

Supporting Older and Disabled People's Needs in Product, Environment and Service Design

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Abstract

For the last decade research by the Loughborough Design School in the UK has led a computer-based tool called HADRIAN has been developed to encourage empathy between design professionals, policy makers, commissioning clients and potential end-users, including people who are older or who may have some form of impairment. The tool provides a means to evaluate the accessibility and inclusiveness of a design by simulating the abilities of older and disabled people and performing virtual user trials where potential barriers introduced by the proposed design can be identified and rectified before the design is implemented in the real world. This paper presents and discusses three validation trials conducted to evaluate the simulation capabilities of HADRIAN compared to real people interacting with the same tasks. Trials included two laboratory-based tasks and one field trial at a railways station.

Keywords: Disability, usability, design, transport

1. Introduction

McGlone (1992) estimated from survey results (conducted by the Office of Population Censuses and Surveys) that there were 6.2 million disabled adults in Great Britain, with more than two-thirds of them aged 60 years and over. Vanderheiden (1990) states that over 30 million people in the USA have disabilities or functional limitations, either from birth, accident and illness, or through old age. The potential market for businesses of all types in this sector is huge. The Disability Discrimination Act (1995) in the UK and the Americans with Disabilities Act (1990) have, amongst other things, resulted in transport providers having to make transport services accessible. Transport vehicles themselves are covered in the UK by regulations that set out the minimum requirement for accessibility. Trains and trams are covered by the Rail Vehicle Accessibility (Amendment) Regulations, 2000, Statutory Instrument No.3215, while buses are covered by the Public Service Vehicles Accessibility Regulations 2000, Statutory Instrument No.1970. Best practice for access to transport infrastructure, including lifts, escalators, ramps, lighting, facilities, signage and more is given in documents such as Inclusive Mobility (Oxley, 2002).

Many local authorities in the UK now offer free bus buses to people over the age of 60, and with climate change and sustainable design being very topical issues and congestion charges being introduced or proposed in several city centres, the pressure on people to use public transport is only likely to increase. The need for all people being able to get access to jobs, leisure facilities, education, health facilities, and so on is of increasing importance, and public transport has a critical role to play in enabling those without access to private cars these opportunities. People may not be able to access services due to social exclusion, and poor transport provision can reinforce this exclusion (Social Exclusion Unit, 2003). Earlier research enabled the development of HADRIAN (Human Anthropometry Data Requirements Input and ANalysis) computer-based software (Porter *et al*, 2004). This software was designed to allow design professionals and others to run virtual 'fitting trials' with a database of 100 individuals.

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Whereas digital human modelling systems such as SAMMIE (Porter *et al*, 1999) require an expert user to conduct assessment of virtual individuals through given tasks in the computer-aided design environment, HADRIAN automates the process. The participants whose data were collected within HADRIAN were predominantly older and/or disabled people, and the data collected included anthropometry, joint ranges, reach range, and behavioural and comfortable capability measures of 'kitchen' tasks (bend, reach, lift). These data within HADRIAN will potentially allow automated assessment of how many participants could successfully interact with proposed products, using each individual person's actual dimensions, mobility ranges, and likely behaviours in the given situation. The behavioural data within HADRIAN was obtained by collecting data on task-based issues activities using a mock-up kitchen and asking participants to lift different weight to different heights of shelves, and with a 'step rig' designed to simulate ingress and egress from buses/trains/trams/coaches. Current work, some of which is reported in this paper, aims to develop HADRIAN to consider accessibility within a whole journey (Davis *et al*, 2009).

In order to assess the validity of predictions made by HADRIAN and to inform the ongoing development of the software, three trials were conducted to compare real data with HADRIAN predictions. In the first of these, 10 participants whose data was already in the HADRIAN software attempted to reach items in a mock-up 'deep freeze' and a standard washing machine, and comparison was made with the HADRIAN predictions of their success or failure of each task element. In the second set of trials 10 participants used two automated teller machines (ATMs) in an experimental setting, and their ability to reach to the given interaction points was compared with HADRIAN predictions of their success/failure with those tasks. The final study involved 9 new participants performing a series of tasks at Greenwich Docklands Light Railway station, which were then compared with the HADRIAN database of 100 participants, to see if the issues raised in the 'real person' trials were the same as those raised by the HADRIAN virtual trials.

2. Ethical considerations

Ethical approval was gained from Loughborough University Ethical Advisory Committee. All participants gave informed consent before taking part in trials, and were reminded that they were free to stop at any time, giving no reason for doing so. Additional attention was paid to ensuring that participants were not fatigued. The trials lasted a maximum of one hour to reduce this risk. For the trials that took place at Greenwich DLR station permission to take photographs on the station was obtained from CGL, the operators of the station, and a risk assessment was also conducted for the trials.

3. Method 1 – chest freezer and washing machine assessment

3.1 Participants

Ten participants who had previously taken part in data collection trials were selected to represent the variation in size and ability of participants. These were: a man and a woman in wheelchairs, an able-bodied man and a woman over the age of 63 years, an ambulant disabled man and woman over the age of 63, an able-bodied man and woman between 18 and 62 years of age, and an ambulant disabled man and woman between the ages of 18 and 62 years.

3.2 Equipment

A freezer rig (see Figure 1) was constructed to represent the actual dimensions from several high street supermarkets. The chest freezer was not identical to any one design, but incorporated the main elements of those that people may come into contact with. The rig included shelves above the freezer level. The highest shelf was 149 cm from ground level, and the lowest internal level of the freezer was 30.5 cm. The front wall of the freezer rig was 80 cm in height. The weights and sizes of the objects used reflected those used in the main data collection phase, with a two-handed weight of 1000 g, a one-handed weight of 170 g, and a one- or two-handed bag weighing 500 g.

The washing machine tasks were conducted using a functioning washing machine (see Figure 1), although only the door-opening mechanism had to be operated by participants. The machine was 830 mm in height and 620 mm wide. The door opening was 270 mm from the base of the machine, and 250 mm in diameter.



Figure 1: Chest freezer and shelving rig, and washing machine

3.3 Procedure

For the washing machine tasks participants were asked to open the washing machine door and attempt to reach and retrieve three socks (one at the back of the barrel, one in the middle, and one at the front). Video was taken of postures throughout, and a tick-list of achieve/fail recorded. Participants were also asked if they could read the washing machine controls. A note was made of success/failure of this, and also if the participant was able to open and close the washing machine door, as well as any other comments made.

For the supermarket freezer tasks the half of the freezer rig with no shelves was stacked to capacity with items weighing 170 g, 500 g, and 1000 g (see Figure 2). Participants were given one of each item to hold prior to the trials, in order to decide if they would normally lift that weight or not. The items were positioned initially at the front of the rig, and then at the back of the rig. Participants were asked to reach to and remove all of the items that they could comfortably reach and lift, both from the front and from the back of the freezer rig. They were then asked to reach to and remove those items on the shelves on the left-hand side of the freezer rig, again only reaching to and lifting those that they could comfortably achieve. A note was made of which level for each item a participant could reach to, so that the upper and lower limits, and any weight differences in limits, could be ascertained. If a participant was unable or unwilling to lift a weight, this was noted and the next weight attempted. Video was taken throughout, and a tick-list of which weights were placed on which shelves completed.



Figure 2: 1000 g and 170 g items stacked at the rear of the freezer, and 500 g items stacked at the front of the freezer

4. Real person results

All ten participants were able to reach into the washing machine and retrieve all three socks from their positions. All participants were able to open and close the washing machine door, and able to see the controls, although three participants did remark that they could not clearly see the labelling of the controls. When reaching to retrieve items from the front and rear of the chest freezer, a count was taken of the number of each item (170 g, 500 g and 1000 g) the participants could reach to and retrieve. Figures 3 and 4 show the number of items that participants were able and unable to reach to, detailing the number of items left (irretrievable). It can be seen that fewer participants left items when placed at the front of the freezer (Figure 3) than the rear of the chest freezer (Figure 4), indicating, not surprisingly, that participants were able to reach and retrieve more items from the front than the rear of the freezer.

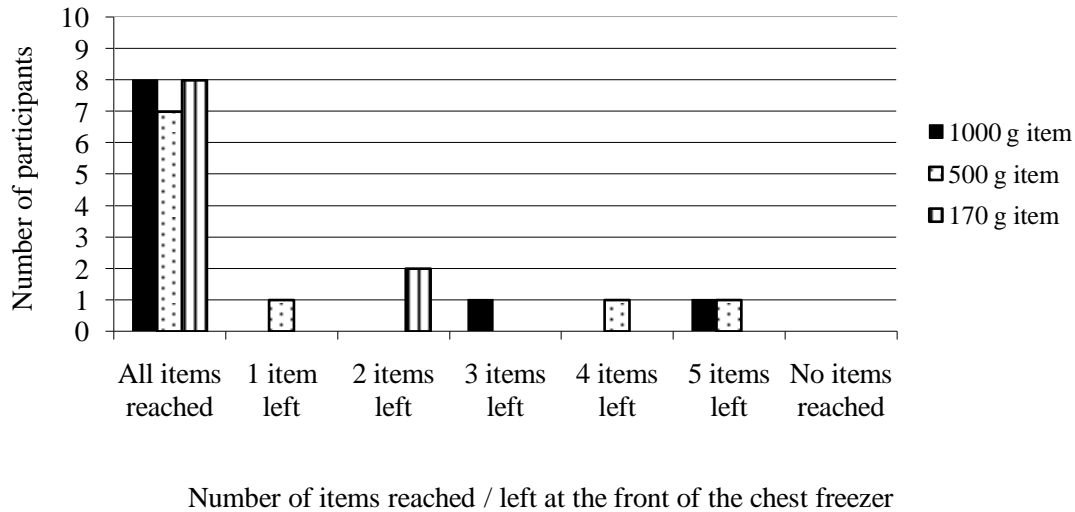


Figure 3: Number of participants able to reach items from the front of the chest freezer (n=10)

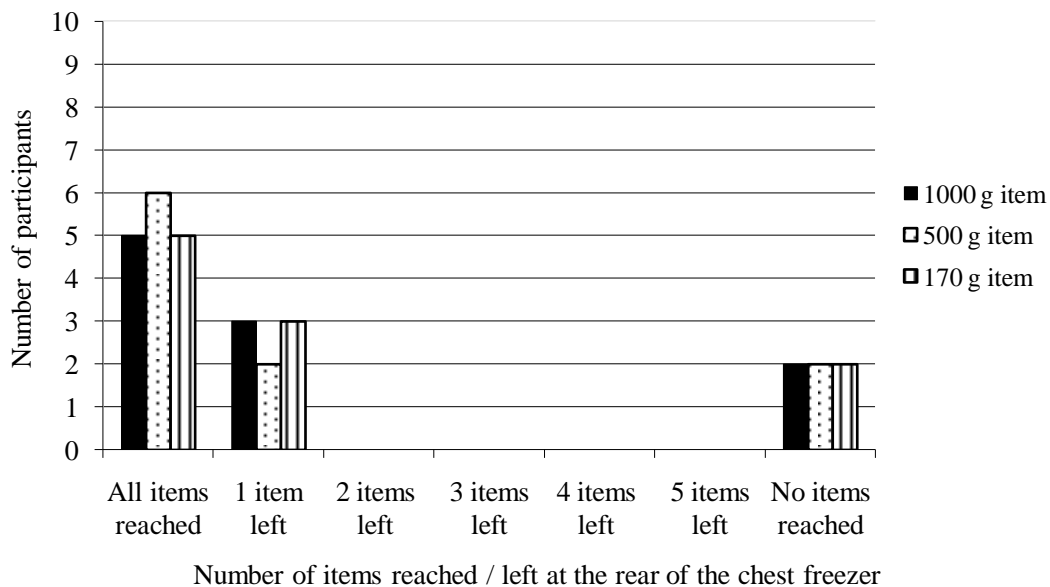


Figure 4: Number of participants able to reach items from the rear of the chest freezer (n=10)

When reaching to items on the three shelves of the freezer rig, eight participants were able to reach to and retrieve all the items from all the shelves.

The other two participants (both in wheelchairs) were able to reach to and retrieve only the 500 g bag and 170 g weight from the front of the bottom shelf, and the 170 g weight from the front of the middle shelf. The freezer itself severely restricted access for wheelchair users (who were unable to reach all items), and also had an effect on the reach capabilities of those standing participants of shorter stature.

4.1 Results predicted by HADRIAN

HADRIAN correctly predicted that the two participants in wheelchairs would be unable to reach any items on the top shelf. However, HADRIAN will always be conservative when predicting postures, and so incorrectly predicted that one participant would be unable to reach the top shelf, when in fact they could reach. The reach, though, was only achieved with considerable effort and by standing on tiptoes.

5. Method 2 – ATM assessment

5.1 participants

Participants were recruited from those who had participated in the HADRIAN data collection trials, so that their anthropometric data, joint constraint data, and so on was already available within HADRIAN. 10 participants who had taken part in the original HADRIAN data collection trials were asked to come back for the ATM validation trials.

5.2 Equipment

In the laboratory trials two real ATM fascias were provided by the manufacturer and project collaborator NCR. These were attached to a specially constructed rig which allowed the height of the ATMs to be changed easily by the experimenters (Figure 5). International standards state that the recommended maximum height of the highest reachable part of the ATM (in this case the statement slot) should be between 1200mm and 1450mm, so the rig was constructed to allow both ATMs to be positioned so that the statement slot was at these two heights, and also could be positioned at intermediary heights of 1250mm, 1300mm, 1350mm and 1400mm. These ATMs were recreated in computer-aided design modelling software to the exact same specification, so that these virtual machines could be used in the HADRIAN analysis.



Figure 5: The ATM rig

5.3 Procedure - real person trials

Each participant, in each position, was asked to try and reach to (on both ATMs):

1. A pre-defined 'card' located within the card slot (pinch-grip reach)
2. Keypad number 5 (finger-tip reach)
3. Screen Function Display Key 1 (finger-tip reach)
4. A pre-defined 'cheque' located within the Scalable Cheque Processing Module (pinch-grip reach)
5. A pre-defined 'bunch of notes' located within the Bunch Note Acceptor (pinch-grip reach)
6. Pre-defined 'cash' located within the Cash Exit (pinch-grip reach)
7. A pre-defined 'receipt' located within the Receipt Interface (pinch-grip reach)
8. A pre-defined 'statement' located within the statement slot (pinch-grip reach)

Pieces of paper were inserted into the given slots and protruded by the amounts specified by NCR as the amount of protrusion that would be expected for that machine in real life. Participants were asked to position themselves however they wanted to, to be able to comfortably reach to the different interaction points. Participants were asked not to over-strain themselves and only to attempt what they would be happy to do in the real world. Participants were reminded that they could stop at any time. Initially the ATMs were positioned so that the highest reach (statement slot) was 1400mm or 1200mm from the ground. In the event that all reach points could be reached, on both ATMs, at both these heights, then the trial would then be complete. If not all reach points could be reached, then the trial would be repeated at each increment as required until a highest and lowest height where all points could be reached was found.

Video footage was taken from the side and front for the duration of the trials. Participants were also asked for any reasons why they adopted the position that they did (ie do they consider security when they position themselves? etc), to capture some of the cognitive and emotional aspects surrounding ATM usage. Still photographs were taken to record the posture at the point where the participant was either able to reach to each interaction point, or their nearest attempt, in the event of a failure to reach. Participants in wheelchairs were asked to maintain their position after successfully reaching to points at each height so that measures of the angle of the wheelchair to the ATM can be recorded.

5.4 Procedure - HADRIAN automated prediction trials

The same 10 participants who took part in the real-person trials were selected from the HADRIAN sample of 100 people. Each participant's anthropometry and joint constraints were already in the system from earlier data collection trials. The HADRIAN system then conducted the assessment of which individuals could reach to which interaction points and at which heights.

6. Results 2 – ATM assessment

10 participants took part, covering a range of expected problems with using ATMs at different heights, namely due to reaching to the different interaction points. These included people in wheelchairs, of tall and short stature, and visually impaired.

When considering the final success/fail for each participant reaching to each interaction point, in the real person trials there were no failures, with participants able to reach all interaction points at all heights on both ATMs. However, HADRIAN predicted nine task failures across the participants.

7. Method 3 – Greenwich Docklands Light Railway station

Greenwich Docklands Light Railway station was built in 1999. It was designed to provide access for all, and as such has lifts to both platforms and level access from the platform on to the trains.

7.1 Participants

Due to the geographical location of the trials it was not possible or ethical to use the same people from the ATM trials in the Greenwich trials. It was therefore necessary to recruit 10 participants from the local Greenwich area, and it was intended that they be similar in terms of physical impairments to those who took part in the ATM trials. Recruiting participants over distance proved very difficult, and despite the very great help of a disabled persons' forum in Greenwich, in the end only 9 participants took part (detail given later).

7.2 Procedure – real person trials

Participants were met at the station and the procedure was discussed. Participants were asked to:

1. try and buy a one day travel card from the ticket machine
 - a. read the screen
 - b. turn the dial to highlight ticket choice
 - c. push the button to select the ticket
 - d. insert coins and/or cash into the machine
 - e. collect their ticket and change
2. make their way to the platform, via steps or lift eg.
 - a. press lift call button
 - b. enter lift
 - c. press button to select platform once inside the lift
 - d. exit the lift

Photographs were taken at each significant step of the process, including the attempts made by those participants who were not able to reach, for example to the coin slot. Participants boarded the train with one experimenter whilst the other took more photographs (permission was not granted for photographs to be taken on board the trains). The participant and experimenter then travelled one stop, crossed the platform there and returned on the next train.

7.3 Procedure – HADRIAN automated prediction trials

Where the previous validation trials used the same data for the real people and their virtual counterparts, in this trial the total HADRIAN sample of 100 people were used to predict success/failure of the new participants taking part. A computer-aided design model of the ticket machine was constructed and the HADRIAN system then conducted the assessment of which individuals could reach to which interaction points and at which heights.

8. Results 3 – Greenwich Docklands Light Railway station

Nine participants took part, including three wheelchair users, three people who used sticks or wheeled frame as mobility aids, one able-bodied person over 6 feet tall, one able-bodied person under 5 feet tall, and one parent with pushchair. Five participants were unable to use the stairs, but were able to reach the platform using the lift. There were no task failures when using the lifts or getting on to the train. Three participants had task failures when attempting to use the ticket machine. One of these participants was unable to turn the dial or press the button to select a ticket, reach to the slot to put coins in or use the slot designed to accept notes. The second participant had the same problems although was able to push the button in the centre of the dial on the ticket machine. A third participant could not reach to the slot to insert coins. In summary, three participants could not travel independently as they were unable to use the ticket machine to buy a ticket, and half the participants found having access to the lift essential for them to be able to travel.

The HADRIAN system predicted that 10% (10 of the 100 sample within the system) of the sample population would be unable to complete all the required tasks, with failures occurring with the interaction with the ticket machine (reflecting reality) and the lift console (not found in the real person trials).

9. Discussion

One of the main aims of the computer-based design tool was to enable the estimation of percentage accommodated, to enable design professionals, policy makers and others to gain a greater understanding and empathy with the problems that individuals may experience with products, services and environments, to better inform the design and policy processes. It has been shown that, as it currently operates, HADRIAN is able to do this for reaches to items with free access. HADRIAN does not, though, necessarily predict identical postures to those observed in real life during the validation trials. The data used by HADRIAN to predict the postures in the first two validation studies was that which had been previously obtained for each individual. This means that the postures predicted **were** ones that the individuals concerned *had* got into, even if they were not the same as those observed in the validation trials. Such ‘errors’ in the prediction of postures by the computer-based tool arise due to the fact that individuals may chose different methods of achieving tasks, with there being no ‘right’ or ‘wrong’ posture for those participants able to achieve a task in a number of ways.

To help address this a ‘tolerance level’ will be included within HADRIAN, which designers can adjust if they wish. This tolerance level can be used to determine whether a person has to totally achieve a posture in order to be recorded as completing a task, or whether a ‘near miss’ will be deemed a success by the system.

HADRIAN assumes that all participants will approach a task initially in a facing position, and only if this fails will the system attempt a lateral approach. However, in the ATM validation trials it was often an oblique approach which proved most successful in the real person trials. Also, one participant in particular (for whom HADRIAN predicted 5 failures) did indeed approach in a facing position, but then shuffled forwards on the seat of the wheelchair until they could reach the target. This was beyond the predictive capabilities of HADRIAN.

Data about coping behaviours, such as standing on tiptoes, or using an item to pull another item towards the participant, or shuffling forward in a wheelchair seat to increase reaching capability is not encoded into the HADRIAN system. It is likely to be a limitation of the tool that it cannot predict these novel coping behaviours (and often experts cannot predict them either), although the addition of further posture and behaviour data during different activities may reduce the risk of these errors. However, it should be remembered that, whilst some people can use coping behaviours to achieve tasks, a good design should aim to remove the need for people to adapt their behaviour to achieve the same result, so it is actually preferable that HADRIAN does not predict these ‘non-standard’ methods of achieving tasks, as otherwise it could predict that someone could complete a task only if they adopt a coping behaviour or strategy, which another individual might not be able to do.

With the Greenwich trials, due to the sample size, the time available and the difference in locations there were issues that might have been important for the software development that it was not possible to cover, including the design of the underpass at Greenwich DLR, lighting, signage, and the range of abilities and needs of potential end-users. Whilst the lift was actually accessible to all participants, it was noted that the relatively small size of the lift made it difficult for those travelling in large motorised wheelchairs with an assistant, there being little room for the assistant and limited space for turning and reaching to the controls. The fact that HADRIAN did predict some failures in task completion for participants reaching to the internal lift controls is therefore not altogether unexpected. For one platform it was necessary for the participants to reverse out as there was no space to turn the wheelchair round inside the lift (the lift to the other platform opened at the opposite side to the entry point on reaching the platform, removing this problem). Figure 6 illustrates this point with one participant in a motorised wheelchair.



Figure 6: participant in motorised wheelchair in the lift at Greenwich DLR (control panel is to the immediate right of the participant), this participant had an assistant who travelled with them, who only just fitted in the lift at the same time.

10. Conclusions

The HADRIAN database is undergoing final development, and the validation trials indicate that conducting 'virtual fitting trials' with the sample of 100 people, including older and disabled people within the database yields predictions of task completion and failure that reflect real-life success and failure of the same tasks. HADRIAN will always err on the conservative side in predictions of abilities and task completion, and provides detail of the areas of a design that might cause problems to people with similar abilities and impairments. Involving disabled people, and importantly people with a range of sensory and mobility impairments, in the assessment of designs for products, services and the physical environment is crucial in ensuring that those designs are accessible and usable to the largest number of people. HADRIAN is not intended to discourage the involvement of real people in the design process, but to highlight the needs of different members of the population with respect to designs from the earliest stages of the design process, to inform the development of designs before the prototyping and testing phases.

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