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Involving Older and Disabled People in Assessment of Product, Environment and Service Designs

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Article abstract

For over 10 years research has been conducted by the Design School at Loughborough University in the United Kingdom (UK) into accessibility of products, services and environments with a particular focus on the needs of older and disabled people. As part of this research a computer based tool called HADRIAN has been developed to encourage empathy between designers, planners and people who are older or who may have some form of impairment. In addition, 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.

The paper will present and discuss the need for this work and tool, and the importance of obtaining data directly from older and disabled people, as well as three validation trials conducted to evaluate the simulation capabilities of HADRIAN compared to real people interacting with the same tasks.

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Abstract

For over 10 years research has been conducted by the Design School at Loughborough University in the United Kingdom (UK) into accessibility of products, services and environments with a particular focus on the needs of older and disabled people. As part of this research a computer based tool called HADRIAN has been developed to encourage empathy between designers, planners and people who are older or who may have some form of impairment. In addition, 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.

The paper will present and discuss the need for this work and tool, and the importance of obtaining data directly from older and disabled people, as well as three validation trials conducted to evaluate the simulation capabilities of HADRIAN compared to real people interacting with the same tasks.

Keywords : disability, usability, design, inclusion

Résumé

Depuis plus de dix ans, le Design School du Loughborough University (Royaume-Uni) réalise des recherches sur l'accessibilité des produits, des services et des environnements, s'intéressant tout particulièrement aux besoins des personnes âgées ou ayant des incapacités. Une partie de ses recherches s'est concentrée sur le développement de l'outil informatisé HADRIAN, lequel vise à stimuler l'empathie et la compréhension entre les architectes, les urbanistes et les personnes âgées ou ayant des incapacités. Cet outil permet également d'évaluer le niveau d'accessibilité et d'inclusivité d'un produit, d'un service ou d'un environnement en simulant les capacités des personnes âgées ou ayant des incapacités. Il permet également de réaliser des essais virtuels au moyen desquels différents obstacles présents dans un design peuvent être identifiés et éliminés avant qu'il ne se trouve dans le monde réel.

Cet article discute de l'utilité et des travaux entourant l'élaboration d'HADRIAN et de l'importance de recueillir des données directement des personnes âgées ou ayant des incapacités à l'aide de trois tests de validation de l'évaluation des capacités de simulation en comparant les informations obtenues de l'outil avec celles récoltées auprès de personnes réalisant les mêmes tâches, mais dans un contexte réel.

Mots-clés : handicap, utilisabilité, design, inclusion

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 United States of America (USA) have disabilities or functional limitations, either from birth, accident and illness, or through old age. The Disability Discrimination Act (1995) in the United Kingdom (UK) and the Americans with Disabilities Act (1992) have, amongst other things, resulted in providers of systems and environments having to make services and environments accessible. Transport vehicles are covered in the UK by regulations that set out the minimum requirement for accessibility (Rail Vehicle Accessibility (Amendment) Regulations, 2000, Statutory Instrument No. 3215; Public Service Vehicles Accessibility Regulations 2000, Statutory Instrument No.1970). Best practices for access to transport infrastructure, including lifts, escalators, ramps, lighting, facilities, signage and more is given in documents such as Inclusive Mobility (Oxley, 2002). Guidance for usability in products and assessment of products is given by charities such as Ricability (www.ricability.org.uk).

People may not be able to access services due to social exclusion, which can include political, economic, cultural and social dimensions, with the person being unable to access the same jobs, activities, education and other opportunities that other groups are able to access. This might result in the person not being able to afford the services on offer, or unable to afford the transport costs (particularly public transport) required to access work, education, leisure and other opportunities. Social exclusion can also occur due to poor transport provision, especially for older or disabled people who might be unable to e.g. walk far enough to reach a bus stop on a poorly-designed route (Social Exclusion Unit, 2003). Language barriers can also be a problem, as well as the physical design of facilities, products and environments that exclude people from participating or acting independently.

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. ‘Fitting trials’ typically involve asking a selection of people with different sizes and shapes to try a prototype or mock-up design of a product, system or environment before the design is finalised. In this way it is possible to check the sizes, distances and layouts of the design and see if any changes to dimensions and arrangements need to be made in the final design. Typically this can only be done once a design has progressed far enough to allow a physical mock-up or prototype to be constructed, which can limit the potential for changes to be made to the design before it goes into production. The participants 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) and ‘transport’ tasks (stepping). These data within HADRIAN will potentially allow automated assessment of how many participants could successfully interact with proposed products, systems and environments.

It was considered essential from the start to collect data from older and disabled people. Central to the idea of ‘design for all’ / inclusive design / universal design is the idea that, by considering the needs of those who may have impairments, the resultant designs are easier for all people to use, regardless of impairment. With this in mind, the data collection samples were always purposive and biased towards people over the age of 60 and/or with a degree of impairment. For this reason people who were ambulant disabled (that is, able to walk with the aid of stick(s), frame, or other assistance) and wheelchair users (both manual and motorised) were sought along with people over the age of 60 years. Younger able-bodied people were also included in the sample, to cover a broad range of ability and other relevant measures such as body size and shape (anthropometry).

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 i.e. real people performing tasks with real objects, with HADRIAN predictions i.e. virtual people performing tasks with virtual objects. These three evaluations were designed to assess increasing levels of task complexity that the system could be used to evaluate. In the first of these, ten participants attempted to reach items in a mock-up supermarket freezer, and comparison was made with the HADRIAN predictions of their success or failure of each part of the task. In the second set of trials ten participants used two automated teller machines (ATMs) in an experimental setting, and their ability to reach to the given interaction points was again compared with HADRIAN. The final study involved nine participants performing part of a 'journey' through Greenwich Docklands Light Railway station, which were then compared with the HADRIAN evaluation of discrete stages of that simulated journey.

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 an external location permission was obtained to take photographs in public, and a risk assessment was also conducted for the trials.

Methods

- Real people trials :

Chest freezer

This validation trial was designed to assess the basic prediction functionality of the HADRIAN tool in terms of reach to designated targets. A chest freezer was used as it ensures that the participants have to adopt potentially interesting postures to reach certain extreme locations, and also reflects a 'real world' bend/reach task that people might experience when shopping.

- Ten participants (see Table 1 for further details).
- Bend-reach-lift tasks to heights between 30.5 cm and 149 cm from floor level, with weights (one handed or two handed lift) or 170 g, 500 g and 1000 g. Note was made of which weights participants were able to reach and lift from which heights.
- Video was captured from behind and side positions to enable postural coding for comparison with HADRIAN software.

ATM trials

This validation trial was designed to assess the basic prediction functionality of the HADRIAN tool in terms of reach to designated targets. It was also possible to investigate the orientation that participants took in relation to the ATM and whether this matched the HADRIAN predictions. Two real ATMs fascias were provided by manufacturer and project collaborator NCR. Again, the trial also reflects a 'real world' bend/reach task that people might experience when out and about.

- Ten participants (see Table 1 for further details).
- These were attached to a specially constructed rig which allowed the height of the ATMs to be changed easily by the experimenters. International standards give the recommended maximum height of the highest reachable part of the ATM (in this case the statement slot) should be between 1200 mm and

1450 mm, 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 1250 mm, 1300 mm, 1350 mm and 1400 mm.

- Participants were asked to attempt eight reaching tasks (including finger-tip reach and pinch-grip reach tasks) to simulate using the full range of ATM functions. This was done first at the highest height and again at the lowest height for both ATMs. If all points could be successfully reached during these trials, the trial ended. If participants were unable to reach all areas then the height of the ATM was changed accordingly and the trials repeated.
- Still photographs were taken at the instant of successful task completion for all tasks at all tested heights.
- For wheelchair users, the angle of the wheelchair relative to the ATM was recorded at task completion, to record the orientation of the wheelchair to the ATM.

Greenwich Docklands Light Railway station

Greenwich Docklands Light Railway station was built in 1999. It has two platforms which are reached via lifts or stairs via an underpass beneath the tracks. The station is not staffed and tickets are available from ticket machines at ground level (before moving to the platforms on the upper level). The station 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. Permission to take photographs on the station was obtained from CGL, the operators of the station.

- Due to geographical location it was not possible or ethical to use the same people from the ATM trials in the Greenwich trials. Attempts were made to recruit ten participants from the local Greenwich area, to 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 nine participants took part (see Table 1 for further details).
- Participants were met at the station and asked to : buy a one day travel card from the ticket machine (which involved five stages, all essential for successful completion of the task), and make their way to the platform (via steps or lift).
- Still photographs were taken at each significant step of the process, including the attempts made by those participants who were not able to reach e.g. 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.

TABLE 1 : NUMBER OF PARTICIPANTS AND IMPAIRMENTS TAKING PART IN EACH TRIAL

Trial	Gender	Able-bodied (18-59yrs)	Able-bodied (60+yrs)	Ambulant disabled (18-59yrs)	Ambulant disabled (60+yrs)	Wheelchair user (18+yrs)
Chest freezer	Men	0	1	0	2	1
	Women	2	1	1	1	1
ATM	Men	1	0	2	1	2
	Women	1	0	1	0	2
Greenwich DLR	Men	1	0	0	0	1
	Women	2	0	2	1	2

HADRIAN trials

In the first two trials, the automated HADRIAN analysis used the virtual equivalents of the people who took part in the 'real life' trials (as they were participants who had already had their data collected and stored in the HADRIAN system). For the Greenwich trails the total HADRIAN sample of 100 people were used to predict the success/failure of the new participants taking part. In the first two trials, use of the same people (virtual / real) with the same capabilities and behaviour was important as it would allow direct comparison of the predictive capabilities of the software, real Jill could be compared to virtual Jill, real Jack could be compared to virtual Jack. However, the final trial would not allow this comparison to be made but would provide a truer reflection of how the software would perform in use. Ideally, HADRIAN needs to be able to identify the problems likely to be experienced by any of the population in a given evaluation, not only those experienced by the people within its database.

The same tasks were specified to be simulated within the software, and the trials were run by the system. The HADRIAN system then conducted the assessment of which individuals could reach to which interaction points and at which heights.

Results

- Chest freezer assessment

When reaching to retrieve items from the front and rear of the chest freezer, a count was taken of the number of each item. The items were a pot of gravy granules : 170 g, a pack of pasta : 500 g and a box of biscuits : 1000 g. These were chosen to reflect common food item weights that could be lifted with one hand and two hands, and a count was taken of the items the participants' could reach to and retrieve (requiring them to reach, grasp, and remove). Figures 3 and 4 show the number of items that participants were able and unable to reach to, detailing the number of items that the participant was unable to reach, grasp and remove irretrievable). It can be seen that fewer participants were unable to reach and remove 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)

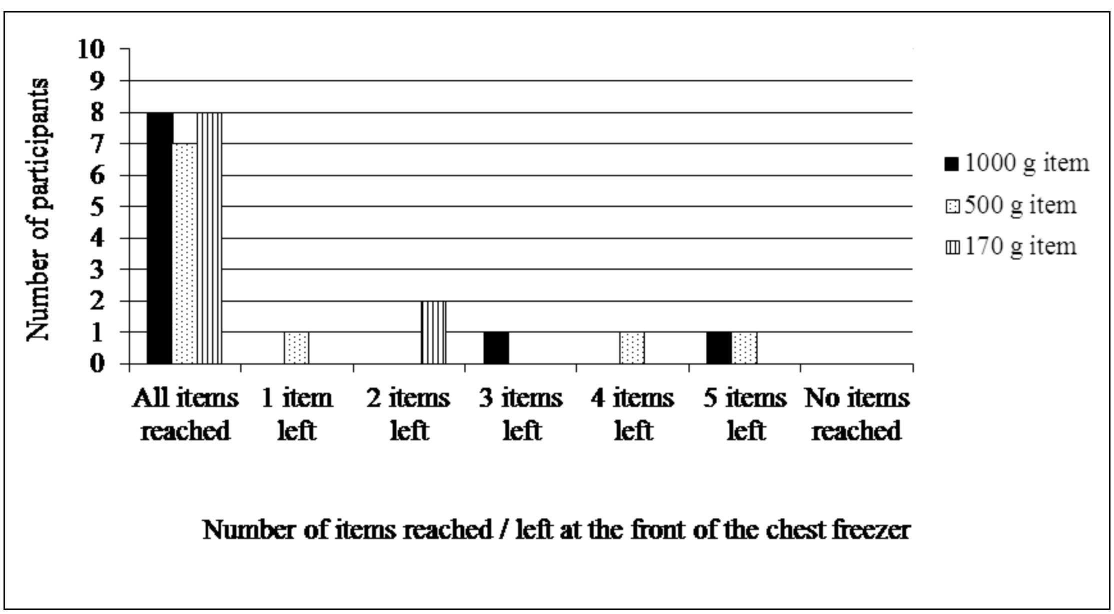
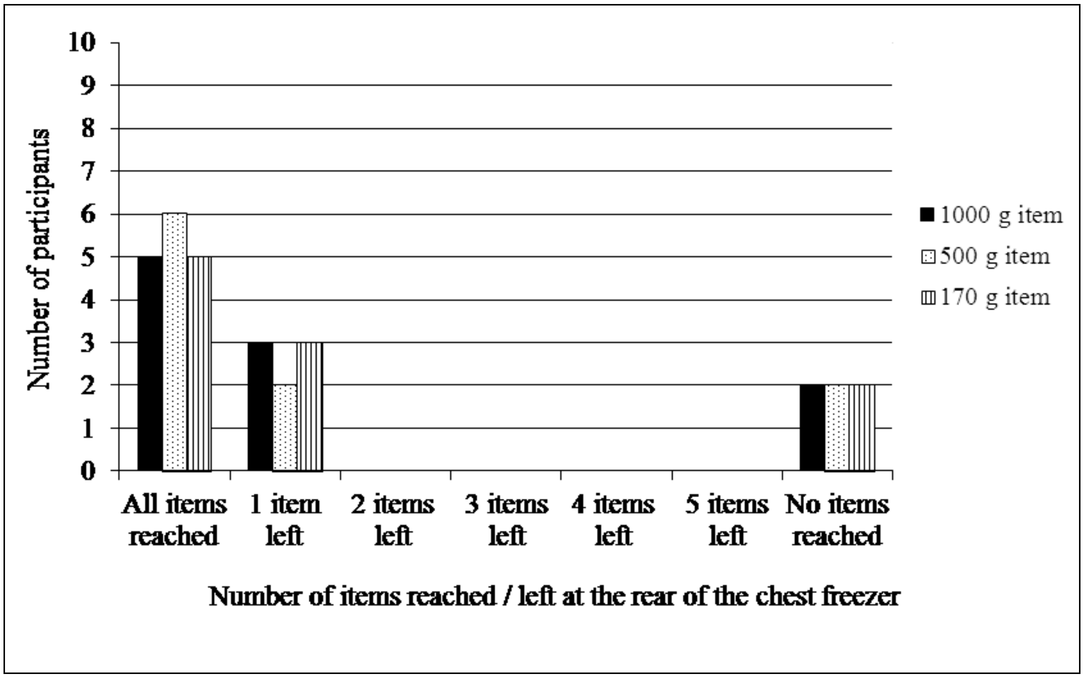


FIGURE 4 : NUMBER OF PARTICIPANTS ABLE TO REACH ITEMS FROM THE REAR OF THE CHEST FREEZER (N=10)



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.

The HADRIAN assessment 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. The current state of detail within the tool does not permit separate assessment of one- and two-handed items, so succeed/fail is given for each participant for each shelf in total (top, middle and bottom).

- ATM assessment

When considering the final success/fail for each participant reaching to each interaction point, in the real person trials and SAMMIE expert user 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.

Again, the predicted failures were due to HADRIAN being over-conservative : one participant achieved all the reaching tasks by shuffling forwards in his wheelchair to bring himself closer to the ATM and enable a successful reach. Coping strategies such as shuffling forward like this are currently beyond the predictive powers of HADRIAN.

FIGURE 5 : PHOTOGRAPHS FROM THE CHEST FREEZER TRIALS AND THE SAME PEOPLE IN THE HADRIAN PREDICTION SCENARIO

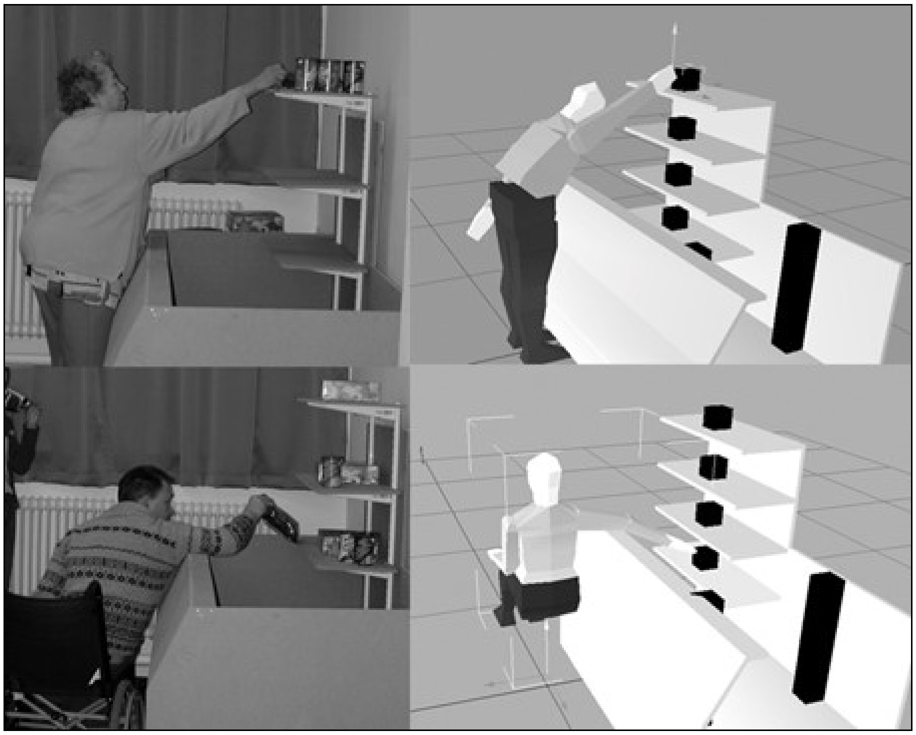
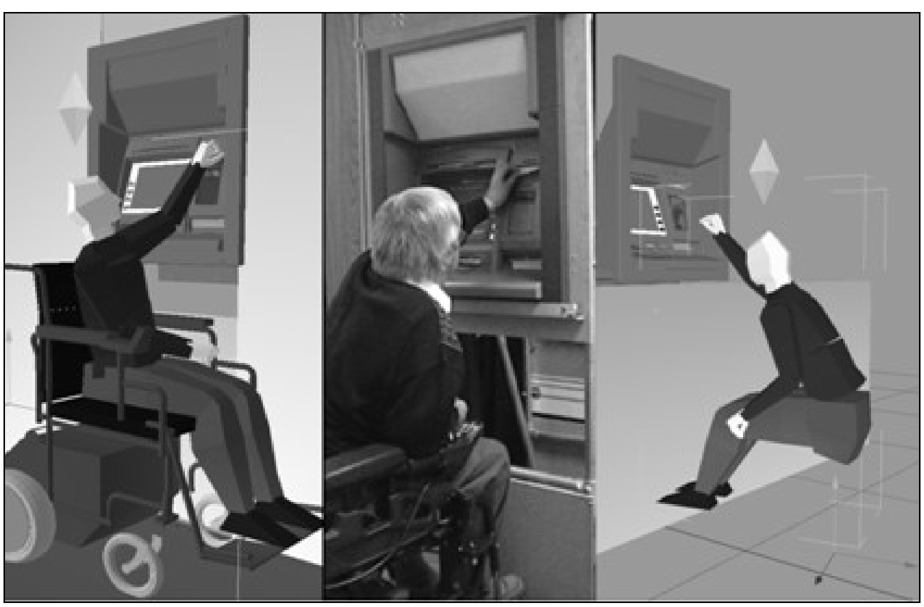


FIGURE 6 : IMAGES SHOWING SAMMIE EXPERT USER PREDICTION, REAL PERSON, AND HADRIAN PREDICTION OF FINAL POSTURES WHEN REACHING TO THE RECEIPT INTERFACE (SUCCESS, SUCCESS, FAIL)



- *Greenwich Docklands Light Railway station assessment*

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 were unable to successfully reach and interactive with the required aspects 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, as already stated, the station is not staffed), and half the participants found having access to the lift essential for them to be able to travel.

The HADRIAN system predicted that 10 % (ten of the hundred 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).

Discussion

One of the main aims of the computer-based design tool was to enable the estimation of percentage accommodated. It has been shown that, as it currently operates, HADRIAN is able to do this for reaches to items with free access. HADRIAN is able to predict representative task behaviour and reach ability for a broad range of people simulating a virtual fitting trial. 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* adopted, 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 issue 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.

FIGURE 7 : HADRIAN SIMULATION AND REAL LIFE PHOTOGRAPH OF ONE PARTICIPANT ATTEMPTING TO COLLECT THEIR TICKET FROM THE TICKET MACHINE AT GREENWICH DLR STATION

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 the wheelchair users often took an oblique approach in relation to the ATM, and this proved most successful (both in the real person trials and SAMMIE expert user trials). Also, one wheelchair-using participant in particular (for whom HADRIAN predicted five failures) did indeed approach in a facing position, but then shuffled forwards on the seat of the wheelchair until they could reach the target (see Figure 6). This was beyond the predictive capabilities of both HADRIAN and the SAMMIE expert users.

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, HADRIAN does also contain video footage of all participants attempting all tasks, which can be used to illustrate coping behaviours for consideration by design professionals even if HADRIAN cannot actually predict such behaviours. It is also worth remembering 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 the HADRIAN tool itself does not predict these 'non-standard' methods of achieving tasks, as otherwise 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.

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 and an assistant, with little room for the assistant and limited space for turning and reaching to the controls (Figure 8). 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 or mobility scooter 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).

It can be seen that, in order to validate a design tool such as HADRIAN, which aims to predict success and failure of task elements to highlight to design professionals the good and bad aspects of their design in terms of 'design for all', that involving older and disabled participants is key. It would not be possible to predict the different postures and coping behaviours that people adopt in order to complete tasks, without accessing and investigating those postures and behaviours directly, in as realistic a setting as possible. Although the data that went into HADRIAN, and was subsequently used to validate the tool, were mostly collected in a laboratory setting, the aim at all times was to gather data that was as naturalistic as possible. Participants were reminded to only attempt to do tasks they would be happy to attempt at home, trials were ended if any signs of fatigue were detected, and participants were also asked about their behaviours to enable some triangulation of responses and behaviours.

The HADRIAN tool does contain a broad range of representative postures and encoded behaviours. Some postures might not be the exact ones seen in real life, but reflect realistic postures that some people might attempt and achieve. Current digital human modelling provision does not currently offer this aspect, and HADRIAN offers the possibility of assessing designs early in the design process, allowing changes to the design to be made more easily and cheaply than if fitting trials are run only at the prototyping stage when a physical design has been produced.

FIGURE 8 : HADRIAN SIMULATION OF THE LIFT AT GREENWICH DLR, HIGHLIGHTING THE LACK OF SPACE WHEN A MOBILITY SCOOTER OR LARGE WHEELCHAIR IS USED

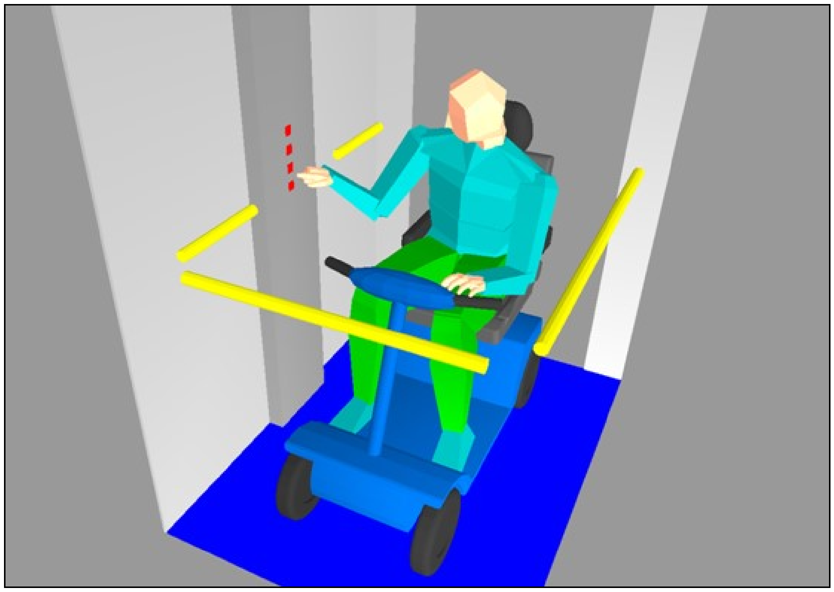


FIGURE 9 : EXAMPLE OF VIDEO STILLS SHOWING POSTURES ATTAINED BY PARTICIPANTS REACHING TO LOW SHELVES ON 'KITCHEN' RIG DURING TRIALS, AND AS SIMULATED IN HADRIAN (FROM MARSHALL ET AL, 2010)

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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