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ASSESSING INCLUSIVITY THROUGHOUT THE DESIGN PROCESS

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Abstract

Everyday design solutions often cause unnecessary levels of discomfort or even exclusion, affecting mainly older adult users and people of all ages with a variety of functional impairments. Designers' intuitive and informal approaches to the evaluation of product usability and accessibility attributes are insufficient when addressing the needs of a wider population. This paper discusses the advantages of using more formal assessment approaches throughout the entire design process. A case study on domestic appliances illustrates the comparison between the implementation of three different assessment methods.

Keywords: usability and accessibility, functional capabilities, assessment methods

1 Introduction - current design practices

There is a scarcity of successful inclusive design solutions that can match the expectations of the growing older adult population in most developed countries and users who may experience temporary or long-term functional impairments [1]. This incompatibility between existing products and services and an increasing market of dissatisfied 'non-mainstream' consumers causes commercial and legislative disadvantages for industry [2]. As these consumers become more sophisticated and aware of their economic and legislative advantages, there is clearly a need and opportunity to develop more inclusive design solutions. The lack of more commercially feasible inclusive design solutions, suggests that designers are either not aware of this facts, or else are not familiar with the tools to address the problem in real-life circumstances.

The aim of this research is, to encourage designers to extend and diversify the assessment techniques they use, avoiding generating pointless discomfort or exclusion to a wide range of potential users. This paper highlights the differences between three assessment methods – i.e. Systematic Approach, Simulation and User Observation coupled with Interviews. The methods are compared in terms of their usefulness to the evaluation of usability and accessibility throughout the design process. An exploratory case study, on the assessment of four different kettles, is presented to illustrate the methods of implementation.

2 Usability and accessibility assessment

Users' expectations about the products or services they choose, buy, use and keep, are usually defined into three different levels [3]: first, consists in selecting and buying the product or service based on subject judgements, such as, trade-offs between cost, aesthetics, branding image and social identity; second, involves the initial use of the design solution where the

user realises the value of other design solution characteristics, such functionality and usability; and, third, the user becomes used to the interaction, whether or not such interaction matches the intended design solution usage, and experiences feelings regarding ownership issues.

While usability may not often be a determinant factor at the design selection and acquisition phase, this characteristic alongside with functionality will have an impact on the efficiency of use, comfort, safety and user satisfaction. The methods discussed in this paper aim at extending typical usability approaches to more knowledgeable evaluations of the accessibility problems that may occur during user-device interaction. Ultimately, to identify the mismatch between the functional capabilities imposed by design solutions, services and environments, and the user's functional and anthropometric characteristics.

2.1 An independent functional capability scale

Achieving reliable assessment results requires the participation of 'representative' users of the intended target population, or comprehensive information about those users. However, because the large non-mainstream population comprises a multitude of different user sub-groups, each one with distinctive functional characteristics, it becomes complex to decide which users to consider within this variety of sub-groups. In addition, it is difficult to know if the type and number of users selected, or the information being used on their behalf, is complete in terms of including all the users who could ideally benefit from an acceptable inclusive design solution. While it may not be realistic to include everyone with one single solution, it is important to make sure that all the potential consumers, who could want or need to make use of a particular design, are not being unnecessarily disadvantaged.

One way to manage the complexity of such variety in users' functional characteristics is to structure their profiles into categories and magnitudes of capabilities that will be involved in perceiving, understanding and performing the user-device. The Office of National Statistics (ONS) [4] presents one possible way of structuring and categorising 13 functional capabilities of which seven are particularly relevant when evaluating interaction between users and interfaces, specifically: locomotion; reaching and stretching; dexterity; vision; hearing; communication; and intellectual functioning. For each one of these seven capabilities there is a scale that ranges from a slight capacity loss, through medium loss, to severe impairment and potential users of the design solution are distributed across the full range of capabilities. For example, for the vision capability scale there will be people with some difficulty in seeing across the street, others who can only see at arms' reach and those who are completely blind. It is this concept of an independent capability scale (to which people with various types and levels of temporary or long-term impairments can be mapped) that will be used to measure how accessible a design solution is and, ultimately, how many non-mainstream users are being disadvantaged or even excluded by it.

3 Assessment approaches – case study

There are two generic approaches when addressing the problem of incorporating the necessary knowledge of the user (user needs, wants and aspirations) into the design process. One way is to involve users directly into the evaluation cycle. The other, consists on the implementation of a body of knowledge, which does not depend on direct user participation, but that can (potentially) represent the end-users' human characteristics. The former approach is usually carried out using methods, such as: User Observation, Interviews, Questionnaires,

User Groups, and Expert Users. The latter, uses techniques, such as: Brainstorming, Scenarios, Mood-boards, Simulation, Ergonomic and Anthropometric data, and Role-play. There is a lot of information about these methods in literature [5,6], but little guidance on the advantages, specifically reliability and validity, regarding their application [7]. Since different design consultancies have particular preferences regarding the methods they implement, designers should be able to choose between a flexible variety of methods or techniques. Despite the widespread practice of designers' 'self-observation' approach when predicting how users may interact with any design, proper usability and accessibility evaluation requires more formal and complete procedures. Designer's intuition, creativity and professional skills make them experts at solving usability problems, but not necessarily at identifying them. Consequently, based on the need to formalise designers self-observation approach an exploratory case study performed on four different kettles (refer to Figure 1) is presented using three different assessment methods, namely: Systematic Approach; Simulation; and User Observation combined with Interviews.

Figure 1. From left to right, Kettle1- DeLonghi; Kettle 2- Moulinex; Kettle 3- Phillips; and Kettle 4- KenWood.

Feedback from industry about the cost and time constraints often imposed on design projects, suggests that methods that do not involve direct user participation are likely to be more feasibly implemented throughout the design process. Therefore, Systematic Approach and Simulation, which do not primarily comprise direct user participation, were implemented and the results compared against User Observation and Interviews with real end-users. The main objective was to find out how efficiently and effectively the first two methods could identify, separately and in conjunction, the usability and accessibility problems captured using User Observation and Interviews.

4 Criteria for data categorisation

The categorisation of the assessment results derived from the three methods was defined into two different criteria. For the Systematic Approach, ONS scale descriptions (refer to Section 2.1) and statistical quantification [8] was implemented and the outcome categorised in terms of the most difficult constituent actions of use. Feedback from Simulation, User Observation and Interviews was categorised in terms of: *difficulty* (in performing an action); use of *coping strategies* (to perform an action); *failure* (to complete an action).

Difficult involves the informant (i.e. the assessor during Simulation, or the participant during User Observation) being able to carry out the task the way it was expected, even if with difficulty. Use of coping strategies happens when the informant is not able to perform the action the way it was expected, but manages to recur to alternative strategies to accomplish the necessary activity. Failure to carry out an action happens when the informant either does

not know what needs to be done (due to the design poorly sensory output feedback or lack of cognitive simplicity) or cannot physically fulfil the action.

Based on these criteria, the assessment feedback gathered from each assessment method derived from the feedback of 3 assessors for the Systematic Approach, 3 assessors for Simulation and 6 participants for User Observation and Interviews. The criteria for the final identification, prioritisation and comparison of the usability and accessibility problems identified by the three methods, is discussed later on this paper (refer to Section 5).

4.1 Systematic Approach

The Systematic Approach is a formalised extension of designers' typical self-observation approach to the evaluation of usability and accessibility characteristics [9]. The aim is to complement designers' intuition and experiences on how a design solution may be utilised by users with diverse functional capability profiles. The procedure consists in capturing and scrutinising, in increasing levels of detail, the nature and magnitude of functional capabilities, which may be demanded by the device during the sequence of interaction. Systematic Approach can be enhanced, for instance, with the use of Task Analysis and Link Analysis techniques. Despite the level of detail and completeness of this approach, it is important to be aware it will only represent a subset of all the ways of carrying out user-device interaction.

4.1.1 Procedure

For the Systematic Approach assessors were provided with an assessment procedure to guide them throughout the kettles' ease of use evaluation. The procedure proposes a set of keywords to build up a map of the interaction diagram. The diagram represents possible typical sequences of interaction, which would be expected by the kettles' properties regarding its affordances and constraints of use [10]. Keywords are used to breakdown the motor and sensory observable constituent actions of use, required to achieve the kettle's ultimate goal (i.e. boil water). The level of detail of the interaction is defined by the breakdown of the keywords, which provide an appropriate stopping limit for the assessment. For instance, picking-up the kettle is broken down into: reach for; grip and lift; and hold kettle. The level of detail will depend on the objectives and time available for the assessment. The next step consists in identifying the specific product features (e.g. handle, weight, spout), other objects (e.g. table, sink, water tap) and environmental circumstances (e.g. level of background luminosity and noise) involved in each instance of the interaction. Identification of these surrounding elements/influences allows designers to identify later in the process (once the assessment has been performed) what might be causing problems during the interaction.

Once the map of the interaction diagram is defined (which took, on average, between 20 to 30 minutes), designers applied the ONS scales to assess the kettles functional demands. The scales were used to identify, for each of the seven capabilities, the level of severity impairment from which users would be prevented from performing a specific action. For instance, to measure the magnitude of vision required to see/read the graphical labelling on a gauge, the ONS vision scale specifies/describes a level of impairment about people who: "cannot see well enough to read a large print book" (usually font size 14). This description gives a possible way of measuring how demanding the use of that feature is from a vision capability perspective. The score for the action 'read labelling' would correspond to the aforementioned level, since it is unlikely that people who cannot read a large print book (and people with higher levels of vision acuity impairment) would be able to read the labelling on the gauge.

Due to the fact that the ONS scale descriptions were not developed with purpose of product assessment, but to describe and categorise people's nature and level of impairment, there has been on occasions some variability between results from different assessors. However, it is possible to highlight the most demanding constituent actions of use identified through Systematic Approach. Table 1 shows the data collected from the assessments where the most demanding constituent actions of use for each capability have been identified. The table presents the most consistent assessment results from the assessment of all three assessors.

Table 1. Systematic Approach results.

	Kettle 1 DeLonghi	**Kettle 2 Moulinex**	**Kettle 3 Phillips**	**Kettle 4 Kenwood**
Locomotion	• Carry kettle (full)	• Carry kettle (full)	• Carry kettle (full)	• Carry kettle (full)
Reach & stretch	• Pickup/hold/ carry/pour full kettle	• Pickup/hold/ carry/pour full kettle	• Pickup/hold/ carry/ pour full kettle	• Pickup/hold/ carry/ pour full kettle
Dexterity	• Precision grip: - open/close lid - change filter	• Precision grip: - attach filter	• Precision grip: - open/close lid - change filter	• Precision grip: - hold lid open - change filter - plug kettle
	• Power grip: - pickup/hold/ - carry full kettle	• Power grip: - hold/carry full kettle	• Power grip: - pouring	• Power grip: - hold/carry full kettle
Vision	• See water level	• Read gauge labelling	• See water level	• Read gauge labelling
Hearing	N/A	N/A	N/A	N/A
Communication	N/A	N/A	N/A	N/A
Intellectual functioning	• May forget to turn kettle on. • May forget to perform a key action.			

4.2 Simulation

Simulation consists of designers wearing physical simulators to 'reproduce' the symptoms of physical impairments. While it is complex to simulate cognitive impairments, motor and sensory impairments can be more easily simulated. Simulating motor impairments can be achieved by putting on simulators in key areas of the body, to constraint physical movement, such as elbows, wrists and hands, knees and neck. Decrease in sensory capabilities can be reproduced using special goggles and earplugs. Despite the interactive experience of feeling the symptoms of impairment, simulators are unlikely to allow designers to understand in depth the consequences of being constantly impaired and it is of limited fidelity.

4.2.1 Procedure

Since kettles are generically hand-held devices that require the use of the upper limbs and visual capabilities, emphasis was applied to the reproduction of dexterity, reach and stretch and vision impairments. The adjustment of the level of impairment was also based on the ONS scales descriptions. The main objective of the assessment was a quick identification of the most difficult, or even limiting, actions required by the kettles' sequence of use. For the dexterity simulation, assessors were provided with a special pair of gloves that simulated

power and precision grip limitations. The level of dexterity reproduced was the closest to a medium dexterity level of impairment on the ONS scale descriptions (i.e. people who have difficulty handling a full kettle or a pan, with both hands). For the reach and stretch simulation, the assessors had the elbows and the shoulders constrained, with the objective of trying to match people who have difficult using their arms up to head level, but can still handle objects in front at torso level. Lastly, a pair of goggles simulated users who, according to the ONS scales, cannot read a large print book (i.e. font size 14). The assessors were asked to use the four kettles using the simulators in an environment that resembled (in terms of furniture layout and spatial dimensions) the one where real users were observed. During the simulation the assessors were directly observed and data about the kettles' ease of use was captured throughout the whole process. The assessors were encouraged to verbalise their opinions about the kettles' ease of use and the effects of using the simulators during the interaction. The Simulation session for each kettle took on average 10 to 15 minutes. The results from the Simulation are presented on Table 2. Feedback from this method is categorised in terms of *difficulty*, use of *coping strategies*, and *failure* to complete an action.

Table 2. Simulation results.

	Kettle 1 DeLonghi	**Kettle 2 Moulinex**	**Kettle 3 Phillips**	**Kettle 4 Kenwood**
Difficulty	• Open/close lid • See/find on-off • Hold while filling • See on-off status (power light) • Pour water	• See water level • Attach filter	• Open/close lid • Hold while filling • Check on-off status (pilot light) • Pour water • Attach filter	• See water level • Hold lid opened • Plug kettle • Hold while filling • Attach filter
Coping strategies	• Check water level • Pick-up and carry (full) kettle	• Pick-up and carry (full) kettle	• Check water level • Pick-up and carry (full) kettle	• Pick-up carry (full) kettle
Failure	• See water level • Detach/attach filter		• See water level	

4.3 User Observation and Interviews

User Observation consists in watching people's behaviour during interaction with devices and their surroundings in real-life circumstances (for instance, at home or workplace) or in laboratory environmental settings. Observation has the potential to generate higher validity feedback, because users can be observed directly carrying out the physical task sequences or interactions. However, despite the level of validity of the method, it is well known that people's behaviour may change because they are aware of being observed. At the end of the observation, interviews can be employed to clarify the observed events.

4.3.1 Procedure

The User Observation and Interviews' case studies involved the participation of 6 older adult (65+) participants. The sessions were videotaped, for facilitating later analysis. One assessor

observed the participants carrying out the kettles' interaction. The assessor's presence may have had influence on the participants' behaviour, although it has been observed that people get accustomed to observers over time [7]. Participants were, every so often, reminded that what was being observed was not their performance or skills in using the device, but the device's ease of use attributes. Making sure participants were constantly aware of the objectives of the study, made them progressively more comfortable about verbalising any difficulties they encountered or even their opinion about the ease of use of certain design features. All the participants were observed using the four kettles in the same environmental space (i.e. kitchen). The results from the User Observations and Interviews are presented on Table 3. Feedback from the User Observations and Interviews are categorised in terms of *difficulty*, use of *coping strategies*, and *failure* to complete an action.

Table 3. User Observation and Interviews results.

	Kettle 1 DeLonghi	**Kettle 2 Moulinex**	**Kettle 3 Phillips**	**Kettle 4 Kenwood**
Difficulty	• See/find on-off switch	• See water level (gauge) • Attach filter	• Open/close lid • Check water level. Attach filter	• See water level (gauge) • Hold lid opened • Plug kettle • Attach filter
Coping strategies	• Fill/pickup/carry and pour (half full) kettle	• Carry empty kettle • Fill kettle	• Fill and carry (half full) kettle	• Fill and carry (half full) kettle
Failure	• Open/close lid • Fill/pick-up/carry and pour (half full) kettle • Detach and attach filter	• Pick-up/carry and pour (half full) kettle	• Fill/pick-up/carry and pour (half full) kettle	• Pick-up/carry and pour (half full) kettle

5 Comparison of results

Results from the implementation of the assessment methods presented here are summarised on Table 4. Feedback results from Systematic Approach and User Observation are prioritised from most urgent (i.e. 1st) to least urgent (i.e. 2nd, or 3rd) problem to fix. Although, other problems have been identified using either one of these methods, only the first three major problems are presented. The final results from the Systematic Approach are based on the ONS capability scales statistical quantification, regarding the number of people who could potentially be excluded from performing those actions. Final results from User Observation and Interviews were pined down and ranked based on the higher percentages of participants who experienced those problems. In addition, the results from both methods were further categorised (and ranked) according to the impact of the frequency of occurrence of those constituent actions, during typical usage. Usability problems identified through Simulation are listed, but in order of priority, due to insufficient information details about levels of difficulty between different actions.

Table 4. Comparison of results between methods.

	Kettle 1 DeLonghi	**Kettle 2 Moulinex**	**Kettle 3 Phillips**	**Kettle 4 Kenwood**
Systematic Assessment	• **1st** Open/close lid • **2nd** Pick-up/carry and pour (full) kettle. • **3rd** Detach/attach filter.	• **1st** Pick-up/carry and pour (full) kettle. • **2nd** Detach/attach filter.	• **1st** Pick-up/carry and pour (full) kettle. • **2nd** Open/close lid. • **3rd** Detach/attach filter.	• **1st** Pick-up/carry and pour (full) kettle. • **2nd** Plug kettle. • **3rd** Detach/attach filter.
Simulation	• Open/close lid. • Check (see) water level. • Pick-up/carry and pour (full) kettle. • Check on/off status. • Detach/attach filter.	• See water level. • Pick-up and carry (full) kettle. • Attach filter.	• Open/close lid. • Check (see) water level. • Pick-up/carry and pour (full) kettle. • Check on/off status. • Attach filter.	• Pick-up and carry (full) kettle. • See water level. • Plug kettle. • Hold while filling. Attach filter.
User Observation (& Interviews)	• **1st** Open/close lid • **2nd** Pick-up/carry and pour (full) kettle. • **3rd** Detach/attach filter.	• **1st** Pick-up/carry and pour (full) kettle. • **2nd** Attach filter.	• **1st** Pick-up/carry and pour (full) kettle. • **2nd** Open/close lid. • **3rd** Attach filter.	• **1st** Plug kettle. • **2nd** Pick-up/carry and pour (full) kettle.

5.1 Discussion

Initial analysis of the final results from the Systematic Approach and the User Observation and Interviews, suggests that it may be possible to predict relevant usability problems using the former method. The application of the ONS scales' descriptions during the Systematic Approach allows assessors to map the product demands to the number of users potentially excluded from performing particular constituent actions. However, these descriptions are limited in their ability to distinguish between levels of difficulty of different actions, which require the same functional capability. Further analysis on the results from the Systematic Approach shows the need to extend the evaluation criteria to the *frequency of use* and identification of the *importance* of certain product features. For example, in assessing Kettle 1 (DeLonghi) using a Systematic Approach, ONS descriptions identify the same level of exclusion for *reach and stretch* and *dexterity* capabilities, when performing any of the actions described in the table. However, *detach/attach* filter is performed less frequently than any of the other constituent actions, and *open/close the lid* is the most critical function to fix, since this kettle does not allow filling (key action) through the spout. Similar criteria were applied to the other kettles throughout the Systematic Assessment evaluation, allowing more informed judgements regarding the relative importance of various problems.

Although the primary objectives of this case study did not include ranking the kettles in terms of usability demands, it is worth noticing that such categorisation was only possible using User Observation and Interviews. This approach provided more realistic comparative assessments, due to the amount and detail of information that could be gathered. In contrast, the use of the ONS descriptions during Systematic Approach did not provide enough information to identify, for example, which of the four kettle filters would be the easiest to *detach*. User Observation and Interviews, however, clearly identified this action as one that distinguished the filter from Kettle 4 (Kenwood), as the one presenting least amount of difficulty. In addition, observing real users also allowed the assessor to learn about the participants' experience in using of a multitude of coping strategies. Simulation also provided insight about possible alternative strategies when a particular constituent action could not be performed in the usual way.

In general all four kettles caused uncomfortable levels of *reach and stretch* and *dexterity* demands, once they were at least half full. This information is consistent between Systematic Approach and User Observation, and potentially supported by Simulation results. Despite the limited ability of Simulation to prioritise usability problems, this method allowed assessors to identify in general the same usability and accessibility drawbacks.

6 Conclusion

The exploratory case study discussed in this paper shows one way of implementing more formal approaches to usability and accessibility evaluation. Although this study illustrates the implementation of the methods on existing design solutions, they can be implemented at different stages during the design process. Application of these and other potential methods will depend on the designers' preference, the stage of the process, the form that the device takes, and other resources such as user involvement, cost and time resources [11]. Systematic Approach and Simulation are quick and structured methods for the identification of accessibility faults. Both methods could potentially be utilised throughout the design process on a more frequent basis than, for instance, User Observation and Interviews, which require direct user participation. It is important to be aware that, despite the level of information and detail provided by Systematic Approach or Simulation, it is unlikely that they will replace direct user participation. User Observation and Interviews reveal information about user behaviour that is not easily identified by the other techniques. However, User Observation and Interviews are more expensive and time-consuming to prepare and analyse the results. Due to the usual tight time and cost constraints that designers face, it would be more feasible to implement User Observation at milestones in the design process. Using this method at the beginning of the design process could give access to essential information about potential end-users, even if the aim is to develop a radically new design. Observing the way people interact with their surroundings can provide insightful information about functional skills behaviours. This information can be used, for instance, to 'calibrate' simulators, allowing the designer to use this tool to inform each design decision made, until a more robust and realistic evaluation can be carried out.

The methods discussed here are not meant to be recipes for telling designers how to design. Instead, these methods show possible ways of increasing the objectivity of usability and accessibility assessment throughout the design process. The implementation of an independent functional capability scale has been suggested as a way of 'deciphering' and structuring the interaction between users and everyday products.

Future work involves case studies with other products using a wider variety of simulators. The objectives include adjusting the simulators (using the ONS scales) to an appropriate number of levels of impairment, to enhance the level of assessment detail.

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