Inclusive Design For Assistive Technology

Richard HERRIOTT[a,1] and Sharon COOK[b]
[a] *Design Platform, Aarhus School of Architecture, Denmark*
[b] *Design Department, Loughborough University, United Kingdom*

Abstract. This paper compares the processes and methods of nine cases of assistive technology design (AT) with the predominant model of Inclusive Design (ID).There is a comparison of both process and methods. Design for AT requires a special focus on user-requirements during product development, and as such ID methodology is relevant to AT design. Research in AT design has both drawn from and added to the ID knowledge base. However, mainstream ID operates under different conditions from AT, where the scale of projects is smaller. Semi-structured interviews were carried out with nine designers of assistive technology. This provided raw data on the processes and methods used in a range of products including a children´s wheelchair, a wash-basin system, a wheeled walking frame and breathing apparatus. It was found that design for AT has some overlap with design for mainstream ID, but there are important differences of emphasis, in particular: a) that user investigations must draw on stakeholders other than users (carers and medical professionals) when gathering user requirements and conducting verification testing, b) requirements gathering and definition is under-emphasised and c) prototyping becomes a more important element of the design process.

Keywords. Inclusive Design, Assistive Technology, Design Process

Introduction

This paper continues previous work that explored differences in approach between ID for mainstream products and for AT [1][2]. AT design is distinguished from consumer product design by the fact that the users have a physical impairment requiring the use of the device, and that the device is often purchased by a third party on behalf of the user.

By looking at nine cases of AT design, this paper explores how design for AT is carried out in practice. The intention is to see whether actual design cases conform to an authoritative ID model, and to define more clearly the distinctions between AT and ID methods..

1. Inclusive Design and Assistive Technology

Assistive Technology is “any item, piece of equipment or product system whether acquired commercially off the shelf, modified, or customized that is used to increase, maintain or improve functional capabilities of individuals with disabilities” [3].

[1] Corresponding Author.

Inclusive Design is an approach to the design of mainstream products and services that are "accessible to and useable by as many people as reasonably possible, without the need for specialist design." [4]. It is apparent by juxtaposing these definitions that AT is an end and ID is a means. Furthermore, AT products have specialised designs unlike consumer products, which are the typical outputs of ID processes. The standard approach to AT has tended to use a hard-systems model of development: "Within design for disability, where teams tend to come from clinical and engineering backgrounds, the dominant culture is still one of solving problems" [5]. This means AT design is practiced in the style of medical technology, using design methods allied to those used for medical and rehabilitation devices [6]. The other, more recent approach to AT recognizes the importance of the user and draws from user-centred, social-science based methods of ID. Oishi observes that "effective assistive technologies depend not only on 'good' engineering design […] but also on the extent to which the technology has been integrated with clinical needs, user-requirements, ethical concerns and the social context of the technology's use" [7]. The research presented at the Cambridge Workshop on Universal Access and Assistive Technology and at RCA´s Include conferences shows that this second approach is still a developing field. This blending of soft- and hard-systems methods is where AT design draws from ID philosophy and ID methods. To some extent it exemplifies a conflation of AT design with ID for mainstream products.

The characteristics of ID derive from involving the user in the design process by means of a variety of methods. These include (but are not limited to) focus groups, video ethnography, questionnaires, critical user-forums, workshops, empathic simulation, interviews (both structured and unstructured) and cultural probes. Clarkson et al. [8] also stress user consultation at the requirement definition stage, specification stage and the prototyping stage. De Couvreur (2011) describes user-centred design for individual users and puts extra emphasis on the role of the occupational therapists [9], an approach straddling the ID and participative design.

There are prescriptive design models for processes suggested for ID [8]. However, design models intended for consumer products may not accord faithfully with design for users with capability loss produced under much less commercially favourable conditions. First, the users of AT are fewer. Second, they have physical and cognitive difficulties placing them outside even the "broader mainstream". Third, the influence of market pressures is in some cases indirect since the purchasers of AT may not be the user. By looking at the practice of AT and its design sequence, this paper examines where design energy is expended, and from this empirical approach suggests where AT differs from ID processes.

2. Methodology

Designers at nine manufacturers and design firms were interviewed between May 2011 and January 2013. The projects are heterogeneous in character which reflects the diversity of AT design. The variability of the subjects was also acceptable given that the emphasis of the research was also on the qualitative aspects rather than the quantitative aspects exclusively. Participants were asked to describe what steps they took to incorporate users into their design process. The interviews were recorded and

transcribed. The transcripts were sent to the interviewees for review. None elected to comment or amend the text. Most interviews were conducted by telephone for logistical reasons. The protocol for the interviews loosely follows Christmann [10] (2009), who recommends "a strongly structured guideline which is similar to a standardised questionnaire the only difference being that it includes more open questions than the latter".

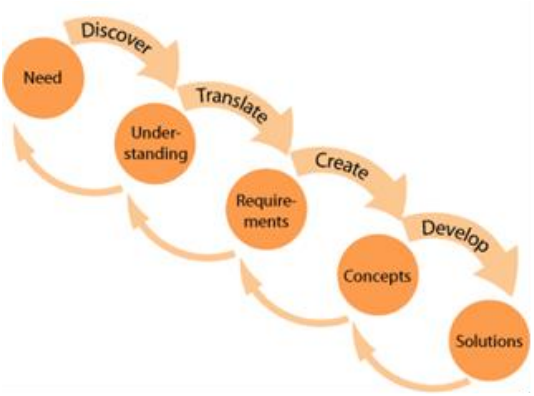

Figure 1. EDC design process [7].

The questions sequence was based on the order steps in the design process as described by the Engineering Design Centre, Cambridge (see Fig. 1). The working assumption was that the processes would approximately have this kind of ordering. To provide context and to enable comparison, the interview sequence began with a description of the project and the planned design process. A full list of the questions is available at inclusivelydesigned.wordpress.com. The EDC model was revised in 2013 such that it is less prescriptive and more indicative of the "semi-structured" qualities of the design process.

3. Results

This section presents the information obtained from the interviews in a compressed form. The subjects´ identities have been generalised to preserve anonymity.

3.1. Student Design Project, Denmark

Two final-year MA design students developed a concept for a respirator for patients with chronic obstructive pulmonary disorder, a disease causing irreversible deterioration in respiration capability. The team had a planned design process, a systems-model, before beginning the project but this was not followed. The actual process was described as chaotic. The reason for this disruption was the emergence of several unexpected technical problems that forced changes of direction. The close link between the aesthetics and the engineering elements meant it was difficult to separate these areas into more manageable sub-tasks. Additionally, while users were expected to be a large part of the process, their illness prohibited this. The team had a pre-defined

notion of what they needed to know but their research immediately became time-consuming and complex because a) it was hard to find reliable information on the two possible design concepts and b) their user-investigation methods were inappropriate for severely disabled people. From the initial data the list of problems users had was translated into an action list of possible solutions. Because of the ill-health of their user-group, it was necessary to cross-check this list with a single "super user" for verification rather than with all their initial contacts.

Ideation involved brain-storming and working with fellow students followed by sketching in batches of ideas. Users were not involved at this stage. Concept selection was done without users and instead the designers used themselves and other students as subjects to test ideas using sketch models. For development of the final design further use was made of approximately twenty 1:1 sketch models. The critical element of the final design was shown to the super-user for approval. Feasibility validation was done in co-operation with an engineer who advised on technical matters.

3.2. Research And Innovation Consultancy, Denmark

The aim of the project was to create new types of AT products, with an emphasis on comfort and hygiene. The project proceeded to prototype stage and two items went into production. There was a pre-determined design process which was followed except that there was unexpected cycling and re-iteration of research, analysis and concept development. As the subject said: "it´s never a linear process in that way but in the broad sense we followed the plan". 94 users were interviewed, with an anthropologist as part of the team and then ideas were generated for further work. Observation was conducted in the subjects' homes. This included discussions with caregivers. Themed workshops with caregivers and manufacturers focused on particular areas of interest. Personas were used as references for these workshops rather than real patients. During research, ideas cards were created and used for the writing of the specification but this specification was not cross-checked with users. Instead the project´s sponsors and the designers selected ideas according feasibility. The team used prototyping to generate ideas, which were shown to users; this was followed by revisions. The subject agreed with the proposition that idea generation and concept development phase were blended together. Testing and refinement proceeded to the level of "pre-product" where it was essential that the concept was as close to real as possible for proper evaluation.

3.3. Design Consultancy, Denmark

The project was a wheeled walking frame. The firm followed its in-house design process: Product standards were also referred to. Ideas generation and prioritisation occurred at the same time, leading to a requirements description. Users were shown models to select the ideas they preferred.

There was also a separate ideation stage that did not involve the users. Userswere not involved during ideation. Brainstorming and mind mapping were the ideation methods cited. The designer also had pre-formed ideas in mind, even during initial research: "I have some ideas in my head when I am out doing the user research". For idea selection there is reference to existing designs (successful design features are

adopted), de-selection and "designerly intuition". The definition of the technical specification was done with reference to the existing standards and also with consultation with physiotherapeutic experts. The designer noted that here user input was of limited value: "I think it´s very important how you use the users. When we talk about the users we are talking about the end –user, the elderly person, because sometimes they don´t know what is better for them". A development mock-up was built in accordance with Danish standards which were revised to allow the new solution proposed- The concept design was validated by a presentation to users and buyers at a trade show. Users were not involved after this point in the process.

3.4. Health Authority, Denmark

The subject produces tailored AT equipment for approximately twenty clients annually. These are primarily people with physical disabilities such as paraplegia who often need to use modified IT systems and electronics. The subject agreed with the proposition that it is not his patients that are different (worse or more difficult) but that he and his department decided to use different, tailored solutions for them. Each case involves one user and one or two health professionals. The users often have difficulty expressing themselves and often have no precise idea what they require, so the health-care workers have an important role in defining the problem. The work method is in the first instance to conduct an interview. Then materials such as controllers, joysticks and stock electronics which are brought to the user and a prototype is made and tested. If necessary a second round of revision is undertaken. The design process (which involves no drawings or models) is improvisational, informal and rapid. There is no written specification and no translation of requirements. Idea generation is embodied in the ready-made equipment. Concept selection involves presenting alternatives to the user and testing them in one or two rounds.

3.5. Design Consultant, Denmark

The project was a wheelchair for children. The planned design process consisted of five stages. Phase Zero: (research) interviews with the stakeholders and cataloguing of the information. Phase 1: brainstorm and make sketches with reference to the insight from Phase Zero, where ideas are prioritised. Some requirements are developed at this point. Designers tried wheelchairs to gain insight into the users´ experience. Users were not involved here. Phase 2 (selection): take sketches to the customers to select preferred proposals, to consider "production and cost, materials, volume, and making sure that important parts are designed for other products, making the best junction parts". Further requirements are defined between Phases 2 and 3 where there is another round of selecting. The model phase starts at Phase 3, followed by deciding the means of production, materials, and maximising flexibility and minimising part count. Phase 4: costing and customer´s willingness to follow through the design ideas and checking against the competitors´ products. In phase 4 there is "quality control" so that what was found out earlier is not discarded for pragmatic reasons. For stakeholder evaluation the designers visited a variety of the regional distributors. Validation was done with the therapists, not the users.

3.6. University Design Department, UK

The design process for this product, a non-ratchet stair-climbing aid, was unusually protracted. The early work was reported by Mayagoitia [11]. After an initial research phase, it was decided to use a student-project as a basis for development. The student´s concept was revised and a prototype of the amended design was tested with users followed by debriefing interviews. As such, this project started with much conceptual work and research already completed in what could be termed the preliminary phase. The process was structured around the norms of ergonomic methods and resembled a sequence of fitting trials.

Deviations from the planned design process were required when trials revealed a risk of hand-injury due to user´s gripping the device at unexpected points. Users were involved throughout the design process. This involved prototyping (three stages) and reference to users in focus groups and one-to-one interviews. There was no clear data on how the requirements were turned into a specification. Revised health and safety requirements were met and users were consulted about the specification in two rounds. All the stakeholders were consulted.

3.7. Design Consultancy, UK.

The subject was the director of a London-based design consultancy. The product was a redesigned reaching device. The firm had a planned design process. The importance of ergonomics was emphasised. The client´s reason for the re-design was to take advantage of the tooling for the existing product reaching the end of its service life, while the consultancy saw an opportunity to improve the product´s usability and appearance: “I think people are beginning to buy these things personally and that´s one of the differences”, said the interview subject. The firm interviewed 15 existing users and researched existing products. The design requirements were defined and sketches and photos made. Following a review with the client, feasibility and costing problems were identified and a new definition of the product made. Sketching was undertaken throughout the project as a communication tool. Users were shown sketches during the process. Users were involved in idea generation to check if the ideas were acceptable rather than to propose new ideas. Concepts were presented as static and animated CAD models and also as mock-ups.

3.8. Sanitary-ware producer, Denmark

The firm designs and produces sanitary ware for the care-home market, in this case a variable-height toilet for users with dementia. The design process was not worked out in advance in formal terms. The process is more experimental and based on a need identified by the firm's director via user observations, and on published research. Inputs from suppliers were matched with those from hospital and care home managers during a workshop organised by the Danish Department for Commerce. This featured brainstorming and discussions. Ideas created at this stage were refined by professional external consultants. Customer interviews were conducted at the product development stage. The design was then tested in a care home for a six-month period. The difficulty

has been with the user´s diminished capacity to discuss the product so surrogates were required, care-givers in this case). After testing, the prototype was refined using CAD models. There was no user input at this stage.

3.9. Stair-Climbing Equipment Producer, UK

The subject was the concept design manager. The project was a stair lift for narrow staircases, intended for users who were typically aged 50 and over and who had reduced knee and hip flexibility. The firm has a prepared design process, termed New Product Introduction, comprising a global product strategy, a product strategy, ideas review and a concept phase. User data is provided by the marketing staff. Initial investigations were by interviews and video recordings of users and occupational therapists. A specification is prepared but users are not consulted at this point. Concept generation follows using sketching and an osteoarthritis simulation suit. The concepts are then evaluated, this stage ending with the construction of a physical prototype. This was tested first with staff and then, after revision, with users. This stage revealed the need for a means to secure the user in the device when in motion and the need for anti-slip upholstery. After this stage it became a "live project", during which time there were three build cycles with accompanying live tests of the designs. Each cycle was followed by a review. The aim of this process is to eliminate technical risks. Users were invited to test the final prototype. After any necessary mechanical changes were completed, the design proceeded to production.

4. Analysis of Data

Our initial question is where is design energy expended, and is it possible to see from the data how AT and IT differ in their processes and methods.

The most frequently used design tools mentioned were verbal inquiries such as interviews, discussions and workshops (10) prototyping (9) brainstorming (4) and observation (4). Empathic strategies were used in 3 instances. The other methods were used in one or two instances each. Most subjects reported having a design process in mind but the description of the process did not fit closely to the academic conception of such a process. The authors attempted to sketch out the design process of seven of the projects but concluded the interpretation was too subjective to have value.

There are important differences of emphasis between design for AT and ID, in particular: a) that user investigations must draw on stakeholders other than users (carers and medical professionals) when gathering user requirements and conducting verification testing, b) requirements gathering and definition is under-emphasised and c) prototyping becomes a more important element of the design process.

With reference to point (a), three projects were characterised by difficulties with working with users. For the respirator project there was the discovery that user participation would be very limited. This ruled out the planned process. Surrogates and self-testing were necessary, but a super-user was found to conduct the verification stage. The research and innovation consultancy used personas derived from qualitative interviews in its personal care product project. An ethnographer mediated between the

users and designers, and the final result was two marketable products. The sanitary ware producer was the least orthodox of all, but all the same the final result was a product which met the requirements of the prospective users and customers (care homes). The tailored AT equipment project had no formal design process as such and marks an extreme case, being for users with communication difficulties and without the intention of mass production. Surrogates (ergotherapists) had an important role. Each of the projects completed steps corresponding to the model process but they were completed in a different order; some steps were blended and some were omitted. All three (respirator, personal care, sanitary ware) could be described as non-linear processes that yielded a satisfactory outcome.

The wheeled walking frame, the reacher and the wheel chair were the products of design consultancies working on re-designs. The subject discussing the walking frame expressed the need to qualify user-input with design-intuition and to be selective as to when to engage with users. The UK consultancy´s reacher project and the wheel-chair project were characterised by tension between the wishes the customer´s pragmatism, the physiotherapists' wishes to assist a variety of needs and the wishes of the designer to best serve the user. The consequence of these tensions was compromise in the final product. In the case of the walking frame, the designer was also the owner of the product, as they had decided to commission production themselves. These preferences were not always in accord and the resultant product is a compromise. In the case of the walking frame, the designer was also the owner of the product as they had decided to commission production themselves. This gave the designer a freer hand to define the product´s specification.

The stair lifts used two different approaches: a more obviously academic ID approach and a commercial approach. The manufacturer had the most traditional design process, including the task of persuading the marketing staff of the necessity of the new product. They also provided data concerning the target market, but the design process itself, through multiple phases of user testing, ensured that the users were represented. The academic project is notable for the use of prototypes all the way through the project, including during the investigation phase.

Relating to point (b), the absence of much data on the analysis and translation of user data may be indicative of a lack of emphasis on this stage in the design process. The design processes used by AT developers deploys the "Concepts" and "Develop" steps at a wider variety of points in the design process than prescribed by the EDC. Design for AT is also likely to encounter the problem of the user who can´t express themself. Given the importance of verbal inquiry in ID, this means other tools must be deployed. There is thus a subset of AT defined by the point at which illness or general cognitive incapacity rules out many of the sociological methods of inquiry typical of the soft-systems approach.

Dealing with point (c), and to answer the question posed at the start, prototyping is evidently a focus of design activities, more so than was indicated in the 2013 meta-study by Herriott [2]. In the EDC model, the penultimate output, "concepts", and the subsequent "develop" activity are where models and prototypes feature. In the cases here, prototyping was used earlier and more often.

The aesthetic element of design, as noted by ID researchers Li *et al* [12], is "still the core knowledge of the design profession", and issues of "design and aesthetics are of utmost importance in many markets when shaping selves and self-identities" [13]. However, aesthetics featured strongly only a minority of the interviews: the respirator, the reacher and the wheeled walking frame. Despite the need to reduce the impact of stigmatization, AT is perhaps structurally restricted in the extent to which aesthetics can moderate forms governed by quantitative factors.

5. Discussion and Conclusion

The design processes here show the diversity of the means by which designers solve problems and the variety of conditions under which they solve them. A revision to the concept of design model itself seems to be necessary, with the primacy of tools and methods over the order in which they are used. Design models usually envision ends linked in a defined way by verbal, action-based relationships. Conceivably, methods and techniques can be validly arranged in a large number of different combinations. This is shown by the use of prototypes a design tool at any different in the projects. Each tool or method has an input and output. Perhaps a tool-based design process rather than end-directed design process might provide designers with at least a rough idea of how they will proceed during a given project.

The advantage of the prototype is that users can see and touch the object. The disadvantage is that prototypes can lock-in design assumption at an early stage. Verbal inquiries and exchanges (interviews and focus groups etc) also may be used at various junctures. Whether these exchanges lock-in design choices depends on whether they are intended to generate new ideas (process-opening) or to choose and confirm ideas (process-closing). A similar possibility exists for prototypes. It may very well be constructive to qualify the until-now unqualified categories of interview and prototype as intended for either process-opening or process-closing.

Prototyping, brainstorming, observation, and empathic strategies together cover much of the design process. But the capture of requirements and translation into a specification did not feature strongly even though the questionnaire addressed this directly. The subjects did not seem to wish to expand on their answers or go into depth about the topic. Plos *et al* [14] list 15 methods of requirements analysis. Seven methods are cited in the interviews, all from the "abstract, need centered" quadrant of their perceptual map. Requirements definitions need to be understood by a variety of different specialists and the users. No single method suits all the stakeholders. Indeed, Plos *et al* [15] suggest several repeated methods to survey users' needs. Perhaps some stakeholders are not making informed choices since the requirements definition are not expressed in terms suited to their capacity or specialty.

The research and innovation healthcare project (section 3.2) blended design, prototyping and validation stages since the iterations were done in conjunction with the users to ensure practicality and acceptability. Other projects which relied on prototyping as a design tool were the university stair lift project, the respirator and the local health authority tailored AT project. This particular project was the closest to the idea of "design for (every) one" (sic) which steps beyond the idea of the broader

mainstream and prepares solutions for each individual [9]. The occupational therapist played an important role during the development of the design. Prototyping was a method which appeared to be useable at any point in the various design processes. Similarly, users are present at various points in all these projects, but with the exception of the university project, were never present all the way through. None managed to use co-design or participatory design either.

Plos *et al* [15] recently propose a "universalist strategy" for the design of assistive technology. How does the work described here compare? Their model is ends directed more than relating to details or ordering of the process. They state "these design principles should not be viewed as a process, with a specified sequence, since they should ideally be addressed concurrently" [ibid., p 537]. Looking to the points addressed by Plos *et al*, it is surprising how seldom they are expressly named or inferred in the interviews. The ECD model (revised) and Plos *et al*´s universalist approaches are not exclusive but would appear to be complimentary. A combination of the two would be an improvement on much reported industry practice in AT design. Perhaps a study to see how the two approaches could be synthesised might provide inspiration for future work.

References

[1] Herriott, R (2012) When users cannot be included in inclusive design". In Langdon, P., De Couvreur, L (2011) Design for Everyone: co-creation as a bridge between universal design and rehabilitation engineering. CoDesign: International Journal of CoCreation in Design and the Arts. Volume 7, Issue 2, 2011. pp 107-121.

[2] Herriott, R (2013) Are Inclusive Designers Designing Inclusively: An Analysis of 66 Design Cases." The Design Journal. Vol 16, Issue 2, pp 138-158.

[3] Public Law 100-407, the Technical Assistance to the States Act, USA

[4] BS 7000-6 Design management systems. Managing inclusive design.

[5] Pullin, G. (2009). When Design Meets Disability. MIT, USA. (p. xv).

[6] Cook, A., Hussey, S.M., (2002) Assistive Technologies – Principles and Practices. Mosby. St.Louis, MA. (p.21)

[7] Oishi M.M.K., Mitchell I., Van Der Loos, H.F. (eds.)(2010) Design and Use of Assistive Technology. Springer, New York.

[8] Clarkson, J., Coleman R., Hosking, I., Waller, S (2007) Inclusive Design Toolkit. Enginering Design Centre, University of Cambridge, Cambridge, UK (pp 2.1-2.61)

[9] De Couvreur, L., Goossens, R (2011) Design for Everyone: co-creation as a bridge between universal design and rehabilitation engineering. CoDesign: International Journal of CoCreation in Design and the Arts. Volume 7, Issue 2, 2011. pp 107-121.

[10] Christmann, G (2009) "Expert interview on the telephone: a difficult undertaking" in Bogner, A., Littig, B., and Menz, W (eds) (2009) Interviewing Experts. Palgrave Macmillan, Basingstoke, UK, p164

[11] Mayagoitia R., Kitchen S., Harding J., King R., Turner-Smith, A. (2006) User-centred approach to the design and evaluation of a stair-climbing aid, In Clarkson *et al* (eds) Designing accessible technology. Springer, London. pp. 127-134

[12] Li, Y., Bichard J.,Coleman, R (2008) Designing with users, how? Proceedings of the DMI Education Conference, ESSEC Business School, Cergy-Pointnoise, France.

[13] Ravneberg, B. (2009) Identity politics by design: users, markets and the public provision for assistive technology in Norway. Scandinavian Journal of Disability Research. Vol 11, No 2, pp101-115.

[14] Plos, O., Buisine, S., Auossat, A., Dumas, C (2007) Analysis and Translation of User Needs For Assistive Technology Design. Proceedings of the International Conference on Engineering Design.

[15] Plos, O., Buisine, S., Aoussat, A., Mantelet, F., Dumas, C., (2012) A universalist strategy for the design of Assistive Technlogy. International Journal of Industrial Ergonomics 42, 533-541.