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The Design and Evaluation of Assistive Technology Products and Devices Part 3: Outcomes of Assistive Product Use

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This article is the second of three parts and discusses the design of assistive products. Part 1 considers design and Part 3 the outcomes of assistive product use.

Assistive Product Outcomes: Introduction

It is useful to both evaluate assistive products throughout the life cycle and evaluate the outcomes of their use by particular end-users or groups of end-users. However, the two types of evaluation do not always have similar results. In particular, good design, usability, accessibility and a number of other performance factors will generally be necessary for assistive product to perform well for end-users, but they are not sufficient. Good end-user outcomes also depend on compatibility of the product with the user's lifestyle and aspirations, as well as a number of other factors. Therefore, a high evaluation of end-user outcomes for a particular assistive product will generally imply that the product is well designed, but a low evaluation of end-user outcomes does not imply that it is poorly designed.

Part 2 (Hersh, 2010) of the paper considered the evaluation of assistive products at the different life cycle stages and this Part 3 paper will discuss the evaluation of the outcomes of assistive product use. The paper is organised as follows. The remainder of this section considers some general issues in outcome assessment. Section 2 discusses criteria and frameworks for outcome assessment and Section 3 end-user defined criteria to be used in the assessment. Functional and economic evaluation are considered in Sections 4 and 5 respectively. The definition and measurement of quality of life are considered in Section 6 and goal attainment scaling in Section 7. Conclusions are presented in Section 8.

As discussed in the introduction to Part 2 of the paper (Hersh 2010), relatively little attention has been given to the evaluation of assistive products. Most of the discussion of evaluation in the context of assistive technology has focused on the outcomes of assistive product use and, in particular, changes in quality of life. This is possibly indicative of the extent of the accessibility and other barriers still experienced by disabled people and the extent to which they are still socially excluded and in great need of improvements in their quality of life. In addition, the term assistive product covers a very wide range of different types of things. Some assistive products may be well designed and have positive outcomes for the user, but not significantly improve their quality of life because of their limited importance in the user's life. However, this does not mean that disabled and elderly people should not be supplied with such products, but that techniques used to evaluate user outcomes should be appropriate to the product being evaluated, as well as the particular user(s) being considered.

There are a number of factors that complicate the evaluation of the impact of a particular assistive product for a particular user or group of users. In particular, individuals may use several different assistive products, the use of each of which impact on the use of the others, and/or several interventions may be made at the same time, making it difficult to identify the effects due to a particular assistive product. It may also be difficult to isolate changes due to an assistive product from those due to other causes (Smith 1996), such as a change in circumstances, for instance moving to a new house closer to family and friends or getting a job, particularly if obtaining an assistive product has enabled the person to change their circumstances, for instance by finding a job. In addition, the combined impact may be (much) greater than the sum of the impacts of the separate products or other interventions on their own. For instance, the different interventions may work much better together than individually or combine to enable the user to carry out activities or make changes in their life, which cannot be ascribed to the action of a particular product or intervention. This makes it difficult and sometimes not very useful to try to isolate the outcomes associated with a particular assistive product.

The impacts of a particular assistive product will frequently depend on the context in which it is used, end-user characteristics (Gelderblom and de Witte 2002) and lifestyle and the match between these characteristics and lifestyle and product features. Thus, the evaluation process should take account of the groups of people the product can support and the environments it can be used in (Feil-Seifer et al, 2007). Where possible, the evaluation should include thorough testing with appropriate users in the environments the product is going to be used in. Otherwise, an assessment will be required of whether evaluations carried out in a particular environment and/or with particular groups of users can be transferred to other environments or users, for instance from laboratories to users' homes. The procedures and measures should be culturally appropriate for the particular user (groups). However, measures are frequently only suitable for use in the particular country and cultural context for which they were developed or culturally similar countries and contexts. Therefore, they may need to be modified for use elsewhere or with ethnic and other minority groups. This will generally require the involvement of or consultation with users from the relevant culture and/or country. Outcome measures should be sufficiently flexible to allow measurement of both the specific impacts of a particular assistive product on the quality of life of a given disabled or elderly person and the impacts of a particular product or type of product on a given group of disabled or elderly people. They should also include both qualitative and quantitative measures.

Since a number of studies have found high rates of abandonment of assistive products, for instance (Blackstone 1992; Garber and Gergorio 1990; Ko et al. 1998; Murphy 1997; Phillips and Zhau 1993; Shepherd and Ruzicka 1991), the extent of device usage can itself be used as an evaluation measure, other than for products that are only intended to be used for a short period. This measure could include whether the product is still being used, frequency of usage, whether the product is a major or supplementary support for the particular activity and whether it is being used for the intended application, the intended and other applications or solely for other applications. The length of time after product acquisition at which it is appropriate to measure continuing usage will depend on the particular device.

It may also be useful to investigate the reasons for intermittent usage or device abandonment. This could include the following factors (Day et al. 2001; Wehmeyer 1988):

- Changes in circumstances, as a result of which the product is no longer suitable or required.
- Poor design, leading to the product not functioning as intended.

- A mismatch to the user's context, lifestyle, interests and priorities.
- A lack of or unsatisfactory support systems, including training and repair and maintenance facilities.

Frameworks for Evaluating Assistive Technology Outcomes

There have been a number of approaches to developing frameworks for the evaluation of assistive technology outcomes. For instance, a list of seven criteria to be met by assistive technology outcomes measurement systems has been proposed by the Assistive Technology Outcomes Measurement System (ATOMS) Project (Edyburn and Smith 2004). These criteria has been validated with a convenience sample of various stakeholders obtained from conference participants, which probably did not include disabled people, since they were not listed amongst the groups attending the conference. The criteria are as follows:

1. The measurement system should be based on a theoretical framework supporting the relationships between the variables.
2. Outcome assessment instruments should be readily available and not require extensive training and expertise.
3. The data collection tools should allow the use of paper and pencil, portable handheld devices and web-based interfaces.
4. There should be tools for assimilating data from multiple sources and instruments in ways that facilitate comparisons.
5. There should be easy-to-use tools to produce easily comprehensible graphics from multiple scores. This should be replaced by easily comprehensible graphics or text descriptions for accessibility to blind and visually impaired people.
6. There should be tools that facilitate dynamic norming (individual and group comparisons) in the case of unique or low incidence assistive technology provision.
7. There should be decision support tools.

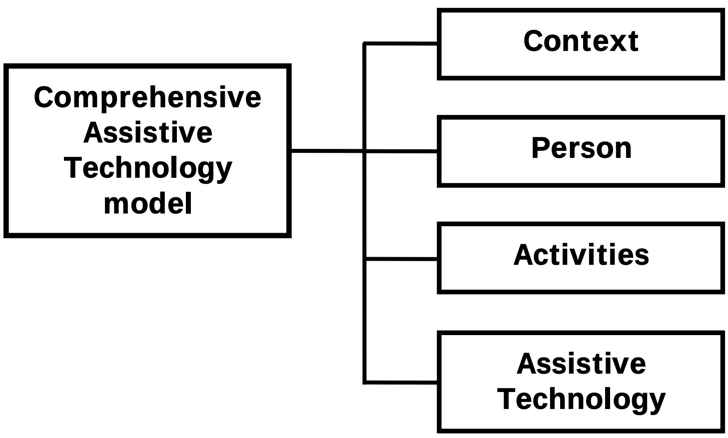
Probably the best known and most commonly used outcomes modelling framework is the Matching Persons and Technology (MPT) Model (Fuhrer et al. 2003; Scherer and Craddock 2002). It is divided into the three main components of the person using the technology, the technology and the milieu or environment. There are two versions of the assessment procedure for adults, developed in Ireland and the U.S.A, with the U.S. version translated into French and Italian. There is also a version for children under 15, known as the Matching Assistive Technology and Child (MATCH) version. The assessment procedure requires the service provider and end-user to complete slightly different versions of a number of forms, followed by a discussion of the outcomes and action. The approach draws on the medical model of disability and aims to determine 'limitations' on functioning and identify goals and technologies that could be used to improve functioning, as well as characteristics of the person, environment or technology that could lead to inappropriate use or abandonment of these technologies. In addition, the model includes some personal characteristics, experiences and attitudes to technologies and degree of satisfaction with different aspects of life.

Another framework, proposed by the Consortium for Assistive Technology Outcomes Research (CATOR) and which can be used for both short and long term outcomes, involves a taxonomy of assistive products. It draws on the International Classification of Functioning Disability and Health (ICF) (WHO 2001) and is based on three broad sets of descriptors called vantages (Jutai et al. 2005): effectiveness, social significance and subjective well-being. However, the CATOR framework seems better suited to rehabilitation than assistive product provision. Many of the categories in the three 'vantages' are for people who are in ill-health, dependent and require care and supervision rather than personal assistance. Thus, many of these categories are not relevant to many users of assistive products. The approach also does not take account of the choices which disabled people may want to make between the use of assistive technology and personal assistance. For instance, a particular disabled person may prefer to use personal assistance for personal care tasks, as this is faster and less tiring and gives them the time and energy necessary to work full or part time or engage in leisure activities. There is a need for research on the factors that influence the preferences of disabled people for assistive technology or personal assistance to carry out a particular task or activity in a given context. This would enable the provision of support and the use of resources to be better tailored to meet their needs. It would also be more compatible with the definitions of independence and autonomy in terms of the ability to control and plan one's life (Brisenden 1986; EUSTAT 1999), which are discussed briefly in Section 6.

The Human Activity Assistive Technology (HAAT) model (Cook and Miller Polgar 2008) and the Comprehensive Assistive Technology (CAT) model (Hersh and Johnson 2008ab) are both structured hierarchical models of the human assistive technology system with the four main components at the top level of person or human, context, assistive technology and activity, as shown in Figure 1 for the CAT model. The CAT includes contextual features which allow its use in countries with a less developed infrastructure, has a wider model of the person component which includes attitudes and preferences, and decomposes the activities categories into fundamental and contextual activities. A number of different graphical and other representations have been developed for it, increasing its flexibility.

Both models provide a framework which could be used for the systematic description and evaluation of the use of assistive products by a person in a particular context to carry out specific activities. The evaluation can identify both good design features and any shortcomings or disadvantages of a particular assistive product solution with a view to developing a modified and improved version or other solutions with better performance and that better meet end-user requirements.

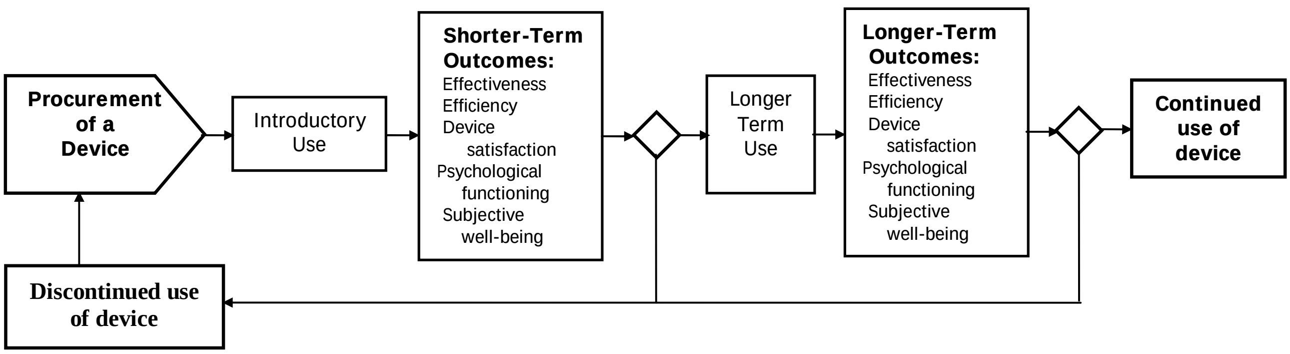
Figure 1: CAT model



The person, context and activities attributes of the CAT model can be used to develop a personal or group assistive technology profile. In the activities attribute the focus would be on activities of interest to the person or group, but which they experience barriers to carrying out. This profile can be used to evaluate the match of the product being considered to the requirements or an individual or group, including contextual factors such as culture, language and available infrastructure. The profile can be updated in response to a change in circumstances or context. Development of this profile would require the development of questionnaire based instruments to obtain information. Application of the profile at a number of points in time, for instance before obtaining an assistive product, a week and several months after obtaining this product, could be used to investigate changes in the person's circumstances and the extent to which barriers to activities of interest have been removed or reduced. Although a useful approach, it still requires work to develop the questionnaire based instruments and modifications to the CAT model would be required to use the profile to assess user satisfaction with the assistive product. Forms based on the HAAT model have been developed to obtain background information on the user and assess the movement and control of different body parts, including the hands (Cook and Miller Polgar 2008). However, further development work would be required to obtain questionnaire based instruments to determine the appropriate assistive technology for a particular user or assess their satisfaction with it.

Figure 2 shows the schematic of a conceptual framework to be used in assistive technology outcomes assessment. It is based on an adaptation of the approach frequently used in the health sciences and most of the factors considered to influence the outcome of device and service provision have been obtained from the MPT model. There are three key stages: device procurement, introductory use, and longer-term use and two decision points in the model, indicated by a diamond representing the flow chart 'OR', where the end-user may continue to use the device or reject it. Each of these three stages is a complex process that will support detailed models incorporating activities such as assessment, training, and outcomes analysis. Thus the model recognises that there are time-dependent elements in assistive technology use, including feedback from previous use, changes in circumstances, increasing skill in device use and emotional factors.

Figure 2: Conceptual framework for assistive technology outcomes assessment



(Hersh and Johnson 2008a, based on MPT (Fuhrer et al., 2003))

Obtaining End-User Criteria for the Evaluation of Assistive Products

Due to the centrality of end-users to assistive products, it is useful to determine what factors they consider should be used to assess their performance. A modified Delphi method approach based on panels of consumer experts with mobility and sensory impairments respectively has been applied to deriving and prioritising 17 evaluation factors for 11 types of assistive devices (Batavia and Hammer, 1990). The approach is based on the premise that satisfying the needs of the disabled user should form the basis of evaluation of assistive devices and that disabled people who use assistive devices over a period of time develop criteria based on their past experiences for accepting or rejecting new assistive products, but the factors considered by users in determining whether a device meets their needs are poorly understood. In addition to having physical or sensory impairments, panel members were required to have used one or more assistive devices for at least five years and have good analytical and communication skills so they could identify, prioritise and report on their factors for assistive technology evaluation. Broad assistive product areas, such as telephone and environmental control systems, rather than specific products were used for the assessment. This allowed panel members to consider their specific needs in the area of technology being assessed and avoided them assessing devices that were not relevant or being biased by the features of specific products.

The approach involved the following stages:

1. Statement by panel members of the factors they used in assessing technologies for their own use in a number of categories and modifying the list of factors drawn up to the researchers to include additional factors identified by the panels.
2. Determination of the order of the agreed list of factors (which have been randomised) under the assumption that the product being considered has an average level of each factor.

The factors and their average rankings over all the products assessed were as follows, where factors listed under the same bullet point had similar but generally not identical average ratings:

- Effectiveness.
- Affordability, operability, and dependability.
- Portability.
- Durability, and compatibility.
- Flexibility and ease of maintenance.
- Securability, learnability, personal acceptance, physical comfort, and supplier repair.
- Physical security, and consumer repair.

In some cases, the most important factors may be product specific and the interpretations of effectiveness and operability device specific and not necessarily totally unambiguous for each device. In addition, as noted by one panel member, end-users may find it difficult to determine whether a particular product meets their needs without using it for an extended period of time. The fact that a particular assistive device is rated highly by the majority of users does not mean that it will perform well or even satisfactorily for all users.

A participatory action research approach to evaluating assistive products (Scherer and Lane 1997) has been developed by the Rehabilitation Engineering Research Centre at the University of Buffalo (RERC-TET) based on Batavia and Hammer's criteria. Their criteria were reduced in number to 11 through discussion by focus groups with 700 end-users, with each criterion representing a specific product attribute. These criteria were then validated by application to several hundred products from the ABLEDATA database of assistive products and found to cover all the product attributes provided by end-users. The methodology for product evaluation had five stages and was generally applied to four focus groups at a time.

Analysis of audio or videotapes of the focus groups was used to produce questionnaires containing 150-180 statements with responses on a seven point agreement-disagreement scale. Thurstone's Case V scaling procedure (Bauer 1997) was then used to order preferences within categories, including reliability and effectiveness. The profile of an ideal device was produced from statements with at least 70% agreement on their importance.

The approach of using criteria proposed by actual end-users is a very useful one. However, the work in this area does not seem to have led to a process that is actually being used in practice, possibly due to the limited extent to which assistive products and their outcomes are being evaluated. This approach potentially has the following applications:

- Evaluation of end-user opinions of a particular assistive product.
- Comparative evaluation and production of ranked lists of assistive products of a particular type, such as manual wheelchairs textphones or screenreaders.
- Evaluation of assistive product use for a particular individual or group of individuals.
- Choosing assistive products to meet the needs of a particular individual.

However, further work will be required to develop instruments that can be used in these applications in practice. This should include further work on the development of the criteria, including an investigation of whether different criteria are appropriate in different contexts, such as for use in different countries or ethnic minority groups. It may also be useful to produce shorter and longer versions of the questionnaire instruments. While the questionnaires described above (Scherer and Lane 1997) could inform these instruments, they are rather lengthy and seven-point scales are too long for many users and give the impression of greater precision than is in fact the case.

Functional Evaluation

One of the approaches to the evaluation of the impacts or outcomes of the use of assistive technology involves evaluation of the user's functioning and changes in this functioning. A number of instruments have been developed to support functional evaluation. However, many of these instruments are not designed to be used with assistive technology. For instance, a study of 100 widely used health and rehabilitation outcomes instruments (Rust and Smith, 2005) found that 30% of them did not consider assistive technology or give any guidelines as to whether performance should be evaluated with or without the technology.

Where assistive technology is included in the instruments, its treatment is inconsistent. Some 44% of the instruments reduce scores when assistive technology is used and treat it as a proxy for reduced functioning. In some of these instruments all the items consider the use of assistive technology and physical assistance and each item is scored lower when assistive technology is used on the assumption that a fully independent person does not require special technology. In other instruments assistive technology is considered in some but not all the questions. Some 22% of the instruments explicitly allow for the use of assistive technology and do not reduce scores on account of its use. Four instruments provide a mixed treatment, with some questions or rating scales allowing the use of assistive technology and others not. Thus most of these instruments have construct validity problems, as they do not document or control the use of assistive technology, potentially leading to a confounding of the results of the application of assistive technology and other interventions. The inconsistent treatment of assistive technology in the different instruments has also resulted in inconsistent treatment by different therapists, leading to lack of consistency and reliability in evaluations by different raters (Smith 2002).

Few of the instruments treat assistive technology as an independent variable, making most of them unsuitable for determining the outcomes specifically due to its use (Rust and Smith, 2005). Many of the instruments are based on an implicit definition of independence and functioning which is unsuitable for disabled people, for whom the use of appropriate assistive technology and/or human assistance should be seen as enablers to enable participation in desired activities rather than an indication of reduced functioning. This also shows that evaluation techniques for medical rehabilitation will not necessarily be suitable for application to assistive products. Furthermore, the instruments do not always cover all the domains of human functioning. For instance, one instrument does not include any items on communication (Abrams et al. 2002).

The impact of an assistive product or other assistive technology can be obtained by evaluating the individual's functioning with and without the product¸ without reducing performance measures when it is in use. The difference in the results is then due to the assistive product. Repeated evaluation would allow the impact of an assistive product over time to be measured and represented, for instance, graphically or in tabular format. This approach of repeated evaluation has been called Time Series Concurrent and Differential (TSCD) (Smith 2002). However, this type of approach is very firmly embedded in the medical model of disability and does not take account of the priorities of the particular disabled or elderly person. These priorities may be participating in employment, education and/or leisure activities rather than improving their 'functioning'.

Therefore, it may be more appropriate to evaluate the functioning of assistive products rather than any changes in individual 'functioning' as a result of their use. This would require consideration of the following issues.

- The product's functionality.
- A comparison of the product's actual functionality with its specified functionality.
- An evaluation of performance i.e. how well the product carries out its functions.
- The range of functionality, for instance whether it is single or multi-functional and whether it has functions in one or more domains of activity.
- How useful and/or important users consider this functionality.
- How useful and/or important other stakeholders consider this functionality.
- What barriers the product overcomes.
- What activities users are able to carry out using the product.

This type of functional evaluation should be carried out together with usability evaluation to investigate whether the product can actually be used by the intended users. In the case of evaluation of the outcomes of product use by a particular individual, it may be useful to investigate whether and the extent to which the product supports the individual in carrying out desired activities.

Economic Evaluation

Social services, health care and other organisations supplying assistive technology to individuals and called upon to be accountable for not unlimited budgets may find the use of economic evaluation attractive. However, it should be used with great care to ensure that all costs and benefits are included, whether or not they are paid for or there are monetary inflows and outflows which can be recorded. There are both practical and ethical problems associated with the monetary valuation of some of the possible costs and benefits, such as improvements in quality of life and new or foregone opportunities. In addition, some costs may have several components, not all of which it is easy to cost. For instance, it is relatively easy to value the labour costs of the unpaid assistance provided by family and friends if the time involved can be estimated fairly accurately, it is more difficult to evaluate the costs associated with any foregone opportunities or changes in quality of life due to providing this assistance. A discussion of these issues is beyond the scope of this article. However, some of the problems can be avoided by using monetary valuations of costs and non-monetary valuations of benefits (Andrich et al. 1998).

Cost effectiveness involves the comparison of costs in monetary units with benefits in quantitative non-monetary units. This avoids the problems inherent in obtaining monetary valuations of benefits, but not those related to obtaining quantitative measures of qualitative benefits, such as increased self-confidence. While there may be greater problems with the monetary evaluation of benefits than costs, the monetary evaluation of costs is not totally unproblematic and the associated difficulties need to be considered. It is essential to avoid the temptation to value non-monetary costs differently from monetary ones, to exclude them from the analysis or to make decisions which prioritise making monetary savings and ignore 'hidden' costs such as unpaid assistance from family and friends. The real costs of this may be much higher than those of the other options, such as a combination of assistive technology and paid assistance, but they are non-monetary and therefore frequently easier to ignore.

The CERTAIN tools for cost-outcome analysis of the provision of assistive technology to individuals (Andrich et al., 1998) were developed by the Cost Effective Rehabilitation Technology through Appropriate Indicators (CERTAIN) Project. This project aimed to develop criteria and methodologies for the socio-economic evaluation of assistive devices. The tools discussed briefly here provide a useful approach to structuring the process and including non-monetary costs which are likely to be otherwise omitted. However, there seems to be an assumption that the end-user is receiving treatment from the medical system, which may not be the case, and the approach may give more weight to the clinician's perspective than that of the disabled person. The approach could be carried out by other professionals than clinicians.

The tools include:

- A data collection package: questionnaire/checklists for case and outcomes reporting, a data collection form for costs and resources, effectiveness and utility instruments and guidelines. It is to be completed under the supervision of a professional with clinical responsibility for the individual.
- The SIVA-CAI cost-analysis instrument: a mathematical-financial model that produces short and long term indicators. It uses marginal operating costs rather than average costs and excludes the costs of the assessment process. Quality-adjusted life years (QALYs) can be calculated using quality of life or client satisfaction scores. The SIVA/CAI tool considers the costs of providing assistive technology to an individual from an existing programme - direct and indirect technology-related and assistance-related costs, including hidden costs borne by the disabled person and/or their family. Assistance costs are based on the market value of three categories of assistance: (i) no special skills or qualities, (ii) requiring strength and control, but no professional qualifications, (iii)

- A reporting structure: identification data (an anonymous code), clinical background and a case history of the individual's assistive technology programme. The case history includes the initial situation, the action plan and the situations at the end of the action plan and after an adaptation period. The outcomes description describes the overall goals, successes and failures in the five areas of contextual outcomes, outcomes related to individual, family and professional expectations and community outcomes. End-user views should be considered as well as those of the professionals.
- A database of all the processed case studies, which can be used to generate reports and statistics.

A number of case studies have been carried out (Andrich et al. 1998), but as with most of the other methodologies and approaches, the CERTAIN tools do not seem to have been adopted to any real extent in practice.

Definition and Measurement of Quality of Life

One of the considerations in deriving appropriate and robust outcome measures is the choice of variables to give a good insight into the impacts of assistive products. One possibility is changes in quality of life. However, it should be noted that quality of life has a strong subjective element and can be difficult to measure. In addition, a given assistive product may have a positive impact without necessarily resulting in significant changes to quality of life.

The closest area to assistive technology in which quality of life approaches are well-developed is the health domain. Therefore approaches to assessing health related quality of life will now be discussed. The field of health related quality of life assessment is particularly well developed with over a thousand citations each year (Fuhrer, 2000) and quality of life measurements are often used in clinical trials (Bowling 1995; Bowling et al. 2001). However, a generally accepted definition of quality of life has not yet been obtained. For instance, a review of 87 studies from the literature found 44 different definitions (Hughes et al. 1995). In addition, these approaches tend to focus on medical rather than wider issues and frequently either implicitly or explicitly assume that impairment reduces quality of life. The development of indicators should also involve disabled people to ensure that the indicators cover the areas they consider to be important, which may not be the same as those considered important by researchers (Hughes et al. 1995). Several sources of information should be used and methodologies combined and their results compared (triangulated) to increase the reliability and validity of assessments.

There have been two main approaches to defining quality of life for disabled people using assistive technology, involving respectively fifteen (Hughes et al.1995) and eight factors (Schalock 1996). Schalock's approach has the advantages of being more compact and solely concerned with the impact on the person, rather than how these impacts are obtained. It also avoids an explicit or implicit assumption that impairment automatically reduces quality of life, whereas the categories of personal competence and support services used by Hughes are less likely to be included in a quality of life assessment of non-disabled people. Further research would be required to investigate the appropriateness of the framing of the categories to a range of different countries and cultures or whether modifications would be required.

Health related quality of life studies focus on the measurement of symptoms and functioning. For instance, a random sample of 75 articles (Gill and Feinstein 1997) found that most of them use an assessment of functioning consistent with the medical model of disability (Fuhrer 2000). However, studies show that satisfaction with life increases with the extent of social integration, employment and mobility and is not correlated with the degree of (physical) impairment (Fuhrer et al. 1992; Fuhrer 1996) or health status (Diener 1984; Eid and Diener 2004). Neither the formulation of health related quality of life measures for people who are considered 'patients' nor the focus on unaided functioning are particularly relevant for assistive products. It is both more useful in practical terms and more empowering to disabled and elderly people to consider independence and autonomy. Here independence is understood in the sense of 'control of their life and choosing how that life is led ...(and) the amount of control they have over their everyday routine' (Brisenden 1986; EUSTAT, 1999). Autonomy is defined as the ability to plan one's own life, to enter into relationships with others and together actively participate in the construction of society. These definitions are applicable to both disabled and non-disabled people. A non-disabled person who finds it difficult to plan their life will be non-autonomous, whereas a disabled person who successfully plans their life, enters into relationships and participates in society with the aid of assistive technology or a personal assistant will be autonomous.

Subjective quality of life (sometimes called well-being) has been defined as 'the degree to which people have positive appraisals and feelings about their life, considered as a whole' (Fuhrer, 2000). Specific measures include the Patient Generated Index (PGI) (Ruta et al. 1994) and the Satisfaction with Life Scale (Diener et al. 1985). Although the person defines the areas to be considered in the PGI, this is in the context of the areas affected by their impairments and based on the medical model of disability.

The quality of life instruments database currently includes 1000 items, with full descriptions given for 454 of them (QoL). The majority of the instruments or systems for measurement or assessment are medically based and seem to relate quality of life to wellness, lack of disability and/or functionality. Many of the instruments are specific to populations with particular illnesses or impairments. Few of the instruments in this database seem to be based on a wider understanding of quality of life or to be appropriate for a general population, including both disabled and non-disabled people and people both with and without (serious) illnesses. This is consistent with the tendency of some researchers in the area to use the terms quality of life and general health status interchangeably and to assume that a multiple item health status questionnaire can provide a satisfactory measure of quality of life (McDowell and Newell 1996).

Another approach used in the medical context defines quality of life as the gap between an individual's hopes and expectations and their actual experiences (Calman 1984). This approach has the advantage of including subjective elements and being defined by the individual rather than the researcher. However, there is the associated disadvantage that hopes and expectations are difficult to measure and a preference for the use of definitions which can be quantified and measured. Quality of life scales based on the Calman approach include the Schedule for the Evaluation of the Individual Quality of Life (O'Boyle et al. 1992, 1993). It is also available in a shorter form, SEIQoL-DW (Browne et al. 1994; Hickey et al. 1996), in which the quality of life scale is uniquely defined for each individual and based on the five quality of life domains that they consider the most important (Mountain et al. 2004).

Assistive Technology Quality of Life Procedures

There are a number of different quality of life procedures, which have been influenced to varying extents by the health quality of life approach and the assumption that disabled people automatically have a reduced quality of life, but a universally accepted approach has not yet been obtained.

LIFE-H (Fouygerollas et al. 1998) measures the quality of social participation using life habits (Noreau et al. 2002), including essential activities, such as sleeping and eating, and other activities. It is divided into 12 categories. Assessment is by a self or interviewer compiled questionnaire, with shorter and longer versions for general screening and more detailed assessment respectively, and a version for children. The difficulty in carrying out each life habit and the assistance required are assessed on a 10-point scale and the satisfaction with its accomplishment on a five-point scale. Comparison of the assessments with and without an assistive product could give an evaluation of the device's impact.

OT (occupational therapy)-FACT (Smith 2002) is a software based approach which measures 'function' in terms of 'observed performance' by an occupational therapist and the user's subjective evaluation of satisfaction with this performance. Question branching is used to investigate areas in which the user experiences difficulties or barriers (unfortunately called 'deficits). The TSCD (Time Series Concurrent Differential) methodology version is used to investigate the impact of assistive products by comparing performance with and without them.

PIADS (Psychosocial Impacts of Assistive Devices Scale) (Day et al. 2002; Jutai and Day 2002) is a 26-item self report questionnaire which assesses the effects of assistive device use on functional independence, well-being and quality of life. It is divided into three sub-scales: competence (12 items), adaptability (6 items) and self-esteem (8 items). Responses range from -3 (most negative impact) to +3 (most positive impact). The questionnaire generally takes 5-10 minutes to complete.

QUEST 2.0 (Quebec User Evaluation of Satisfaction with Assistive Technology) (Demers et al. 2002ab) evaluates satisfaction with assistive technology expressed in a linear general framework (Simon and Patrick 1997). Satisfaction is defined as 'a person's critical evaluation of several aspects of a device' and may be influenced by various subjective factors. It comprises 12 items, divided into an eight item device scale and a four item services scale, with a 5-point satisfaction scale for responses.

MPT (Matching Person and Technology) (Scherer 2000; Scherer and Cushman 2000; Scherer and Craddock 2002) is an assessment procedure for determining the appropriate assistive technology for a particular person in a given environment and the need for training and additional support to obtain the best use of the technology. It is based on the three component MPT model: person, technology and milieu. It comprises a number of forms. All these forms, except the healthcare form, have two versions to be completed by the service provider and user respectively. Comparison of the two completed versions can then be used to identify characteristics of the user, environment or device that could result in inappropriate use or abandonment. The process involves a six stage procedure. The first three stages use questionnaires to investigate 'limitations' and satisfaction in areas such as communication and mobility, prioritise areas the user most wants to improve and factors relating to device use. The latter three stages use interviews to discuss the outcomes of the questionnaires and obtain an action plan for obtaining an appropriate device, including funding and training if required.

IPPA (Individually Prioritised Problem Assessment) (Wessels et al. 2000, 2002) assesses the extent to which assistive technology provision reduces problems and barriers. The user is asked to identify up to seven barriers to carrying out everyday activities that could be reduced by assistive technology. For each issue an IPPA form is completed and the respondent identifies the importance and level of difficulty of the activity using a multiple choice format with five values. This is used to calculate an average weighted difficulty score and can be compared with the difficulty score obtained a few months after the provision of assistive technology.

None of these methods seems to be in regular use in practice. However, this is as much a comment on the lack of evaluation of assistive technology as on the methods themselves. The most studied of the methods are probably MPT, PIADS and QUEST. A number of studies to validate the methods or to investigate the impacts of the provision of particular technologies have been carried out, for instance (MPT) for a summary of the validation studies for MPT; (Day and Jutai 1996; Day et al. 2001; Jutai and Day 2002) for examples of studies for PIADS and (Demers et al. 1999; Demers et al. 2002; Stickel et al. 2002; Wessels and de Witte 2003) for QUEST. However these studies are all one-off examples and not reports of the use of the methods in actual practice following the provision of assistive products.

Other Methods

Goal Attainment Scaling

Although developed for evaluation of the outcomes of mental health treatment programmes, Goal Attainment Scaling (GAS) has been widely used in other human service programmes (Kirusek et al. 1994) and could be applied to the evaluation of assistive products. It involves choosing a number of goals or areas of life that the assistive technology is expected to affect. The expected outcome in each goal area is given the value 0. Outcomes which are possible, but respectively somewhat and much less/more than expected are given the values ±1 and ±2. Goal attainment can then be evaluated at suitable interval(s) after device provision. The approach has the advantage of allowing goals to be set by the end-user and being compatible with both the social and medical models, as well as giving a degree of transparency to the process. However, this method is more suitable for use in the context of individual end-users or, possibly with relatively homogenous end-user communities. In applications to an end-user community problems could be encountered if consensus cannot be obtained across the community on a reasonable number of goal areas and research would be required to investigate this. Further problems could occur due to the nature of the scale used, with both positive and negative values and only two points in either direction, possibly resulting in a meaningless outcome. A possible modification would involve obtaining the numbers of people with each score for each goal and then calculating the percentage of respondents with each possible change in score from -2 to +2.

Item Response Theory and Rasch Measurement Scaling

Item response theory (IRT) (Hays et al. 2000; Reise et al. 2010) comprises mathematical tools and statistical methods that can be used to analyse items and scales, create and administer health outcome measures, and assess self-reported health outcomes. The main component is the item response function which gives the mathematical relation between an individual's underlying level on a construct or latent trait, such as a health domain, and the probability of a particular item response using a nonlinear monotonic function. IRT can be used to determine an item response function for each item on a measure and the functions can be used to evaluate item quality. There are different types of IRT models with different functional forms for the response functions. Items on scales with different response formats can be combined if their responses have a specifiable relationship with the underlying construct.

The IRT tools could be, in principle, be adopted to be used for other domains than health outcomes. Further research would be required to determine appropriate domains to measure to evaluate the impact of assistive products, as well as whether the use of the IRT tools has advantages over existing approaches.

Rasch Measurement Scaling is based on Item Response Theory. It allows customisation of a question set by allowing questions to be chosen from a battery of questions and customisation of questions and their difficulty levels into an interval scale. This could possibly allow conversion between different outcome measurement instruments, but would require development of a universal scale to which each instrument could be related. However, the method has the drawback of requiring a priori data for each population and subpopulation and would need to be very large to cover all assistive technology combinations and environments. This data contributes to a central database which supports the development of an interval scale (Smith 2000).

Conclusions

Despite the importance of the evaluation of assistive products, there has been limited work in the area, with evaluation techniques and methodologies still under development and few cases studies. The focus has generally been on evaluating outcomes rather than the design and technical and market performance of assistive products throughout their life cycle. Part 2 of this three part paper discussed the evaluation of assistive products, whereas this article, Part 3, considers outcome assessment.

One of the best known approaches is the Matching Person with Technology method. However, it has been designed to evaluate the match between the user and an assistive product in their current circumstances rather than the outcomes of using a particular assistive product. Quality of life methodologies are promising, since one of the important potential impacts of an assistive product is an improvement in the user's quality of life. A number of quality of life procedures developed specifically for assistive technology have been discussed, but they all have limitations. Instruments based on the Comprehensive Assistive Technology (CAT) and Human Activity Assistive Technology (HAAT) models have advantages in considering the wider context of the user and the CAT model additionally in being based on a philosophy of overcoming barriers. However, questionnaire based instruments would require to be developed and in their current format the approaches are not able to evaluate user satisfaction. Goal Attainment Scaling is a simpler, but useful approach of assessing the expected outcomes in a number of goal areas that the assistive product is expected to affect.

Other approaches considered include functional evaluation and economic evaluation. However, existing approaches to functional evaluation treat assistive technology as an independent variable and are generally unsuitable for determining outcomes due to its use. In addition, end-users may have other priorities than improving ‘functioning’, particularly in the limited sense generally associated with functional evaluation. Economic evaluation includes both monetary evaluation of all costs and benefits and cost-outcome analysis in which non-monetary quantitative values of benefits are used. The latter avoids some of the problems associated with the conversion of all benefits to monetary values, but not with the quantification of qualitative variables. There may also be a tendency to bias decisions towards those which reduce monetary costs.

Thus, in summary, existing approaches all have advantages and disadvantages. Further research will be required to develop evaluation procedures and move beyond the limitations of existing approaches. It would also be useful to carry out a comparative evaluation of the different approaches, which could be used to inform further research.

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