THE RELATION OF DESIGN TOOLS TO UNIVERSAL DESIGN THEORY

Richard Herriott

[1]Department of Design, Design School Kolding, Kolding, Denmark

[1]rhe@dskd.dk

Abstract: Are researchers in Universal Design (UD) using UD theory? There is a link between theory and the appropriate use and selection of tools in design research. On that basis, 256 conference papers from the Cambridge Workshop of Universal Access and Assistive Technology (2002 to 2020) are reviewed for instances of tool use and links to UD and general design theoretical content. From this, it is shown that the instance of explicit tool use can be found in a minority of articles. Those that do have articulated links between the tool of inquiry and theory are classed into four groups, a minority of which are based on UD theory. A recommendation is made for a more explicit explanation of the basis of tool use in research design in order to improve the transparency and comprehensibility of the research design.

Keywords: Universal Design, design theory, design tools, design research, Inclusive Design minimum three words.

Introduction

Tools "without theoretical substance can be sterile, representing technical sophistication in isolation" (Van Maanen et al., 2007, p.1146). In the light of this proposition, this article consists of an examination of the linkage between design theory and the use of design tools in Universal Design (UD) research. Design tools matter for the design process, being a connection between the user and the mind of the designer. Examples include drawing, mood boards, A/B testing, focus groups and cultural probes. The importance of theory is the two-way relation between it and data, connected by the instruments of

inquiry, the design tool. Ideally, these are strongly connected (Fawcett, 1978; Wacker, 1998, p.362; Swanson & Holton, 2005, p.8; Van Maanen et al. 2007, p.1145; Sileyew, 2019, p.28).

Rather than re-iterate the main points of UD, readers needing background are referred to the comprehensive overview of the definition, scope and features found in Persson et al., (2015) and also Patrick & Hollenbeck (2021). In brief, the main ambition of UD is to maximise accessibility without the need for specialised features by acquiring and structuring information about users´ needs (Ning & Dong, 2016, p.147).

Ning and Dong write that design tools are part of this gathering of data (ibid). Or, as Persad et al. (2006) write: "In the product design process, designers require systematic methods, tools and data in support of product design evaluation" (p.1). Further, design tools "capture human goals and actions and their impact on the functional parts of a given product" (Mieczakowski, et al. 2010, p.142). Using tools is not easy or necessarily straightforward and Goodman et al. (2006) write about the problems designers have with design methods (here meaning tools): "When they do use methods, the methods are not always applied appropriately or consistently and they are often applied in inappropriate situations leading to disappointing results" (p.47). With this in mind, it would be good to know on what basis design tools are used and what effect this has on the research/design outcome. It would also be good to find out if there is much evidence of researchers making clear the theory-tool relationship.

The literature on the linking of theory to tools in UD is not extensive. Some articles touch on the matter but do not deal with it as a primary focus. Dong et al. (2003) discuss the discrepancy between theory and practice in commercial settings. They conclude that the "provision of design support tools is necessary to bring inclusive design theory and practice closer together". Ruffino et al. (2006) is quite a detailed examination of the Universal Design for Play Tool. The link to theory is noted a being the tool´s basis in the seven principles of UD. The article does not discuss UD theory any further. Cremers et al. (2016) is a focused paper that links UD to their ICT design tool. They see the link as being from 1) standards and guidelines, 2)

anchoring of design patterns in ethics and values and 3) situated design derived from case analyses. The pattern that emerges is that searches in using Google Scholar do not produce results that suggest there has been much work done on the general theory-to-tool linkage. This is true for searches using the terms Universal Design, Inclusive Design or Design for All.

This paper builds on previous work regarding tools' relation to method (Goodman-Deane et al., 2008) and the nature of tools in design (Rampino & Colombo, 2012; Dalsgaard, 2017; Herriott & Akoglu, 2019). It also relates to the instantiation of theory in UD research (Herriott, 2023). That article concluded that research into UD theory had a tendency to omit elements that were related to principles of implementation. Design tools are derived from theory, in particular principles of implementation: according to Jones & Gregor´s (2007) proposal for the structure of a design theory, such principles are "a description of processes for implementing the theory (either product or method) in specific contexts" (p.27).

What we are interested in here are the design tools that depend on the content of UD theory, which is the articulation of why and how to maximise accessibility without the need for specialised features. Since UD has commonality in general design principles, some tools used in UD may be based on what one might call "standard user-centred design". In passing we will also encounter design tools based on other theory from outside UD and its related fields.

With the desire to improve UD practice (meaning better grounds for tool use) and to improve UD theory-building in relation to principles of instantiation, these questions will be addressed:

- To what extent do researchers in UD use design tools that are dependent on UD theory?

- How do researchers in UD use existing design tools if they use them?

- What is revealed about the relationship between tools and UD theory?

The terms Universal Design (UD), Inclusive Design (ID) and Design For All are treated as being synonymous in much design research literature (Stephanidis, 2001; Ostroff, 2009, p.3; Heylighen & Bianchin 2013, p.93; Persson et al. 2015, p.2; Zhu et al., 2020, p.2). As such, all of those terms will be encountered in citations and the general discussion of the subject in this text. The term UD will be used here without the intention to exclude ID and Design for All.

Design tools and theory

Before moving to the review of research, it is necessary to lay out a conception of what tools are. Though there is a large body of design research involving tools, research articles about tools theory are not numerous. However, the few available are adequate for the purposes of this article. First, where are tools located in the hierarchy of specificity? Rampino & Colombo (2012, p.85) explored terminology in design research. They proposed a hierarchy of research levels, from general to specific:

1) nature of the research,

2) research process,

3) codified research procedures,

4) specific instruments.

Tools are classed as specific instruments. The related term "method" may be placed in category 3 or 4. As with Herriott & Akoglu (2019), Rampino and Colombo (2012) find that the terms "method" and "tool" are used interchangeably but prefer to place them in separate classes, i.e. to assign the word "tool" and "method" different meanings. Rampino and Colombo (2012) define a "research tool, or instrument" as "a structured procedure sharply focused on a precise objective, for example, on collecting empirical data, elaborating those data, analysing them and so forth" (p.89).

Casais (2020) offers this definition of tools and so links tools to theory: "Design tools are compact vehicles of data, often with game elements, that deliver methods of working, inspire with ideas or solutions, and summarise complex information in a format that is possible to handle. Such tools have the

potential to increase eloquence in intricate matters, by streamlining concepts and theories" (p.3). Casais produced this rubric of the nature of tools:

1) summarising theoretical knowledge;

2) providing inspiration/displaying design cases;

3) understanding the user; and

4) providing methodological support. (Casais, 2020, p.5)

It is understood that these four characteristics are demonstrated to some degree in tools.

The work on tools´ nature is not unequivocal. There exist differing conceptions of tools. One is a directly instrumental view, where something happens or is discovered: design tool as an instrument of inquiry (e.g. Dalsgaard, 2019). Another is more abstract, the design tool "as an instigator and mediator in small and large social transactions" (Winton & Rodgers, 2020, p.11).

Having looked at what tools do, we must also ask what they are for. Tools do something more than inquire. Designers might be said to use them to "capture human goals and actions and their impact on the functional parts of a given product" (Mieczakowski et al., 2010, p.142). This implies tools help interpret what is found out.

Although a rigid demarcation is not feasible, some form of distinction is needed between tools and methods. Pragmatically one might define the difference between a tool and a method as being that tools are more prescriptive or constraining (think of a knife that affords just cutting). Methods are more general and would involve the choice of tool(s) and sequence of use e.g. the order and timing of steps in a process. That is how they are distinguished here with the proviso it is still a matter of interpretation and context. One could think of tool as like nouns and methods as being analogous to a verb.

One further point is to do with terminology. As well as methods being conflated with tools (e.g. the term "framework" is also used in relation to

design inquiry and analysis, e.g. Goodman-Deane et al. (2008; p.23) and Karam & Langdon (2016; p.187). The Goodman-Deane et al. (2008) text concerns a framework for selecting methods and tools. They studied the choice of design methods (by which term they seemed to mean tools). The work determined by research what tools were used at what stages. In this instance, what is called a framework is not a directly applied means to achieve a design end. It appears to be a categorisation of existing things which themselves are instruments of inquiry. It is derivative of existing tools but a case can be made that it is a tool not a method. Karam & Langdon (2016) discuss a framework "highlighting the somatosensory system in our understanding of the design and development of computer interactions for the human body…. and this framework is intended to serve as a *tool* for broadening our understanding of the multidisciplinary aspects that influence all interactions designed for the body" (p.187, italics added). Here the word "tool" could be replaced by the word "means". The framework here is broadly a kind of mid-level theory rather than a direct way to interact with the world. It meets only the first criteria of Casais (2020, p.5).

Having clarified that point, it is possible to say that for the purposes of this study, the target of the inquiry is descriptions of sharply-constrained structured procedures (to paraphrase Rampino and Colombo, 2012) that might be named as tools or methods. In this article, the focus is on looking for descriptions of tool use and the design of tools. This is related to the nature and extent of any linkage to UD theory or design theory in general.

Zitkus et al. (2012) is representative of the difficulty of identifying tools in research texts with several terms being used at once. The term "techniques" is used to refer to "co-designing methods" (p.145) and to physical items like an age-simulator suit (p.145) and to "impairment simulator tools" meaning screen-based exclusion calculators (p.146). The critical reader might also point out the absence of Nickpour & Dong (2010) from the final selection. The paper, titled *Developing user data tools*, deals with issues related to the design of tools to support designers and is detailed and thorough. For instance, they identify challenges, limitations and opportunities during exploration, conceptualisation and evaluation stages. However, the relation to theory – a model of design – is not made explicit other than this passing reference:

"Inclusive design is an excellent example of how such support tools become both essential and significant" (p.79).
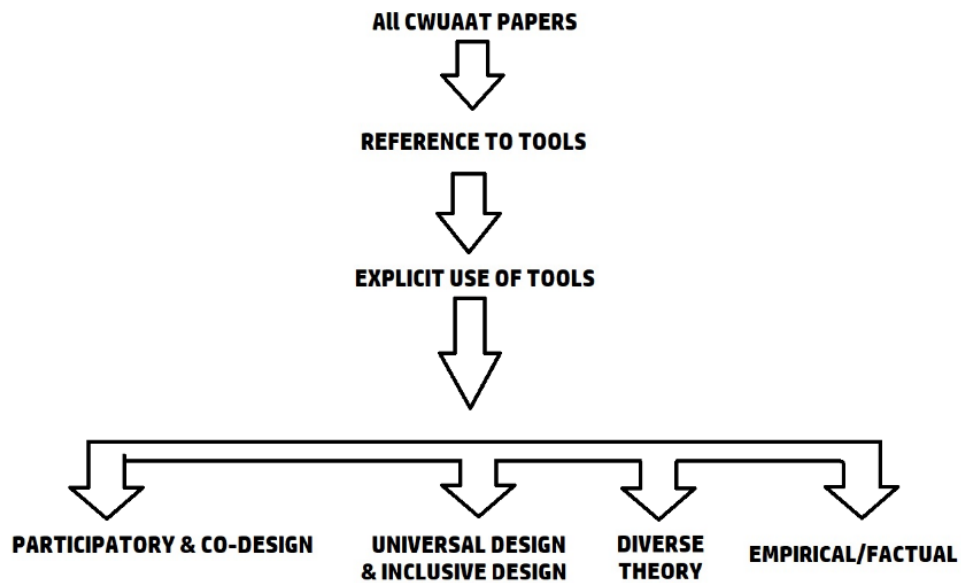
Methodology

To source the data, a long-running series of conference papers was chosen, that of the Cambridge Workshop on Universal Access and Assistive Technology (CWUAAT). This ensured consistency of the source material and regularity of the series (no gaps or breaks). The conference is recognised for its significance in UD research. Every paper from 2002 to 2020 was read and inspected for descriptions of the use of design tools. The use of a design tool was noted and illustrative text was extracted for analysis. Additional notes were made regarding the theoretical basis of the tool use, if present.

The advantage of this method lies in its consistency of approach. The disadvantage is that analysing only the CWUAAT engineering design tradition might lead to a systematic omission of other design research methods. Counter-balancing this point is there are no clear boundaries between industrial design and engineering design methodologies. At an abstract level, the basic difficulty in this process involved deciding what constituted a theory since the nature of theory is not a settled matter (Rosenberg, 2016). There was a danger of the selection process falling prey to the "one true Scotsman" problem (see Anderson, 2017 for an explanation).

It is a deliberate decision that the terms for the tools recorded were not amalgamated into more general categories. This is to limit the chances of inconsistent interpretation/classification in addition to inconsistencies that might arise from selecting what counts as a significant instance of tool (a term already conflated with method).

The filtering process is shown in Fig. 1 below:

Figure 1. The selection process. At the top is the entire data set. At the bottom, the final selection of papers that deal with tool use and the basis of use..

All CWUAAT PAPERS

⇩

REFERENCE TO TOOLS

⇩

EXPLICIT USE OF TOOLS

⇩

PARTICIPATORY & CO-DESIGN   **UNIVERSAL DESIGN & INCLUSIVE DESIGN**   **DIVERSE THEORY**   **EMPIRICAL/FACTUAL**

Data

Ten volumes of CWUAAT proceedings were inspected, amounting to 242 papers. 56 papers contained references to design tools and the use of tools. See Table 1, below. Something was designated a tool if it was a distinct unit in a design research process and that did not seem to be capable of subdivision into smaller named units.

Table 1. The design tools referred to in the CWUAAT conference proceedings.

Year	Total no. of papers in volume	No. of papers with an identifiable tool	Tools referred to
2002	28	4	1) Inclusive Design Cube, 2) Interviews, 3) Focus group, 4) User-trials, 5) user-group
2004	26	5	1) Questionnaires, 2) user-observations, 3) Focus groups, 4) Interviews, 5) Diary studies, 6) Critical user studies, 7) user-trials, 8) ethnographic studies, 9) self-observation, 10) brainstorming, 11) expert-heuristic evaluation, 12) task-analysis, 13) simulation, 14) cognitive ability scales, 15) participatory design interviews.
2006	24	7	1) focus groups, 2) user trials, 3) A CAD model of a human, 4) A tool to evaluate the capability demand relationship, 5) cultural probes, 6) UC video ethnography, 7) toilet audit tool.
2008	25	6	1) Exclusion calculator, 2) Ergonomic measurement tool, 3) Focus groups, 4) Audit, 5) user observations, 6) interviews, 7) sketching, 8) prototyping.
2010	22	2	1) User-data tools, 2) Colour contrast assessment system.
2012	23	3	1) VR for HCI, 2) Cognitive impairment interpreter, 3) Data representation about UD, 4) interviews.

Year	Total no. of papers in volume	No. of papers with an identifiable tool	Tools referred to
2014	24	4	1) User capabilities analysis, 2) Effort analysis, 3) Kano questionnaire, 4) Checklist tool, 5) Field-base survey, 6) Focus groups, 7) Self simulation, 8) Photo
2016	27	13	1) Unspecified quantitative and qualitative tools, 2) tool for testing graphics, 3) Prototypes, 4) Anthropometrics, 5) Personas, 6) Mock-ups, 7) participant observation, 8) interviews, 9) document analysis, 10) phone interviews, 11) real-world observations, 12) focus groups, 13) diary studies, 14) Eye-tracking, 15) storyboards, 16) data collection toolkit, 17) 3D scanners, 18) photography, 19) big data analysis.
2018	24	5	1) Topological data analysis, 2) Workshop, 3) Colour contrast evaluator, 4) Photovoice, 5) Semi-structured interviews, 6) Prototyping.
2020	19	6	1) Design kits, 2) Unspecified, 3) Co-operation platform, 4) Exclusion calculator, 5) PDF accessibility checker, 6) Focus groups, 7) Interviews, 8) Ethnographic studies.

Following this, the instances of the tool use were extracted. Table 2 (below) shows the instance and the paper describing its use.

Table 2. Occurrence of types of tools.

	Type of Tool	Instance	Reference
1	Focus Group	11	Hine et al., 2002; Gheerawo & Donahue, 2004; Cardosa et al., 2004; Goodman et al., 2004; Boyle et al., 2006; Savitch et al., 2006; Baskinger & Hanington, 2008; Andrews, 2014; Raheja & Suryawanshi, 2014; Williams et al., 2016; Liu et al. 2020;
2	Interviews (all types)	8	Hine & Evans, 2002; Gheerawo & Donahue, 2004; Cardosa et al., 2004; Allen, 2004; Hurtienne 2008; Jokisuu et al., 2012, Skjerve et al., 2016; Steenwinkel et al., 2016; Williams et al., 2016; Morris et al., 2016; Jellema et al., 2018, Nguyen et al., 2020
3	User-observation	6	Gheerawo & Donahue 2004; Cardosa et al., 2004; Hurtienne et al., 2008; Andrews, 2014; Steenwinkel et al., 2016; Williams et al., 2016
4	Personas	4	Broulé & Joiffrais, 2016; Afacan, 2016; Morris et al., 2016; Kunur et al., 2016
5	Questionnaires	3	Gheerawo & Donahue, 2004; Cardosa et al., 2004; Ma & Dong, 2016
6	Audit	3	Bichard et al., 2006, Mayagoitia et al., 2008; Froyen, 2008,
7	User trials	2	Porter & Lesley 2002, Cardosa et al. 2004; Boyle et al. 2006
8	Exclusion calculator	2	Waller et al., 2008; Goodman-Deane, 2020
9	Guidelines	2	Kwok et al., 2008., Shamshirsaz & Dong, 2014

	Type of Tool	Instance	Reference
10	Prototypes	3	Hurtienne et al, 2008; Boyd et al., 2016; Chakraborty & Nguyen, 2018
11	Ethnographic studies	3	Cardosa et al., 2004, Raheja & Suryawanshi, 2014, Nguyen et al., 2020
12	Capability demand assessor	1	Persad et al., 2006,
13	Sketching	1	Hurtienne et al, 2008
14	Visual documentation	1	Raheja & Suryawanshi, 2014
15	Image Schemas	1	Hurtienne et al. 2008
16	Diary studies	1	Gheerawo & Donahue, 2004
17	User-group forum	1	Smith et al., 2002
18	Critical user-studies	1	Gheerawo & Donahue, 2004;
19	Self-observation	1	Cardosa et al., 2004; Raheja & Suryawanshi, 2014
20	Brainstorming	1	Cardosa et al., 2004;
21	Expert/heuristic evaluation	1	Cardosa et al., 2004;
22	Task analysis	1	Cardosa et al., 2004;
23	Simulation	1	Cardosa et al., 2004;
24	Capability scales	1	Langdon et al., 2004
25	CAD model	1	MacDonald et al., 2006
26	Cultural probes	1	Dewsbury et al., 2006, Nickpour & Dong, 2010

	Type of Tool	Instance	Reference
27	Collage	1	Andrews, 2010
28	Foam models	1	Andrews, 2010
29	Product feedback method	1	Andrews, 2010
30	Storytelling	1	Andrews, 2010
31	Video ethnography	1	Gough, 2006.
32	Inclusive Design Cube	1	Keates & Clarkson, 2002.
33	Torque-measurement tool	1	Yoxall et al., 2008.
34	User data tools	1	Nickpour et al., 2010.
35	Colour contrast assessment	1	Dalke et al., 2010.
36	Virtual Reality device	1	Ceccacci et al., 2012.
37	Medical diagnosis interpreter	1	Jokisuu et al., 2012.
38	Data provision tool for designers	1	Zitkus et al., 2012.
39	Mapping	1	Heitor et al., 2014.
40	Level of effort analysis	1	Heitor et al., 2014.
41	Kano questionnaire	1	Shamshirsaz & Dong, 2014.
42	Lead user testing	1	Andrews, 2014.

	Type of Tool	Instance	Reference
43	Design cards	1	Andrews, 2010; Broulé & Joiffrais, 2016.
44	Workshop	1	Broulé & Joiffrais, 2016; Bridge, 2018.
45	Critical artefact methodology	1	Chamberlain et al., 2016.
46	Data collection toolkit	1	Ma & Dong, 2016.
47	Graphics testing tool	1	Waller et al., 2016.
48	Anthropometrics	1	Holt et al., 2016.
49	Mock-up	1	Afacan, 2016.
50	Document analysis	1	Steenwinkel et al., 2016.
51	Diary studies	1	Williams et al., 2016.
52	Eye-tracker	1	Chakraborty et al., 2016.
53	Story boards	1	Kunur et al., 2016.
54	Topological data analysis	1	Persad et al., 2018.
55	Contrast evaluation tool	1	Danschutter & Deroisy 2018.
56	Photovoice	1	Jellema et al., 2018.
57	Design kits	1	Winton & Rodger, 2020.
58	Co-creation platform	1	Liu et al., 2020.
59	PDF accessibility too	1	Jembu-Rajkumar et al. 2020.

Finally, from this sub-sample could be created a list of papers that offered reasoning for the tool use. Four categories emerged by inspection (see Table

3 below). The 1st class differs from the second by directly drawing on participatory design (and related fields).

Table 3: Four classes of foundation for tool use in universal design/inclusive design research.

Participatory design & co-design	Universal design/ inclusive design	Other theory	Empirical factual
Allen (2004); Goodman-Deane et al. (2008); Raheja & Suryawanshi (2014); Brulé & Jouffrais (2016); Liu et al. (2020).	Langdon et al. (2004); Persad et al. (2006); Bichard et al. (2006); Waller et al. (2008); Froyen (2008); Ma & Dong (2016), Goodman-Deane et al. (2020).	Keates & Clarkson (2002); Savitch et al. (2006); Gough (2006); Dewesbury et al. (2006); Hurtienne et al (2008); Chamberlain et al. (2016); Jellema et al. (2018); Heitor et al (2014);	Goodman-Deane et al (2004); Kwok & Ng (2008); Zitkus & Langdon (2012); Shamshirsaz & Dong (2014); Waller et al. (2016); Danschutter & Deroissy (2018).

In the introduction some questions were posed and in the following sections they are answered.

The first question asked to what extent do researchers in UD use design tools that are dependent on UD theory. In quantitative terms, 25 out of 242 papers made explicit reference to the basis for the use of design tools. Seven of the 25 used inclusive design theory (and related fields) as the basis for the use of the tool or the development of the tool. Given that the entire data set is about design for accessibility one might be surprised at this result. But the question is very narrow, not about UD/ID research but the use of theory to support tool use in UD/ID. It turns out that one can conduct research in this field while drawing on other sources for theory supporting the tools of inquiry. Some of the tools articles, unsurprisingly, rely on the co-design theoretical tradition. Eight draw on fields outside and six of the 24 used proto-theoretical or, simply

put, a factual basis for the selection and use of the tools. The good news, so to speak, is that practitioners are drawing from fields outside UD and co-design and these papers, when used in subsequent research become part of the ID/UD body of knowledge.

Most UD/ID research relies on a small number of tools. Focus groups, interviews and field observations top the list with a long tail of tools with under four instantiations. The large majority are instantiated just once. It is possible to probable that the top five tools are themselves under-reported. Familiar-tools such as prototyping and sketching only got a pair of mentions. However, it is very unlikely that the absence of researchers naming sketching is a true indication of the use of sketching. More likely is the banal fact that researchers are not making very strenuous efforts to accurately report their research process. The long tail conceivably consists of tools named in the article because the authors considered them sufficiently distinctive to be interesting.

The second question is 2) how do researchers in UD use existing design tools. Table 4, below, summarises the data. The third column "How tool was used" notes the role of the tool in the research. As well as being for data gathering and affecting change on the design (the point of a tool) the tool in the articles served as instantiations of how to change researchers´ behaviour, how to select and use tools, how to develop them and about the provision of accessible data.

Table 4. How tools were used in research.

Context	Tools	How tool was	Author
Healthcare	Co-creation tools	Behaviour change	Liu et al. (2020)
Visual	Design cards,	Tool created for	Brulé & Jouffrais
Education	field-based observations, focus groups, visual documentation and self-simulation	Tool selection	Raheja & Suryawanshi (2014)
Assistive	Interviews	Tool selection, use	Allen (2004)
Unspecified	Design guidance	Tool creation,	Langdon et al
Digital product	Capability	Tool creation	Goodman-Deane
Packaging	Data collection	Method of use,	Ma & Dong (2016)
Toilet design	Audit	Usability	Bichard et al.
Unspecified	Exclusion guide	Usability	Waller et al.
Software	Cultural probe	Tool selection,	Dewsbury et al.,
Visual design	Image schemas	Tool selection,	Hurtienne et al.
Social design	Critical artefacts	Tool selection,	Chamberlain et
Hospital design	Photovoice	Tool selection,	Jellema et al.
Social design	Focus group	Tool use, tool	Savitch et al.
HCI	Conceptual	Tool design	Keates &

Context	Tools	How tool was	Author
Packaging	Video	Tool development	Gough (2006)
Building design	Spatial analysis	Tool development,	Heitor et al.
Mobile ´phone	Focus group	Tool selection,	Goodman et al.
Building design	Guidelines	Tool design	Kwok & Ng
Social design	Quality table	Tool design	Shamshirsaz &
Product design	Data presentation	Data provision, use	Zitkus et al.
Product design	Data presentation	Data provision, use	Waller et al.
Building design	Data presentation	Data provision, use	Danschutter &

Under the separate categories we find that category 1 articles (based on participatory design/co-design theory), there were tools for behaviour change, tool creation, tool selection and intensity of use. Under category 2, work based on UD/ID theory related to tool design and form-giving, methods of tool use and tool adaptation. Category 3 (other theory), the articles reported work on tool selection and use, mode of use, form-giving output, tool development. The last category (4), papers using data or proto-theory, reported insights on tool selection, tool use, tool design and data presentation. There is not enough data to see if there are any correlations between the theory type and the tool or the context of use.

Analysis

Dealing with question first (3) what is revealed about the relationship between tools and UD theory, I will look particularly at which theory provided the support for the tool use (see Table 3, above).

Participatory design and co-design provides the basis in five papers. The most elaborated is Liu et al. (2020) concerning co-creation in healthcare engineering. The tool is a platform aimed to promote co-creation and the basis for the use and elaboration of the tool is in Sanders & Stappers (2008). The effect on the process was to change the methods of researchers who came primarily from an engineering design background; thus the theory about user-involvement translates into changes of behaviour in terms of the specific selection of tools and the resultant output – an expected outcome. Brulé & Jouffrais (2016) discusses the design and testing of a tool for designers working with visual impairment. For this, co-design is offered as the theoretical basis. The paper describes the steps from initial discussions with stakeholders. The process had three phases: general inquiry, design-card creation and then workshops. Personas are used to get around the tricky matter of dealing with many child subjects. In their paper on universal access in educational environments, Raheja & Suryawanshi (2014) use a participatory approach. That translated into using a range of tools that would detect user experiences: field-based observations, focus groups, visual documentation and self-simulation. This "showcases a methodology for inclusive planning and design for implementation on campus-built environments" (p.173). Allen (2004) deals with product semantics in assistive device design. The work is based on the framework of designer-facilitated participatory design and the tool of inquiry is the interview. Like Goodman-Deane et al.´s (2008) article on tool selection, the connection to theory is implicit.

The second group is general level UD theory and its cognates. This theory is used to support tool use in a group of papers about building design, packaging, product design and product interfaces. This theory is that which makes up the main corpus of UD thinking on how and why to go about design for inclusivity: the work of the Cambridge Engineering Design Centre, publications by London Royal College of Art/Helen Hamlyn Centre and design standards. It is theory from inside the UD research community. Examples: Langdon et al. (2004) makes explicit the theory-to-tool link, based on "a simple cognitive user model" (p.60) and the Cambridge Inclusive Design model. Those lead to the design of design-guidance measures. Persad et al. (2006) also make use of previous EDC work (in this case it is Keates & Clarkson, 2002) in their

capability-demand relationship tool. Specifically, the product interface features are targeted following on from the cognitive user-model. Goodman-Deane (2020) examines how to quantify exclusion for digital products, drawing from the theory outlined in Persad et al. (2006). These ideas shape the form of the tool which analyses product tasks individually for capability assessment. Ma & Dong (2016)´s investigation of packaging openability applies Clarkson (2010) to adapt a research process for ergonomics study in an Asian social context. It produced a data-gathering methodology that found out what the users could and could not do (p.122). The two other papers in this set, Bichard et al., (2006) Waller et al., (2008) leave the theory implicit. The former refers to BS899 to construct their toilet design audit tool. The latter produces a useful and usable exclusion guide but leaves the underlying UD principles under-explained.

The third group is based on a heterogenous body of theory from outside the co-design and UD fields. Four items draw on an articulated theory of tool use: 1) Dewsbury et al., (2006) refer to Gaver´s (1999) cultural probe theory; 2) Hurtienne et al. (2008) exploit the concept of image schemas in a design process using existing design tools; 3) Chamberlain et al. (2016) use critical artefact theory while 4) Jellema et al. (2018) refer to the photovoice literature (Wang & Burris, 1997) which prompts decisions on tool selection and use. Jellema (2018) and also Dewsbury et al. (2006) are clear on which theory they draw on but focus most on the case and context in which it is used. That leaves three works with explicit and clear links from theory to implementation. HCI theory supports Keates & Clarkson's (2002) concept of the Inclusive Design Cube; medical theory on dementia supports Savitch et al. (2006); Jordan and Miller´s product pleasure work is used by Gough (2006) for a paper on tool development while space syntax theory underpins Heitor et al.´s (2014) research on architecture and accessibility. Standing out for particular attention is Gough (2006) which is one of very few in this study to explicitly set out to describe the development of creative design tools. Gough developed user-centred, video-ethnographic research techniques to enable in-house design groups to conduct work with key consumers (Gough, 2006): "the tool formalises key insights from the research and provided an intuitive visual interface for evaluation and comparison" (p.211). Gough (ibid.) derived this

from video recordings that showed a) which elements of the packaging helped and b) which did not. The way the tool was derived coordinated its structure with the product pleasure concepts, that is, to target which elements of the products reconciled (or not) the interaction with the packaging. In a similar vein, Chamberlain et al. (2016) builds on earlier work to develop a design research tool. This is critical artefact theory which is used to focus on the needs of groups of individuals who are under-represented in the UD/ID research arena, including individuals from diverse ethnic communities …" (p.100). The work uses objects and artefacts as a means to stimulate and structure thinking and so allow the complexities of people´s life to be understood. The resultant theory is made material as "an exhibition in a box" (p.104). The subject's home becomes a research field. As with Gough (2006) there is a direct and tangible line from theory towards a physically manifest design research tool which is desirable. Heitor et al. (2014) translate concepts of space syntax analysis (the work of Hillier & Hanson, 1984) which is a set of theories and techniques for the analysis of spatial layouts. By mapping these concepts to the tool the researchers could represent, quantify and compare spatial systems. Again, abstract concepts were transformed into specific means to capture elements of the physical environment and the likely way users could be either helped or hindered. As with Gough (2006) and Chamberlain et al. (2016) the tool was deployed in a case study. Keates & Clarkson (2002) devote their effort to translating HCI work in model human processors. The result is a tool (they use the term "method") for dividing the population according to their ability to perform functions. The tool then allows the designer to identify "which level of capability to address" (p.16). For a designer the tangible output is to "highlight the aspect of the product which needs to be improved" (p.17). What is missing is how to map the design geometry to the range of capability, which could be provided in the form of a rubric.

Returning to Hurtienne et al. (2008), one may understand this work as putting a pre-existing theory (human cognition) into an existing design method using known design tools (user observation, interviews, sketching and prototyping). This means the theory altered the way in which standard tools were used rather than leading to a new tool or a revision. The direct link to the theory

came at two points, the generation of design proposal and in the result, the extent to which the design was in accord with Johnson´s (1987) image schema concept.

The last category is that of tool-orientated design research based on what one might call proto-theoretical foundations or, simply, factual evidence. For a study on mobile ´phones, Goodman et al., (2004) the decision to use focus group relied on factual knowledge of older users´ needs. Kwok & Ng (2008) provides a tool in the form of guidelines for designing a good living environment using empirical research. Shamshirsaz & Dong (2014) followed a similar path, leading to a quality table tool for a form of service design for care homes. Zitkus et al., (2012), Waller et al., (2016) and Danschutter & Deroisy (2018) are concerned with how to supply designers withknowledge of inclusion. The papers deal with accessible data-provision. It is derived from observations of designers´ difficulties in using tabulated statistical data. The first two are addressed to product designers; the last one is for building designers. All three discuss the creation of a design tool with elements traceable to the foundational concepts.

In summary, the relation between UD theory (and other theory) is detectable in a small set of the papers examined and the reported relationship is one-way. Without a forensic re-reading of the texts for subtle signs, no authors unambiguously offer clear feedback to UD design theory. Where authors do explain the forward influence from theory to design tool we see a positive relationship: the theory leads to a hypothesis that suggests the use of one tool over others.

Conclusion and discussion

The three questions posed by this paper lead to the following discoveries. One, that researchers in UD do not make very much explicit use of UD theory in their choice and use of design tools. Given that researchers might be expected to have a strong interest in theory/data relations, this is something of a surprise. Further work is needed to question researchers about their attitude to the theory-tools relationship. This echoes an earlier call by Stolterman & Pierce (2012) in an article looking at HCI designers choice of tools. That article

offered little evidence to believe theory was a strong consideration for HCI designers and it may not be a strong consideration for UD designers.

A priori, and based on practising designers' very restricted use of design research (see Mieczakowski et al., 2010 and Fisher and Taffe, 2022, for example) one might expect an even less promising situation in commercial settings. Perhaps those working with UD could be more fastidious about the basis of their tools use. Further work is needed.

The second question indicates that those researchers in UD inclined to use design tools in relation to theory mostly seem interested in tool selection, tool adaptation and tool design rather than having feedback to modify theory.

What is revealed about UD theory (and theory in general) and tool use is that the relationship is one-way. UD researchers are not feeding back findings explicitly into revised theory. When one uses a design tool one makes discoveries not only about the user but also about the tool and by extension the theory it is based on. There is a gap in design research for explorations of UD that exploits the leverage a tool has on theory; if the theory is sound and suggests plausible hypotheses then the tool ought to be a means to work with the theory. In reverse, the tool can be a mechanism to explore the theory as much as it is a means of inquiry into the user and the design situation. Every use of a tool tests the theory it is based on. The findings of the tool use reveal something about the theory such as its validity, scope and completeness.

The literature examined here only hints at the problem with tools. Mieczakowski et al., (2010) show designers don´t really use tools; and that designers´ cognitive models are themselves and people they know: "…they do not have the capacity to represent and match how different users interpret and use a given product with how designers intend that product to be understood and used" (p.142). The inquiry also raised the question of how tools are conceptualized and taught for those students interested in (or explicitly studying) Universal Design and this is a direction planned for further work.

The survey here did not look beyond the range of the papers submitted to the CWUAAT series. An interesting examination might be to see what the more

art-based design research theory-tool relationship might reveal. There is a lot of other design research available, research founded much less on the kinds of natural-science-inspired work represented by the CWUAAT series. But even artistic design research must have some basis in design theory. It might be profitable to examine what kind of tools are used and whether in that arena there is less, more or the same kind of linkage shown in this study. This work suggests that UD researchers could take some more time and expend more effort to ensure that the theory-tool-data link is made explicit in order to develop theory and to make the process of the design research more transparent.

Acknowledgements

References

[1]   Afacan, Y. (2016). Ageing Engagement: Improving the Elderly Experience in Kitchen. In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (eds.) Designing Around People (pp. 199-208). Springer, Cham. https://doi.org/10.1007/978-3-319-29498-8_20

[2]   Allen, J. L. (2004). Beyond functionality—product semantics in assistive device design. In Keates, S., Clarkson, J., Langdon, P., & Robinson, P. (eds.) Designing a more inclusive world (pp. 101-110). Springer London. https://doi.org/10.1007/978-0-85729-372-5_11

[3]   Anderson, R. I. (2017). Is Flew's No True Scotsman Fallacy a True Fallacy? A Contextual Analysis. In Modeling and Using Context: 10th International and Interdisciplinary Conference, CONTEXT 2017, Paris, France, June 20-23, 2017, Proceedings 10 (pp. 243-253). Springer International Publishing. https://doi.org/10.1007/978-3-319-57837-8_19

[4]   Andrews, C. (2014). Accessible participatory design: engaging and including visually impaired participants. In Langdon, P. M., Lazar, J., Heylighen, A., &

Dong, H. (eds). Inclusive Designing: Joining Usability, Accessibility, and Inclusion (pp. 201-210). Springer International Publishing. https://doi.org/10.1007/978-3-319-05095-9_18

[5]   Baskinger, M., & Hanington, B. (2008). Sustaining Autonomous Living for Older People Through Inclusive Strategies for Home Appliance Design. In Langdon, P., Clarkson, P. J., & Robinson, P. (Eds.) (2008) Designing Inclusive Futures (pp. 117-126). Springer, London. https://doi.org/10.1007/978-1-84800-211-1_12

[6]   Bichard, J., Hanson, J., & Greed, C. (2006). Away from home (public) toilet design: identifying user wants, needs and aspirations. In Clarkson, P. J., Langdon, P., & Robinson, P. (Eds.) Designing Accessible Technology (pp. 227-236). Springer, London. https://doi.org/10.1007/1-84628-365-5_23

[7]   Boyd, H., Evans, N., & Harris, N. (2016). A clock that does not tell the time: How the day clock meets the needs of people living with dementia. In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (eds.) Designing Around People (pp. 137-146). Springer, Cham. https://doi.org/10.1007/978-3-319-29498-8_14

[8]   Boyle, H., Nicolle, C., Maguire, M., & Mitchell, V. (2006). Older users' requirements for interactive television. In Clarkson, P. J., Langdon, P., & Robinson, P. (Eds.) Designing Accessible Technology (pp. 85-92). Springer, London. https://doi.org/10.1007/1-84628-365-5_9

[9]   Bridge, C. (2018). Participatory Design Resulting in a 'Do-It-Yourself Home Modification'Smartphone App. In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (eds.) Breaking Down Barriers: Usability, Accessibility and Inclusive Design (pp. 101-111). Springer International Publishing. https://doi.org/10.1007/978-3-319-75028-6_9

[10]   Brulé, E., & Jouffrais, C. (2016). Representing children living with visual impairments in the design process: A case study with personae. In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (Eds.) Designing Around People (pp. 23-32). Springer, Cham. https://doi.org/10.1007/978-3-319-29498-8_3

[11]   Cardoso, C., Keates, S., & Clarkson, P. J. (2004). Comparing product assessment methods for inclusive design. In Keates, S., Clarkson, J., Langdon, P., & Robinson, P. (Eds.) In Designing a more inclusive world (pp. 31-40). Springer, London. https://doi.org/10.1007/978-0-85729-372-5_4

[12]   Casais, M. (2020). Facilitating complex knowledge in design education through design tools. In Research & Education in Design: People & Processes & Products & Philosophy (pp. 3-12). CRC Press. eBook ISBN 9781003046103.

[13]   Ceccacci, S., Germani, M., & Mengoni, M. (2012). How to Use Virtual and Augmented Reality Techniques to Design Highly Usable Human–Machine Interfaces. in Langdon, P., Clarkson, J., Robinson, P., Lazar, J., & Heylighen, A. (Eds) Designing Inclusive Systems (pp. 65-74). Springer, London. https://doi.org/10.1007/978-1-4471-2867-0_7

[14]   Chamberlain, P. M., Craig, C. L., & Dexter, M. (2016). InTacT: Insights into Telehealth and Care Technologies. In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (Eds.) Designing Around People (pp. 85-94). Springer, Cham. https://doi.org/10.1007/978-3-319-29498-8_9

[15]   Chakraborty, J., McGuire, M. P., & Pandey, G. (2016). Preliminary findings from an information foraging behavioural study using eye tracking. In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (eds.) Designing Around People (pp. 259-268). Springer, Cham. https://doi.org/10.1007/978-3-319-29498-8_27

[16]   Chakraborty, J., & Nguyen, N. (2018, April). The Effect of Simulation in Large-Scale Data Collection—An Example of Password Policy Development. In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (Eds.) Breaking Down Barriers Usability, Accessibility and Inclusive Design (pp. 263-273). Springer, Cham. https://doi.org/10.1007/978-3-319-75028-6_23

[17]   Clarkson PJ (2010) Towards better design: An evaluation of the pilot study. Available   at: https://beta.ukdataservice.ac.uk/datacatalogue/studies/study?id=6997 (Accessed March 14, 2023).

[18]   Cremers, A. H., Neerincx, M. A., & De Jong, J. G. (2013). Inclusive design: bridging theory and practice. In Engineering Psychology and Cognitive Ergonomics. Applications and Services: 10th International Conference, EPCE 2013, Held as Part of HCI International 2013, Las Vegas, NV, USA, July 21-26, 2013, Proceedings, Part II 10 (pp. 323-332). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-39354-9_35

[19]   Dewsbury, G., Sommerville, I., Bagnall, P., Rouncefield, M., & Onditi, V. (2006). Software co-design with older people. In In Clarkson, P. J., Langdon, P., & Robinson, P. (Eds.) Designing accessible technology (pp. 199-208). Springer, London. https://doi.org/10.1007/1-84628-365-5_20

[20]   Dalke, H., Conduit, G. J., Conduit, B. D., Cooper, R. M., Corso, A., & Wyatt, D. F. (2010). A colour contrast assessment system: design for people with visual impairment. In Langdon, P., Clarkson, P. J., & Robinson, P. (Eds.) Designing inclusive interactions (pp. 101-110). Springer, London. https://doi.org/10.1007/978-1-84996-166-0_10

[21]   Dalsgaard, P. (2017). Instruments of inquiry: Understanding the nature and role of tools in design. International Journal of Design, 11(1). https://www.ijdesign.org/index.php/IJDesign/article/view/2275

[22]   Danschutter, S., & Deroisy, B. (2018). A Practical Tool for the Evaluation of Contrast. In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (Eds.) Breaking Down Barriers: Usability, Accessibility and Inclusive Design (pp. 159-168). Springer International Publishing. https://doi.org/10.1007/978-3-319-75028-6_14

[23]   Dewsbury, G., Sommerville, I., Bagnall, P., Rouncefield, M., & Onditi, V. (2006). Software co-design with older people. In Clarkson, P. J., Langdon, P., & Robinson, P. (Eds.) Designing accessible technology (pp. 199-208). Springer, London. https://doi.org/10.1007/1-84628-365-5_20

[24]   Fawcett, J. (1978). The relationship between theory and research: A double helix. Advances in Nursing Science, 1(1), 49-62. https://doi.org/10.1097/00012272-197810000-00007

[25]   Fisher, E., Taffe, S. (2022)Engaging with research during design practice: A mismatch of activities and attitudes,The Design Journal,25:3,374-396, https://doi.org/10.1080/14606925.2022.2058681

[26]   Froyen, H. (2008). Universal design patterns and their use in designing inclusive environments. In Langdon, P., Clarkson, P. J., & Robinson, P. (Eds.) (2008). Designing Inclusive Futures (pp. 249-260). Springer London.

[27]   Gaver, B., Dunne, T., & Pacenti, E. (1999). Design: cultural probes. interactions, 6(1), 21-29. https://doi.org/10.1007/978-1-84800-211-1_24

[28]   Gheerawo, R. R., Donahue, S. J., . (2004). Introducing user-centred design methods into design education. In Keates, S., Clarkson, J., Langdon, P., & Robinson, P. (Eds.) Designing a More Inclusive World, 21-30. https://doi.org/10.1007/978-0-85729-372-5_3

[29]   Goodman, J., Dickinson, A., & Syme, A. (2004). Gathering requirements for mobile devices using focus groups with older people. In Keates, S., Clarkson, J., Langdon, P., & Robinson, P. (Eds.) Designing a More Inclusive World (pp. 81-90). Springer, London. https://doi.org/10.1007/978-0-85729-372-5_9

[30]   Goodman, J., Langdon, P. M., & Clarkson, P. J. (2006). Providing strategic user information for designers: methods and initial findings. In Clarkson, P. J., Langdon, P., & Robinson, P. (Eds.) Designing accessible technology (pp. 41-51). Springer, London. https://doi.org/10.1007/1-84628-365-5_5

[31] Goodman-Deane, J., Langdon, P. M., Clarke, S., & Clarkson, P. J. (2008). User involvement and user data: a framework to help designers to select appropriate methods. In Langdon, P., Clarkson, P. J., & Robinson, P. (Eds.). Designing inclusive futures (pp. 23-34). Springer, London. https://doi.org/10.1007/978-1-84800-211-1_3

[32] Goodman-Deane, J., Bradley, M., Waller, S., & Clarkson, P. J. (2020, March). Quantifying exclusion for digital products and interfaces. In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (Eds.) Cambridge Workshop on Universal Access and Assistive Technology (pp. 140-149). Springer, Cham. https://doi.org/10.1007/978-3-030-43865-4_15

[33] Gough, K. J. (2006). Creating User Centred Creative Design Tools for the Packaging Industry Using Video Ethnographic Research Techniques. In Clarkson, P. J., Langdon, P., & Robinson, P. (Eds.) Designing Accessible Technology (pp. 209-214). Springer, London. https://doi.org/10.1007/1-84628-365-5_21

[34] Heitor, T., Medeiros, V., Nascimento, R., & Tomé, A. (2014). Investigating accessibility to achieve inclusive environments: The spatial experience of disability at a University Precinct in Lisbon. In Langdon, P. M., Lazar, J., Heylighen, A., & Dong, H. (eds Inclusive Designing (pp. 93-103). Springer, Cham. https://doi.org/10.1007/978-3-319-05095-9_9

[35] Hine, N., Arnott, J. L., Beattie, W., & Sergeant, P. (2002). User Involvement in the Design of a New Multimedia Communication Service. In Keates, S., Langdon, P., Clarkson, P. J., & Robinson, P. (Eds.) Universal Access and Assistive Technology: Proceedings of the Cambridge Workshop on UA and AT'02 (pp. 161-170). Springer London. https://doi.org/10.1007/978-1-4471-3719-1_16

[36] Herriott, R., & Akoglu, C. (2020). Tools, methods or theories in design research?. Research & Education in Design: People & Processes & Products & Philosophy, 166-173. eBook ISBN 9781003046103.

[37] Heylighen, A., & Bianchin, M. (2013). How does inclusive design relate to good design? Designing as a deliberative enterprise. Design Studies, 34(1), 93-110.

[38] Hillier B, Hanson J, Peponis J, Hudson J, Burdett R, 1983, "Space syntax: a new urban perspective" Architects Journal 178 (48) 48-63. https://doi.org/10.1016/j.destud.2012.05.002

[39] Holt, R. J., Coats, R. O., Bingham, G. P., & Mon-Williams, M. (2016). Beyond Anthropometrics: Prehensile Control Analysis for Capability Assessment. In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (eds.) Designing Around

People (pp. 159-166). Springer, Cam. https://doi.org/10.1007/978-3-319-29498-8_16

[40]   Hurtienne, J., Weber, K., & Blessing, L. (2008). Prior experience and intuitive use: image schemas in user centred design. In Langdon, P., Clarkson, P. J., & Robinson, P. (Eds.) Designing inclusive futures (pp. 107-116). Springer, London. https://doi.org/10.1007/978-1-84800-211-1_11

[41]   Jellema, P., Annemans, M., & Heylighen, A. (2018). At home in the hospital and hospitalised at home: Exploring experiences of cancer care environments. In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (Eds.) Breaking down barriers: Usability, accessibility and inclusive design (pp. 215-226). Springer International Publishing. https://doi.org/10.1007/978-3-319-75028-6_19

[42]   Jembu-Rajkumar, A., Jordan, J. B., & Lazar, J. (2020). Improving PDF accessibility tools for content developers: looking towards the future. In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (Eds.) Designing for Inclusion: Inclusive Design: Looking Towards the Future (pp. 173-181). Springer International Publishing. https://doi.org/10.1007/978-3-030-43865-4_18

[43]   Jokisuu, E., Langdon, P. M., & Clarkson, P. J. (2012). A framework for studying cognitive impairment to inform inclusive design. in Langdon, P., Clarkson, J., Robinson, P., Lazar, J., & Heylighen, A. (Eds) Designing inclusive systems (pp. 115-124). Springer, London. https://doi.org/10.1007/978-1-4471-2867-0_12

[44]   Jones, D., & Gregor, S. (2007). The anatomy of a design theory. Journal of the Association for Information Systems, 8(5), 1. https://doi.org/10.17705/1jais.00129

[45]   Johnson M, (1987). The body in the mind: the bodily basis of meaning, imagination, and reason. University of Chicago Press, Chicago, IL, US.

[46]   Karam, M., & Langdon, P. M. (2016). Designing Human Somatosensory System Interactions: Not Just for Haptics Any More!. In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (Eds.) Designing Around People (pp. 187-196). Springer, Cham. https://doi.org/10.1007/978-3-319-29498-8_19

[47]   Keates, S., & Clarkson, P. J. (2002). Defining design exclusion. In Keates, S., Langdon, P., Clarkson, P. J., & Robinson, P. (Eds.) Universal access and assistive technology (pp. 13-22). Springer, London. https://doi.org/10.1007/978-1-4471-3719-1_2

[48] Kunur, M., Langdon, P. M., Bradley, M. D., Bichard, J. A., Glazer, E., Doran, F., ... & Loeillet, J. J. (2016). Reducing exclusion in future cars using personas with visual narratives and design anthropology. In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (eds.) Designing around people (pp. 269-277). Springer, Cham. https://doi.org/10.1007/978-3-319-29498-8_28

[49] Kwok, J. Y. C., & Ng, K. C. H. (2008). User friendly living environmental research and Design for Older People. In Langdon, P., Clarkson, P. J., & Robinson, P. (Eds.) Designing inclusive futures (pp. 261-272). Springer, London. https://doi.org/10.1007/978-1-84800-211-1_25

[50] Langdon, P. M., Keates, S., & Clarkson, P. J. (2004). New cognitive capability scales for inclusive product design. In Keates, S., Clarkson, J., Langdon, P., & Robinson, P. (Eds.). Designing a more inclusive world (pp. 59-68). Springer, London. https://doi.org/10.1007/978-0-85729-372-5_7

[51] Liu, L., Jiang, Y., Dong, H., Lee, T. C., & Liu, Q. Y. (2020, March). The co-creation process of a platform for healthcare engineering design and innovation (HEDI). In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (Eds.) Designing for Inclusion: Inclusive Design: Looking Towards the Future. Springer Nature. (pp. 47-55). Springer, Cham. https://doi.org/10.1007/978-3-030-43865-4_5

[52] Ma, X., & Dong, H. (2016). Packaging Openability: A Study Involving Chinese Elders. In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (Eds.) Designing Around People (pp. 107-116). Springer, Cham. https://doi.org/10.1007/978-3-319-29498-8_11

[53] Macdonald, A. S., Loudon, D., Rowe, P. J., Samuel, D., Hood, V., Nicol, A. C., & Conway, B. (2006). InclusiveCAD: a software resource for designers. In Clarkson, P. J., Langdon, P., & Robinson, P. (Eds.) Designing accessible technology (pp. 93-99). Springer, London. https://doi.org/10.1007/1-84628-365-5_10

[54] Mayagoitia, R. E., 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, P. J., Langdon, P., & Robinson, P. (Eds.) Designing accessible technology (pp. 127-134). Springer London. https://doi.org/10.1007/1-84628-365-5_13

[55] Mieczakowski, A., Langdon, P. M., & Clarkson, P. J. (2010). Investigating designers' cognitive representations for inclusive interaction between products and users. In Langdon, P., Clarkson, P. J., & Robinson, P. (Eds.) Designing inclusive interactions (pp. 133-143). Springer, London. https://doi.org/10.1007/978-1-84996-166-0_13

[56] Morris, J. T., & Mueller, J. L. (2016). Assets, actions, attitudes: Hearing and vision impaired mobile technology personas. In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (eds.) Designing Around People (pp. 249-258). Springer, Cham. https://doi.org/10.1007/978-3-319-29498-8_26

[57] Ning, W., & Dong, H. (2016). Collecting Data for Inclusive Design: Emerging Tools and Methods. In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (Eds.) Designing Around People (pp. 147-156). Springer, Cham. https://doi.org/10.1007/978-3-319-29498-8_15

[58] Nguyen, P., d'Auria, V., & Heylighen, A. (2020). Detail matters: exploring sensory preferences in housing design for autistic people. In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (Eds.) Designing for Inclusion: Inclusive Design: Looking Towards the Future (pp. 132-139). Springer International Publishing, Cam. https://doi.org/10.1007/978-3-030-43865-4_14

[59] Nickpour, F., & Dong, H. (2010). Developing user data tools: Challenges and opportunities. In Langdon, P., Clarkson, P. J., & Robinson, P. (Eds.) Designing Inclusive Interactions: Inclusive Interactions Between People and Products in Their Contexts of Use, 79-88. https://doi.org/10.1007/978-1-84996-166-0_8

[60] Ostroff, E (2009) Universal Design: an evolving paradigm. McGraw Hill Professional, 2001, Bolsover, UK.

[61] Patrick, V. M., & Hollenbeck, C. R. (2021). Designing for all: Consumer response to inclusive design. Journal of consumer psychology, 31(2), 360-381. https://doi.org/10.1002/jcpy.1225

[62] Persson, H., Åhman, H., Yngling, A. A., & Gulliksen, J. (2015). Universal design, inclusive design, accessible design, design for all: different concepts—one goal? On the concept of accessibility—historical, methodological and philosophical aspects. Universal Access in the Information Society, 14(4), 505-526. https://doi.org/10.1007/s10209-014-0358-z

[63] Persad, U., Goodman-Deane, J., Langdon, P. M., & Clarkson, P. J. (2018, April). Exploring user capability data with topological data analysis. In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (Eds.) Cambridge Workshop on Universal Access and Assistive Technology (pp. 41-50). Springer, Cham. https://doi.org/10.1007/978-3-319-75028-6_4

[64] Persad, U., Langdon, P. M., & Clarkson, P. J. (2006). Inclusive design evaluation and the capability-demand relationship. In Clarkson, P. J., Langdon, P., & Robinson, P. (Eds.) Designing accessible technology (pp. 177-188). Springer, London. https://doi.org/10.1007/1-84628-365-5_18

[65] Porter, L. A., & Lesley, S. (2002). An ergonomic one-handed wheelchair. In Keates, S., Langdon, P., Clarkson, P. J., & Robinson, P. (Eds.) Universal Access and Assistive Technology: Proceedings of the Cambridge Workshop on UA and AT'02 (pp. 257-266). Springer London. https://doi.org/10.1007/978-1-4471-3719-1_25

[66] Raheja, G., & Suryawanshi, S. (2014). Inclusive strategies for universal access in educational campus environments. In Langdon, P. M., Lazar, J., Heylighen, A., & Dong, H. (eds.) Inclusive Designing: Joining Usability, Accessibility, and Inclusion (pp. 165-174). Springer International Publishing. https://doi.org/10.1007/978-3-319-05095-9_15

[67] Rampino, L., & Colombo, S. (2012). Method, Strategy or Tool? A Semantic Clarification. Design Research: Between Scientific Method and Project Praxis. Notes on Doctoral Research in Design 2012: Notes on Doctoral Research in Design 2012, 83.

[68] Rosenberg, A (2016) The philosophy of social science. Routledge, NY (Fifth edition, 2016).

[69] Ruffino, A. G., Mistrett, S. G., Tomita, M., & Hajare, P. (2006). The universal design for play tool: Establishing validity and reliability. Journal of Special Education Technology, 21(4), 25-38. https://doi.org/10.1177/016264340602100404

[70] Sanders, E. B. N., & Stappers, P. J. (2008). Co-creation and the new landscapes of design. Co-design, 4(1), 5-18. https://doi.org/10.1080/15710880701875068

[71] Savitch, N., Zaphiris, P., Smith, M., Litherland, R., Aggarwal, N., & Potier, E. (2006). Involving people with dementia in the development of a discussion forum: a community-centred approach. In Clarkson, P. J., Langdon, P., & Robinson, P. (Eds.) Designing Accessible Technology (pp. 237-247). Springer, London. https://doi.org/10.1007/1-84628-365-5_24

[72] Shamshirsaz, S. A., & Dong, H. (2014). Improving residents' satisfaction in care homes: what to prioritise?. In Langdon, P. M., Lazar, J., Heylighen, A., & Dong, H. (Eds.) Inclusive designing (pp. 119-129). Springer, Cham. https://doi.org/10.1007/978-3-319-05095-9_11

[73] Sileyew, K. J. (2019). Research design and methodology (pp. 1-12). Rijeka: IntechOpen. https://doi.org/10.5772/intechopen.85731

[74] Skjerve, R., Giannoumis, G. A., & Naseem, S. (2016). An intersectional perspective on web accessibility. In Langdon, P., Lazar, J., Heylighen, A., &

Dong, H. (eds.) Designing around people (pp. 13-22). Springer, Cham. https://doi.org/10.1007/978-3-319-29498-8_2

[75] Smith, J., Huxley, R., Topping, M., Alcock, S., & Hawkins, P. (2002). Gathering User Needs in the Development of the POWER-HAND Opening Aid— A Successful Consumer Product for the Wider Market. In Keates, S., Langdon, P., Clarkson, P. J., & Robinson, P. (Eds.) Universal Access and Assistive Technology (pp. 267-276). Springer, London. https://doi.org/10.1007/978-1-4471-3719-1_26

[76] Van Steenwinkel, I. , Verstraeten, E., & Heylighen, A. (2016). Adjusting an older residential care facility to contemporary dementia care visions. In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (Eds.) Designing around people (pp. 219-228). Springer, Cham. https://doi.org/10.1007/978-3-319-29498-8_22

[77] Stephanidis, C., Savidis, A. (2001). Universal Access in the information society: Methods, Tools and Interaction Technologies. UAIS (2001) 1: 40-55. https://doi.org/10.1007/s102090100008

[78] Stolterman, E., & Pierce, J. (2012). Design tools in practice: studying the designer-tool relationship in interaction design. In Proceedings of the designing interactive systems conference (pp. 25-28). https://doi.org/10.1145/2317956.2317961

[79] Swanson, R. A., & Holton, E. F. (2005). Research in organizations: Foundations and methods in inquiry. Berrett-Koehler Publishers.

[80] Van Maanen, J., Sørensen, J. B., & Mitchell, T. R. (2007). The interplay between theory and method. Academy of management review, 32(4), 1145-1154. https://www.jstor.org/stable/20159360

[81] Wacker, J. G. (1998). A definition of theory: research guidelines for different theory-building research methods in operations management. Journal of operations management, 16(4), 361-385. https://doi.org/10.1016/S0272-6963(98)00019-9

[82] Waller, S. D., Langdon, P. M., & Clarkson, P. J. (2008). Converting disability data into a format suitable for estimating design exclusion. In Langdon, P., Clarkson, P. J., & Robinson, P. (Eds.) Designing inclusive futures (pp. 3-13). Springer, London. https://doi.org/10.1007/978-1-84800-211-1_1

[83] Waller, S. D., Goodman-Deane, J. A., Bradley, M. D., Cornish, K. L., & Clarkson, P. J. (2016). Walking backwards to quantify visual exclusion. In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (Eds.) Designing Around

People (pp. 117-126). Springer, Cham. https://doi.org/10.1007/978-3-319-29498-8_12

[84] Wang, C., & Burris, M. A. (1997). Photovoice: Concept, methodology, and use for participatory needs assessment. Health education & behavior, 24(3), 369-387. https://doi.org/10.1177/109019819702400309

[85] Williams, M. A., Dubin, B., Amaefule, C., Nguyen, L., Abdolrahmani, A., Galbraith, C., ... & Kane, S. K. (2016). Better supporting blind pedestrians and blind navigation technologies through accessible architecture. I In Langdon, P., Lazar, J., Heylighen, A., & Dong, H. (Eds.) Designing Around People: CWUAAT 2016 (pp. 237-246). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-29498-8_25

[86] Winton, E., & Rodgers, P. A. (2020). Towards Design and Making Hubs for People Living with Dementia. In ILangdon, P., Lazar, J., Heylighen, A., & Dong, H. (Eds.) Cambridge Workshop on Universal Access and Assistive Technology (pp. 3-12). Springer, Cham. https://doi.org/10.1007/978-3-030-43865-4_1

[87] Yoxall, A., Langley, J., Luxmoore, J., Janson, R., Taylor, J. C., & Rowson, J. (2008). Help or hindrance: the use of tools for opening packaging. In Langdon, P., Clarkson, P. J., & Robinson, P. (eds.) (2008) Designing Inclusive Futures (pp. 65-74). Springer, London. https://doi.org/10.1007/978-1-84800-211-1_7

[88] Zhu, H., Gruber, T., & Dong, H. (2020). Value and values in inclusive design. In Human Aspects of IT for the Aged Population. Technologies, Design and User Experience: 6th International Conference, ITAP 2020, Held as Part of the 22nd HCI International Conference, HCII 2020, Copenhagen, Denmark, July 19–24, 2020, Proceedings, Part I 22 (pp. 109-122). Springer International Publishing. https://doi.org/10.1007/978-3-030-50252-2_9

[89] Zitkus, E., Langdon, P. M., & Clarkson, P. J. (2012). Design Advisor: How to Supply Designers with Knowledge about Inclusion? in Langdon, P., Clarkson, J., Robinson, P., Lazar, J., & Heylighen, A Designing Inclusive Systems (pp. 145-154). Springer, London. https://doi.org/10.1007/978-1-4471-2867-0_15

How to cite this article: