, H-W., Nygren, C., Oswald, F., Sixsmith, A., Sixsmith, J., Széman,Z., & Tomsone, S. (2007). Importance of the home environment for healthy aging: Conceptual and methodological background of the European ENABLE-AGE Project. *Gerontologist, 47*(1), 78-84.

Jensen, G., Iwarsson, S., Ståhl, A. (2002). Theoretical understanding and methodological challenges in accessibility assessments, focusing the environmental component: an example from travel chains in urban public bus transport. *Disability and Rehabilitation, 24*(5), 231-242.

Karlamangla, A.,Tinetti, M., Guralnik, J., Studenski, S., Wetle, T., Reuben, D. (2007). Comorbidity in older adults: Nosology of impairment, diseases, and conditions. *Journal of Gerontology, 62A*(3), 296-300.

Krauth, J. (1993). *Einführung in die Konfigurationsfrequenzanalyse (KFA)*. [Introduction to Configural Frequency Analysis (CFA).] Weinheim: Beltz, Psychologie Verlags Union.

Krauth, J., Lienert, G.A. (1982). Fundamentals and modifications of configurational frequency analysis (CFA), *Interdisciplinaria 3*, 1–14.

Kuljis, J., Paul, R.J., Stergioulas, L.K. (2007). Can health care benefit from modeling and simulation methods in the same way as business and manufacturing has? *Proceedings of the 2007 Winter Simulation Conference*, ed. S.G. Henderson, B. Biller, M-H Hsieh, J. Shortle, J.D. Tew, and R.R. Barton, Washington DC, USA

Lawton M.P., Nahemow L. (1973). *Ecology and the ageing process.* In C Eisdorfer, MP Lawton (Eds.), The psychology of adult development and ageing. Washington DC: American Psychological Association.

Lawton, M.P. (1986). (2nd ed.). *Environment and Aging.* Los Angeles, USA: Brooks/Cole Publishing Co.

Nagi, S.Z. (1991). Disability concepts revisited: Implications for prevention. In A. M. Pope & A. R. Tarlov (Eds.*), Disability in America: Toward a national agenda for prevention*. Washington DC: National Academy Press.

Oswald, F., Wahl, H-W., Schilling, O., Nygren, C., Fänge, A., Sixsmith, A., Sixsmith, J., Széman, Z., Tomsone, S., Iwarsson, S. (2007). Relationships between housing and healthy ageing aspects in very old age: Results from the European ENABLE-AGE Project. *Gerontologist, 47*(1), 96-107.

Rencher, A.C. (2002). *Methods of multivariate analysis*. New York: Wiley.

Steinfeld, E., Schroeder S., Duncan J., Faste R., Chollet D., Bishop M., Wirth P., & Cardell P. (1979). *Access to the Built Environments: A Review of the Literature.* Washington, DC: U.S. Government Printing Office.

United Nations. (2006). *Convention on the rights of persons with disabilities.* NewYork: United Nations. http://www.un.org/disabilities/.

Wahl, H.-W. & Iwarsson, S. (2007). *Person-environment relations in old age.* In R. Fernandez-Ballesteros (Hrsg.), Geropsychology. European perspectives for an ageing world, (pp. 49-66). Göttingen: Hogrefe.

Verbrugge, L.M., Jette, A.M. (1994). The disablement process. *Social Science and Medicine, 38*(1), 1-14.

World Health Organisation (WHO). (2001). *ICF: International classification of functioning, disability and health*. Geneva, Switzerland: WHO.

Table 1. Demographics of a sample of older persons in four European countries (N=1,542)

Demographic characteristics	Germany	Hungary	Latvia	Sweden	Total
n (%)	450 (100.0)	392 (100.0)	303 (100.0)	397 (100.0)	1 542 (100.0)
Agegroup					
75-79	-	181 (46.2)	197 (65.0)	-	378 (24.5)
80-84	212 (47.1)	211 (53.8)	106 (35.0)	200 (50.4)	729 (47.3)
85-89	238 (52.9)	-	-	197 (49.6)	435 (28.2)
Sex					
Men	97 (21.6)	76 (19.4)	35 (11.6)	101 (25.4)	309 (20.0)
Women	353 (78.4)	316 (80.6)	268 (88.4)	296 (74.6)	1 233 (80.0)
Housing					
Multi-dwelling	383 (85.1)	315 (80.4)	269 (88.8)	340 (85.6)	1 307 (84.8)
Necessary housing standard	444 (98.7)	357 (91.1)	248 [a] (81.8)	395 (99.5)	1 444 (93.6)

[a] Missing data in two observations

Table 2. Occurrence of functional limitations / use of mobility devices in national samples among older persons in four European countries (N=1,542) [a.]

Letter denotation[b] and functional limitation according to the Housing Enabler	N (%) 1 542 (100.0)
A. Difficulty in interpreting information	131 (8.7)
B1. Severe loss of sight	236 (15.8)
B2. Complete loss of sight	19 (1.3)
C. Severe loss of hearing	245 (16.4)
D. Prevalence of poor balance	583 (38.9)
E. Incoordination	179 (11.9)
F. Limitations of stamina	821 (54.8)
G. Difficulties in moving head	189 (12.6)
H. Difficulty in reaching with arms	366 (24.4)
I. Difficulty in handling and fingering	338 (22.6)
J. Loss of upper extremity skills	60 (4.0)
K. Difficulty in bending, kneeling, etc.	990 (66.1)
L. Reliance on walking aids	481 (32.1)
M. Wheelchair user	18 (1.2)

[a] Note that each person may have more than one functional limitation

[b] (Iwarsson & Slaug, 2001)

Table 3. Non-empirical categorization of functional limitations / use of mobility devices [a] used to construct profiles

Functional limitation / use of mobility device	Category of functional limitations / use of mobility devices. Items included marked with 'I'					
	1. Difficulty in interpreting information	2. Severe loss of sight/blindness	3. Severe loss of hearing	4. Limitations in movement	5. Limitations in upper extremity	6. Use of mobility devices
A. Difficulty in interpreting information	I	-	-	-	-	-
B1. Severe loss of sight	-	I	-	-	-	-
B2. Complete loss of sight	-	I	-	-	-	-
C. Severe loss of hearing	-	-	I	-	-	-
D. Prevalence of poor balance	-	-	-	I	-	-
E. Incoordination	-	-	-	I	-	-
F. Limitations of stamina	-	-	-	I	-	-
G. Difficulties in moving head	-	-	-	I	-	-
H. Difficulty in reaching with arms	-	-	-	-	I	-
I. Difficulty in handling and fingering	-	-	-	-	I	-
J. Loss of upper extremity skills	-	-	-	-	I	-
K. Difficulty in bending, kneeling, etc.	-	-	-	I	-	-
L. Reliance on walking aids	-	-	-	-	-	I
M. Wheelchair user	-	-	-	-	-	I

[a] According to the Housing Enabler (Iwarsson & Slaug, 2001)

Table 4. Profiles of functional limitations / use of mobility devices, based on empirical data from a sample of older persons in four European countries (n=1,333) [a]

Profile of functional limitations / use of mobility devices [b], n (%)	Overrepresented (+) Underrepresented (-) Not significant (ns)	Category of functional limitations / use of mobility devices					
		1. Difficulty in interpreting information	2. Severe loss of sight/blindness	3. Severe loss of hearing	4. Limitations in movement	5. Limitations in upper extremity	6. Use of mobility devices
356 (26.7)	(+)	0	0	0	1	0	0
158 (11.9)	(-)	0	0	0	1	1	0
136 (10.2)	(+)	0	0	0	1	1	1
123 (9.2)	(-)	0	0	0	1	0	1
67 (5.0)	(ns)	0	1	0	1	0	0
44 (3.3)	(-)	0	0	1	1	0	0
40 (3.0)	(+)	0	0	1	1	1	1
39 (2.9)	(ns)	0	1	0	1	0	1
37 (2.8)	(+)	0	1	0	1	1	1
30 (2.3)	(ns)	0	0	1	1	0	1
29 (2.2)	(-)	0	1	0	1	1	0
26 (2.0)	(-)	0	0	1	1	1	0
25 (1.9)	(+)	0	0	0	0	1	0
23 (1.7)	(+)	0	0	1	0	0	0
21 (1.6)	(ns)	1	0	0	1	0	0
18 (1.4)	(+)	0	1	0	0	0	0
18 (1.4)	(ns)	1	0	0	1	1	0
14 (1.1)	(ns)	1	0	0	1	1	1

[a] Only subjects with at least one functional limitation / use of mobility devices included, thus limiting the number of theoretically possible profiles to 63

[b] Of the 63 theoretically possible profiles, remaining 45 had an occurrence less than 1% in the data sample

Table 5. Configurational Frequency Analyses, type profiles among persons with at least one functional limitation / use of mobility devices, significantly over- (+) or underrepresented (-) based on empirical data from a sample of older persons in four European countries (n=1,333) [a]

Profile of functional limitations / use of mobility devices [b]	Observed frequency	Expected frequency	P-value
000100 (+) Limitations in movement	356	276	0.000002
000111 (+) Limitations in movement, upper extremity and use of mobility devices	136	109	0.010596
001111 (+) Severe loss of hearing, limitations in movement, upper extremity and use of mobility devices	40	25	0.001918
010111 (+) Loss of sight, limitations in movement, upper extremity and use of mobility devices	37	26	0.028318
000010 (+) Limitations in upper extremity	25	15	0.012895
000110 (-) Limitations in movement and upper extremity	158	190	0.018677
000101 (-) Limitations in movement and use of mobility devices	123	158	0.004806
001100 (-) Severe loss of hearing and limitations in movement	44	62	0.020996
010110 (-) Loss of sight, limitations in movement and upper extremity	29	45	0.016776
001110 (-) Severe loss of hearing, limitations in movement and upper extremity	26	43	0.009916

[a] Only subjects with at least one functional limitation / use of mobility devices included

[b] The five over- and five underrepresented profiles with the highest observed frequencies (at least ~2%)

Table 6. Comparison of significantly over- or underrepresented type profiles, with regard to ranking of most severe environmental barriers

Environmental barrier item	Overrepresented profiles					Underrepresented profiles				
	000100 (n=356)	000111 (n=136)	001111 (n=40)	010111 (n=37)	000010 (n=25)	000110 (n=158)	000101 (n=123)	001100 (n=44)	010110 (n=29)	001110 (n=26)
Outdoor environment										
A6. Routes with steps	5	12	16	24	56	14	7	9	34	26
A8. High kerbs	9	17	24	44	58	23	11	13	75	37
A9. Kerb ramps with abrupt sides	66	89	103	26	59	89	96	68	15	105
A12. No handrails on steep gradients	4	81	86	71	62	13	85	8	68	22
A13. No resting surfaces or too far between resting surfaces	6	15	19	82	63	20	8	11	95	30
A14. Poor lighting along circulation paths	86	78	1	42	64	124	66	4	74	4
A21. Unstable walking surface in parking space	8	13	18	41	71	16	10	10	69	32
A24. No/too few seating places	7	16	20	83	74	21	9	12	96	31
A25. Extremely low, high or narrow seating surfaces	3	7	11	56	75	7	3	7	82	12
A29. Refuse room/refuse bin can only be reached via steps	67	59	62	13	79	90	50	69	16	106
A30. Letterbox can only be reached via steps or other differ	68	60	63	14	80	91	51	70	17	107
A31. Refuse bin and/or letterbox difficult to reach	62	3	7	40	2	2	45	57	67	6
Entrances										
B2. High thresholds and/or steps at the entrance	69	61	64	15	84	92	52	71	18	108
B6. Heavy doors without automatic opening	12	4	8	48	11	4	15	14	76	8
B9. Doors that do not stay in open position/ close quickly	13	21	25	6	90	27	16	15	3	38
B12. Stairs the only route	14	18	21	3	93	24	12	16	5	34
B13. Stair treads with narrow depth or irregular depth	15	29	33	8	94	28	26	17	8	39
B14. Very high, very low and/or irregular heights of risers	16	30	34	9	95	29	27	18	9	40
B16. No handrails (stairs)	17	8	12	25	97	30	4	19	43	41
B23. Steep gradients	18	22	26	84	104	31	17	20	100	42
B24. Long runs without level resting surface	19	23	27	85	105	32	18	21	101	43
B26. No handrails (ramps)	20	24	28	86	107	33	19	22	102	44
B28. Lift does not stop at same level as building floor	65	46	52	12	109	80	49	60	12	95
B30. Heavy doors without automatic opening	21	5	9	49	12	5	20	23	77	9
B32. Doors that do not stay in open position/close quickly	22	25	29	7	112	34	21	24	4	45
B39. Controls and operable hardware placed too high/low	85	42	50	96	6	9	98	81	91	14
B40. Design of controls requires good hand function	140	115	127	161	17	42	161	141	112	17
B42. No visual signal when the lift arrives	50	112	5	150	120	100	110	2	154	2
B43. Lift signals do not indicate the direction of the lift	51	113	6	37	121	101	111	3	30	3
B47. High threshold/level difference/step	70	62	65	16	125	93	53	72	19	109
Indoor environment										
C1. Stairs/thresholds/differences in level between rooms/floors	71	63	66	17	128	94	54	73	20	110
C5. Slippery walking surface	57	56	53	21	132	78	46	54	13	85
C11. Inappropriate design of wardrobes/clothes cupboards	146	80	83	70	13	57	105	147	79	73
C12. Stairs to upstairs with necessary dwelling functions	24	19	22	4	138	25	13	26	6	35
C13. Stairs to basement with necessary dwelling functions	25	20	23	5	139	26	14	27	7	36

C15. Stair treads with narrow depth or irregular depth	26	31	35	10	141	36	28	28	10	47
C16. Very high, very low and/or irregular heights of risers	27	32	36	11	142	37	29	29	11	48
C18. No handrails (stairs)	28	9	13	39	144	38	5	30	78	49
C20. Handrails placed too high/low	29	10	14	69	146	39	6	31	104	50
C25. Insufficient maneuvering areas	58	11	15	2	14	8	39	55	2	15
C26. Wall-mounted cupboards and shelves placed extremely high	2	1	2	1	1	1	2	6	1	5
C30. Working surfaces too deep	152	14	17	72	7	15	81	153	93	16
C31. Shelves too deep	43	6	10	51	5	6	37	49	80	10
C32. Hobs with ordinary rings	153	108	113	149	3	12	166	154	94	13
C34. Door swings which impede accessibility to storage nits	11	101	98	134	155	22	97	32	111	33
C40. Very small controls	157	128	138	79	18	50	170	158	55	23
C45. Use requires hands (kitchen/laundry room)	161	38	44	101	19	43	90	162	113	18
C48. More than half of apparatus/controls very high	109	53	74	105	8	17	102	103	97	27
C51. No grab bars at shower/bath and/or toilet	1	2	4	20	161	3	1	5	42	7
C52. Grab bars difficult to reach	61	82	84	127	15	10	108	64	90	21
C55. Grab bars inadequately positioned	10	105	109	146	164	47	100	35	121	66
C56. Grab bars not designed for easy grasp	117	83	107	143	4	11	135	118	92	11
C62. Very small controls	167	129	139	80	20	51	175	168	56	24
C67. Use requires hands (hygiene area)	171	39	45	102	21	44	92	172	114	19
C70. Apparatus/controls very high	110	54	75	106	9	18	103	104	98	28
C78. Toilet roll holder in inaccessible position	112	127	131	155	16	46	145	106	108	59
C82. Slippery floor surface	59	57	54	22	177	79	47	56	14	86
C92. Use requires hands (other controls/hardware)	181	40	46	103	23	45	94	182	115	20
C95. Apparatus/controls very high	111	55	76	107	10	19	104	105	99	29
C97. Storage areas can only be reached via stairs/threshold	72	64	69	18	181	95	55	74	21	111
C99. Laundry room can only be reached via stairs/threshold	73	65	70	19	182	96	56	75	22	112
Communication										
D1. No telephone with amplified sound	184	184	3	188	183	184	184	1	188	1

Note: All "top twenty" positions are shaded

The six position 0/1-combination denotes presence or absence of functional limitations / use of mobility devices in the profile. See Table 4.