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APPLYING SIMPLE UX IDEATION TECHNIQUES TO IMPROVE THE USABILITY, DESIGN, AND ADOPTION OF ASSISTIVE TECHNOLOGY

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1. Introduction

In previous work we identified how users favour stigma-reducing wheelchair and assistive technologies that are aesthetically pleasing, over the purely functional [Wilkinson and De Angeli 2014]. This paper presents a simple design insight acquisition exercise that was intended to elicit user feedback to inform the design and development of more user-friendly, usable, and assistive devices. Four existing wheelchair and assistive technology users agreed to participate in this study. One user was diagnosed with osteogenesis imperfecta; a genetic condition identified at birth, another recently completed 6 months of rehabilitation within a wheelchair following a car accident, the third is a haemophiliac who experiences acute instances of immobility relieved only by reliance upon assistive technology, and the final participant was diagnosed with cerebral palsy from birth. Although a micro-sample, these participants are uniquely different and, yet, share remarkably similar experiences. Consideration of their experiences as users of assistive devices permits an insight into their unique needs and helps us appreciate how effectively, or otherwise, current designs satisfy those needs. Crucially, this provides the design community with an opportunity to understand the workarounds that were devised by each user to overcome inadequacies in the original designs, and how these improvisations enhanced interaction. Further, it allows us to consider how these ideas might be filtered into mainstream wheelchair and assistive technology development whilst simultaneously reducing the stigma often associated with the typical design of such devices. This work draws on often intimate and personal accounts of wheelchair users' experiences of assistive technologies and in so doing highlights where the design of mainstream devices remains lacking. Whilst there is no restriction on customising wheelchairs and walking aids for personal comfort, there are clear improvements that can be made to industry standard designs in terms of usability and acceptability. The aim and intention of this article, then, is to emphasise the physical and psychological impact of design on users whilst providing the design community with examples of simple techniques through which design insight can be acquired cost-effectively with the potential to improve wheelchair and assistive technology interaction for all.

2. The importance of user involvement within the design process

Effective design has the potential to enhance a user's ability to perform daily tasks and transform personal mobility [Sidner and Dzikovska 2005]. Further, assistive technologies can be designed to broaden social connectivity; increasing mobility outside the home and allowing users to maintain access to social networks and encouraging physical, social, and psychological interaction [Lauriks et al. 2007].

However, this work indicates that mainstream design may still suffer from a lack of true empathy and understanding, despite growing industry interest in the user centred and participatory design movement.

2.1 Listening to users matters

Lewis, Langdon and Clarkson [2006] observed that designers were typically male and able-bodied, and a survey of the UK design industry in 2010 reinforced concerns regarding a lack of diversity within the design community. The survey revealed that the average UK designer was male, white, and 38 years old, with only 7% coming from ethnic minority backgrounds [Design Council 2010]. Historically, the design community has been accused of failing to understand and engage with distinct user groups, preferring to design from their personal experience and capability: *If I can do this, then so will all the users of the product I am designing.* This crucially risks alienating the user base as a lack of user understanding will be transferred into products that become unsatisfactory, unappealing, unusable and unacceptable to users. Failing to engage with potential users or user groups in this manner misses a commercial design opportunity and an opportunity to design products that satisfy needs in a market-leading way [Wilkinson et al. 2016]. Indeed, at the Annual International Day for Persons with Disabilities Lecture, Jackie Ashley [2015] observed that her husband, the BBC journalist Andrew Marr who experienced a debilitating stroke at the age of 53, often remarked that *"you can't imagine how it feels unless you experience it for yourself".* This exemplifies the importance of involving users at every stage of the design process and throughout, as this reduces the reliance of designers to base solutions on their own experience, whilst empowering users. Further, such involvement can provide unique design insights that can transform the 'adequate' into a trend and standard setting, market leading, product. This, in turn, has positive implications for product engagement, adoption, and commercial success.

2.2 Overcoming exclusion through participatory design

Participatory Design aims to develop technologies with the close involvement of stake-holders and end-users throughout cycles of requirements gathering, prototype development, implementation, and evaluation [Sharma et al. 2008]. It is important, for the reasons outlined above, to capture user and usage information ideally at the earliest and every stage of the design process. Participatory Design, then, can be viewed as an attempt to better understand actual product users with varying degrees of capability, prior experience, needs, and desires; factors that are imperative in creating more appropriate, usable, and useful products [Lindgaard et al. 2006]. This idea is perhaps encapsulated best by Sanders [2002], who suggested that participatory design was a belief that all people have something to offer at every stage of the design process, and that they can be articulate, creative, and inspirational, in generating new ideas and developing current thinking. Rather than historically being considered an ill-afforded and expensive luxury as noted by Grudin [1991], involving users within the design process can improve the applicability, acceptability, and adoption of the finalised product. In so doing, it can reduce development risk [Mayhew 1999], and potentially add value in terms of improved design output. This, in turn, has the potential to yield greater commercial success whilst enhancing the overall experience of product interaction for the user [Dorrington et al. 2016].

3. Understanding the user's experience

User acceptance and acceptability were two of the fundamental requirements of assistive technology revealed in previous research [Wilkinson et al. 2016]. An obvious challenge therefore is to develop wheelchairs and assistive technologies that are equally usable and acceptable to users with a diverse set of needs and capabilities. ISO 9421 states that usability is; “The extent to which a product can be used by specified users to achieve specified goals, with effectiveness, efficiency and satisfaction in a specified context of use.” However, just because something can be used easily and effectively, does not justify the assumption that it will automatically be acceptable to a user. The author suggests that this distinction may be extrapolated to a divide between the physical and the psychological; whilst a product or technological device may be usable and satisfy a need from a physical perspective, it may not necessarily be acceptable from a psychological perspective. Indeed, it is misguided to assume individuals will use assistive devices purely because they are required [Hirsch et al. 2000]. Users often perceive such technology as a symbol of dependence and frailness, and consequently feel stigmatised by association,

suggesting that solutions merely addressing a clinical need are insufficient [Wilkinson and De Angeli 2014].

Affirming this notion, one contributor to this study volunteered that whilst their doctor attempted to convince them that they needed to use a wheelchair, they remained reluctant as doing so represented an unwelcome identity and life altering adjustment. One aspect that is crucial to the psychological health of the user is maintaining a positive sense of personal identity, and assistive devices have, in certain circumstances, been viewed by users as a threat to that identity [Forlizzi et al. 2004]. In this study, one user revealed that it was *"...difficult to find your identity. I'm always afraid to be defined by others as the girl with the wheelchair or crutch; but actually I realized that the problem is that I define myself as such (and I shouldn't). Each user has different needs, that's why it's crucial to adapt and customize the assistive technology. Also, to have to use an ugly wheelchair doesn't help [a user] to accept it"*. A reluctance to use assistive technologies that emphasise a user's impairment was frequently reported in this and previous research: *"I tutor from home, but standard chairs aren't adapted as well as my wheelchair to cradle my back. As my number of students has increased, I have found myself suffering intensive injuries to the back region, but have resisted moving to my wheelchair for teaching as I feel it highlights my weakness over my strengths and might make me a less confident teacher. I have strongly considered taking on less students over teaching in my wheelchair. I would love to modify it and find myself explaining it away or apologising for it a lot"*. Working collaboratively to design and overcome these challenges is only possible by understanding in greater detail the complexities and holistic experience of actual and potential users with their involvement within the design process, and this in turn, can help improve engagement and deliver more appropriate end products and designs (Figure 1).

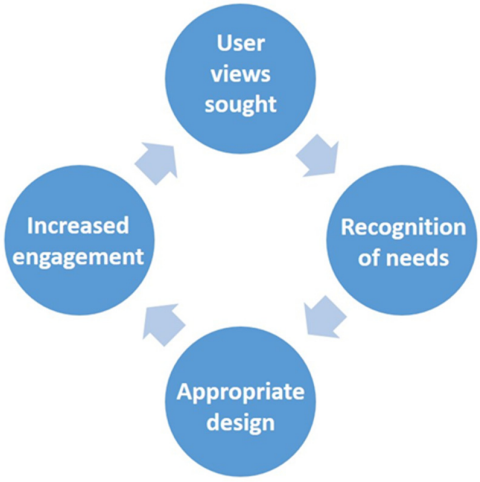

Figure 1. Positive user centred cycle of design

4. Experimental approach and methodology

A small sample of wheelchair and assistive technology users was assembled, consisting of four users with varying degrees of mobility. The intention of the study was to investigate the effect of current design upon user perception, and how design can influence feelings of identity, personal independence, social and physical mobility. Extensive interviews with each participant were designed to reveal individuals' experiences of using assistive devices and the enhancements or improvements they made or envisaged that would improve their interaction and usability. Further, these interviews captured the methods adopted by users to make the devices more cosmetically or aesthetically pleasing and acceptable. A key element of the approach was to allow participants to draw their own interpretations of the solutions, or to provide images or photographs that might highlight the issues they deemed important. These were all critical factors that from a user experience perspective affect the usability and acceptability of assistive technologies. The intention is to show that this cost-effective and transferable participatory approach will contribute toward the development of enhanced design solutions that are more usable and desirable to wheelchair users and users of assistive technology in general.

4.1 Participants

Participants were pooled from personal requests made via social media due to the sensitive nature of the research. As awareness of the project increased so, too, did the pool of volunteers. In the study, each participant was asked to provide details about their reasons for using wheelchairs or walking devices and their experience of using them. Participants ranged in age between 27 and 54. The group consisted of 1 male and 3 female wheelchair or assistive technology users. Participants were asked to respond to a series of questions either in person, in which case the conversation was recorded on digital media for ease of retrieval, or remotely, in which case responses were recorded on paper and returned.

4.2 Procedure

Two participants were assigned to each of the data capture formats described, and information on the devices (Manufacturer, Model, and Age) and the modifications made to increase usability, comfort, or aesthetic appeal were recorded. Interviews were conducted separately with each participant to elicit information on their personal experiences of interacting with assistive technologies. A portion of the exercise was allocated to understanding and documenting each user's unique journey of interaction with assistive devices, before focussing upon the functionality of the specific device and how effectively it met the user's needs; this was also useful in determining and defining the requirements expected and required of such technologies. The modifications made to the device to improve cosmetic or functional aspects of the design were then obtained. Paper was provided to allow participants to sketch examples of the devices and the modifications, in conjunction with a request for digital images. The interviews concluded with an assessment of how, psychologically, the participants felt the design of the device may have influenced or affected their perception of the device or themselves as individuals and users.

4.3 Protocol

Due to the sensitive nature of this exercise, participants were fully briefed apriori, and the study only commenced with informed consent granted. Participants were reminded throughout that participation was entirely voluntary and that they were welcome to withdraw from the study at any time without recourse, redress or comment, and were debriefed accordingly after the event. The following results section presents the main and most revealing findings from the study. In the interests of brevity and open access, the consent form, interview and survey material, are available online at the following web address: http://cantab.academia.edu/DrChristopherWilkinson.

5. Results

The results section focusses on some of the overarching elements identified with the use of the sketching techniques described. To reiterate, paper was used as a tool to allow participants to sketch examples of the devices and modifications made, in conjunction with a request for digital images to highlight specific features or to help tell the story of each individuals' experience. Subsequently, a greater focus on the structured interview material, initially summarised, will permit the consolidation of participants' responses to specific questions regarding their interaction with their wheelchair or assistive device.

5.1 Sketching and imaging techniques

Figure 2 indicates how one participant explained the medical condition they experienced, and the issues that impeded usability using simple sketching techniques. Two images depict fractured vertebrae and, separately, the surgery to – and the subsequent fusing of – the pelvis. The use of the 'extended leg' or foot-rest of the wheelchair was intended to facilitate blood-flow as the participant suffered from extremely low blood pressure at the time. However, this intervention caused them to experience significant issues when interacting with the environment. Problems were particularly manifest when they attempted to accomplish everyday tasks such as opening cupboard doors, accessing the wash basin in order to wash or to clean their teeth. The sketch also depicts potential improvements that were envisaged to the wheelchairs back support that was considered '*too flexible*' and rather than supporting the user, wrapped around their back and encouraged poor posture. Further aspects of this user's experience will be presented in the section that covers the structured interview material.

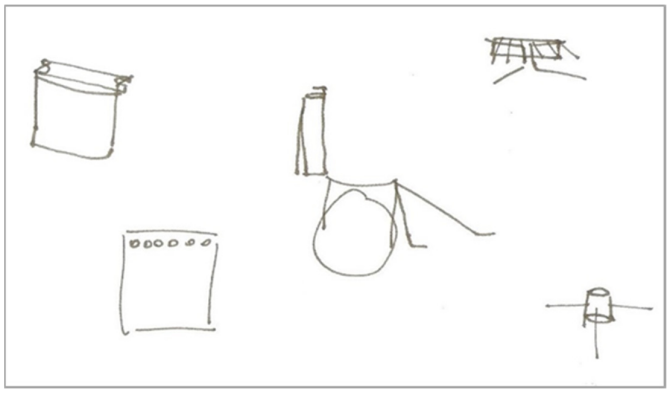

Figure 2. A participants sketch used to explain both their medical condition and the design workarounds developed to improve the usability and user experience of wheelchair interaction

Figure 3 highlights some of the modifications another participant made both to the device and to the paraphernalia that they carry with them at all times. Poor storage capacity was identified as a key issue, and the individual had devised a way of attaching a storage device underneath the chair as well as attaching a rucksack to the back support. Cycling waterproofs were also employed to minimise water ingress, and the attachment of a water bottle was another addition from the cycling fraternity that was utilised to enhance the user experience of living with the device as a daily support system. The participant's sketch (bottom right) also indicates the elements of customisation that the participant felt important to incorporate, such as a multi-layered and handmade cushion, lightweight front castor wheels, and Spinergy traction wheels. The "clean-up kit" that is continually carried, also speaks volumes in terms of where the design of the device negatively impacts usability. The need to carry gloves highlights the fact that hands can swiftly become soiled through interaction with the traction wheels; particularly unpleasant if animal or environmental detritus is encountered during every day use. Indeed, the gloves pictured are primarily used for clean-up purposes; two of the participants opted for cycling gloves on a regular basis for additional support and comfort during normal interaction with their chairs.

Figure 3. Photographs and a participants sketch highlight personal enhancements made and the aspects that negatively impact the usability and experience of wheelchair interaction

5.2 Interview responses

A focus on the structured interview material, initially summarised, permits the consolidation of participant's responses to specific questions regarding their interaction, although not every participant responded to every question. Wheelchair was unanimously the term of choice: “wheelchair user” was deemed acceptable; “wheelchair-bound” was considered unacceptable and derogatory. For added context, the symptoms of the participants included; 6 broken ribs, 5 transverse process vertebrae fractures, a fractured pelvis and broken pubic symphysis; fragile bones, hyper-mobility, predisposition to bone fracture, and scoliosis; short and long-term immobility, bleeding into joints and haemarthrosis (erosion) and shortening of muscles; a lack of balance and inability to walk without assistance.

What do you need in an assistive device or wheelchair?
Responses ranged from something to assist with exercise and balance, good back protection, good cushioning, increased wheel traction for pushing and a ‘slide rim’ to aid free-wheeling, to immobilisation of an injured limb and to minimise the impact upon regular life activities as little as possible and to help retain self-sufficiency.

What tasks do you perform in it?
Transfers; from bed to chair, chair to shower, easy navigation of a flat rehabilitation environment. Everyday living; socialising, shopping, eating, transportation. Everything an able-bodied person would want to do; wash, cook, clean, travel, visit friends. Access and navigate my home and outside.

How much time do you spend in it?
Participants would spend up to 12 hours a day in their chairs.

What terrain do you cover?
Responses ranged from the flat and smooth rehabilitation environment to cobbled streets, and included stairs, playgrounds and pavements.

How does it cope with that terrain and how comfortable is it?
Flat smooth surfaces are ideal. Grass requires more effort and gravel, sand, snow or mud is impossible. Mud is rapidly transferred from ground to wheel to hand to clothes. Cobbles are hard and uncomfortable, pavements are not flat but often slope to facilitate water run-off, and mounting them is difficult.

What problems are there with the existing Solution?
P1: The first chair was too large and didn’t ‘fit’, there was a lack of back support (Figure 2), and a fixed leg support that impeded access to solid objects such as doors. P2: Turnaround time from specification to delivery (6-12 months). Foot supports were cumbersome and impeded interaction. Foot-hip and femur-back measurements were incorrect. Rubber wheel rims became detached. Poor storage. Difficult to secure chair in public spaces to walk somewhere. A magnet for the inebriated. P3: Wet wheels caused wet hands, wet sleeves and wet clothing. I would avoid going out – wheels get black [transferring] grease onto clothing and furniture. [unable to cope with] Stairs, cobbles, and narrow doorways.

What workarounds did you devise?
P1: The addition of rubber around the wheel rims improved traction, reducing the effort expended in pushing. The removal of the leg support improved access to doors and kitchen appliances. Air and gel cushions relieved pressure sores and extended brake levers improved the control and interaction. P2: Drinks holder stolen from another user and additional storage added to carry university books (Figure 3). P3: The Remploy Roller provided a barrier between the [users] body and the wheels which helped with stray fabric and water splashing. Cycling gloves used to reduce friction burns on hands.

How did the workarounds improve interaction?
P1: Improved access to the environment and reduced effort required to accelerate and decelerate the chair. P2: Rear rucksack and under-seat storage allows greater use and practicality for shopping,

travelling and attending lectures. Under-seat storage adapted from textile motorcycle pannier and has less adverse effects upon [the chair's] centre of gravity. P3: Friction burns made constant use painful; gloves increased the time taken to get friction problems.

Did you find the device disappointing cosmetically or aesthetically?
P1: [I] didn't care initially but aesthetically, yes it was massive. P3: NHS chairs were unattractive. Ones that deny self-propulsion remove dignity and independence. Using them felt like accepting a state of dependence. I was given the Remploy as a child on account of its aesthetics and I loved that chair.

Did you modify the devices cosmetic or aesthetic appearance?
P1: Later [I] appreciated the use of colour; metallic paints and light frames (that facilitate the 'wheelie' technique to ascend/descend steps), lights in the wheels. Like elegant bikes, you begin to appreciate the design. P3: I removed the safety wheels that prevented the chair from tipping over (they stopped me from doing wheelies and getting up curbs).

What would make the device more usable?
P3: Moderate power assistance would help with terrain [but] if personal ability is reduced to improve independence by powering the device, users can actually be institutionalised rather than freed. The ability to lock the front wheels to freewheel. Reducing the chairs footprint would increase access. Navigating steps and pavements without thought would be a game-changer. P4: If manufacturers would consult the people who use the devices before making changes.

List the 5 best things about the device you use?
P1: Comfort, movability (it gave personal mobility), manoeuvrability, increased independence, [that] it becomes part of you…an extension of the user… and the seat your personal space with invasion causing discomfort and dislike of others touching it; it is an intimate object to the user. P3: Ergonomically placed wheel grips [caused] shoulders to hurt less, low friction and free-rolling [allowed] more efficient and faster movement, [good] styling – I would rather turn heads for good reasons [not negative ones], guards that kept water from wheels off clothing, ease of wheelie-ing for fun and [increased] freedom of movement (to ascend steps and pavements).

List the 5 worst things about the device you use?
P1: The users cannot forget or ignore it, the need for it, the effect of the device on other people: I am still independent me, that it makes you an easy target, the reduced access to anywhere due to urban design, even disabled toilets are not as accessible as they claim to be, despite legislation. P3: Low-backed devices are not easy [for others] to push, [small] front castors allow easy movement on flat surfaces but make graded pavements into a marathon and fatigue increases the risk of rolling off the pavement into traffic, NHS chairs have no barrier between wheels and seat; water would get everywhere, control surfaces of chairs are always metal which increases the bruising and blisters; is there not an alternative? Every table required seat adjustment or transfer to a conventional chair.

Could you list the physical or cosmetic design improvements that were needed or made?
P1: Gel cushion, back support. P2. Colour is crucial; the chair and colour is an integral part of people's first sight of you. Black can be too 'industrial' and shows scratches easily. Purple, glitter, and anodising are available. The chair can also convey your personality as an extension of the user. It needs to be fun but also to form part of your outfit – formal or casual; part of your wardrobe combination. P3: None made at the time, but I would probably now I am an engineer.

Would you use a device that was aesthetically appealing over one that was purely functional?
P1: No – functional only. P2: No – functional only – but if one was prettier the prettier one would be chosen. P3: It would depend upon the event/purpose – in the same way you wouldn't wear a tracksuit to a wedding. P4: I may want one that looks nice but functional is more important.

Would you use a device that was aesthetically appealing over one that was superior functionally? P1: No – functional only. P2: No – RGK [chairs] are the Bentley of the wheelchair world. P3: I would use one that kept me fit and healthier and maintained as much of my independence as possible [although] I would probably avoid using something that I didn't like the look of. P4: I may want one that looks nicer, but functionality is more important.

6. Discussion

The removal of the anti-tip safety wheels seems a common modification for both cosmetic and practical reasons. This is synergous with previous findings where users removed them as the users themselves felt the safety wheels resembled stabilisers [Wilkinson and De Angeli 2014], [Wilkinson et al. 2016]. Also, the revelation that users feel they can become "*institutionalised rather than freed*" reappears in other research that found that the physical effort invested in using an assistive technology was not always worth the personal gain; having someone or something else perform tasks was in some instances preferential, and this ultimately reduces personal independence [Dorrington et al. 2016]. This reliance is a potentially difficult aspect to manage and calls for greater understanding of each and every individual's unique needs. Arguably this is only achievable through effective and bespoke user centred design. In terms of consideration of aesthetics versus functionality, the fact that users feel functionality is important but that assistive devices need to be "*fun but also to form part of their outfit*" resonates with research that identified users desire an ability to "*match a wheelchair to social events in the same way as you might wish to change your clothing to be appropriate for a particular function*" [Wilkinson et al. 2016] and is perhaps summarised succinctly by participant 3: "*It would depend upon the event/purpose – in the same way you wouldn't wear a tracksuit to a wedding*". The influence of design upon aspects of personal identity and personality are particularly reflected in specific responses "*It becomes part of you…an extension of the user… and the seat your personal space with invasion causing discomfort and dislike of others touching it; it is an intimate object to the user*" and "*I would rather turn heads for good reasons*". It is worthy of note that the device and its design affects other people and users, influences others reaction, and affects users self-perception, personal identity and self-worth: "*I am still independent me*" not merely a chair or a person confined to a chair.

The terminology used to describe the assistive devices of the users was clearly important from a personal identity perspective. The term "wheelchair-bound" was deemed unacceptable due to its negative connotation, and the fact that it was considered to categorise and minimise the abilities of the user in an unhealthy way. Understanding user's symptoms helps us understand the range of physical conditions that users of such devices are subject to and the impact that the conditions will have upon the users' quality of life and tasks involved in everyday living. Further, it also helps us understand the impact upon interaction with assistive devices and how improved design might accommodate their condition better. The length of exposure to the condition was important to consider as a unique element of each individual's experience. Those who have lived with a condition for a number of years are likely to have devised coping mechanisms and solutions to imperfect design. Conversely, issues in interaction may be more prominent to those who experience the recent development or introduction of a condition. The requirements of a device naturally ranged extensively. However, the examples provided emphasise the impropriety of the one-size-fits-all mentality often purported by health services, the importance of customisability, and the obvious benefit of user involvement in the design process. The range of tasks users wish to perform using their device may not appear remarkable; in fact, they are perfectly normal and understandable. However, the impact of extraneous factors that may have gone unnoticed without investigating these themes, proves to be revealing; the focus on terrain coverage has allowed us to better appreciate the conditions under which assistive devices and chairs are normally used. Again, without the unique insights afforded by those living with these conditions and devices, it would be impossible to gain such understanding. The built environment even with its often meagre concessions to the physically impaired, clearly presents as many obstacles as the natural one. Further, the results indicate that the design of our urban spaces would also benefit from further user centred consideration, as they evoke and instil both "*fear and bravery in the normal urban landscape*".

7. Conclusion

Whilst there is no restriction on customising wheelchairs and walking aids for personal comfort, there are clear improvements that can be made to industry standard devices. In the example of the participant introduced to a wheelchair following a car accident, there is no justification for a standardised design that fails to offer adequate back support and adversely affects posture and doorway access (Figure 4).

Figure 4. Photographs that depict a user's interaction with their environment and how certain design aspects negatively impact the everyday usability of wheelchair interaction

The aim and intention of this article was to provide the design community with examples of simple techniques through which ideation and design insight can be acquired. Highly qualitative in nature, these techniques yield valuable insight even with a small sample size, and little difference is observable in direct or remote administration in terms of the quality and quantity of output. With the appropriate expertise, such exercises can be performed to directly inform the prototypical development process with minimal financial or humanistic impact. Also highlighted, is the importance of participatory and user centred design to elicit the knowledge that only actual users are uniquely positioned to provide. Such consideration of the usability and the user experience of assistive technologies, will clearly translate into positive user feedback, increased acceptance and adoption, and increases the potential for commercial success. Regardless of the commercial implications, this approach ultimately benefits the end product and produces better products for all wheelchair users, and users of assistive technology in general.

7.1 Could the design community do more?

The main contribution of this paper is to give the actual users of the technology a voice, and to suggest that the design community must ask itself if it has responded adequately to the needs of users in terms of improving mainstream industry standards. If an inadequate response remains due to a lack of awareness, then this article provides a wealth of knowledge and expertise to address these issues. If it remains an issue of perceived cost within industrial design and manufacture, this article proves that user focussed research needn't be complicated or expensive and can subsequently reduce development costs. If it is because of apathy, then that is a question the design community must address personally, particularly when the effects of welfare reform in the UK and Europe are having such a devastating and direct effect on the quality of life for the disabled and disenfranchised [Disability Cuts 2016].

7.2 Applying the knowledge gained from user insight activities

The intention is to liaise with the National Centre for Product Design and Development Research (PDR) in Cardiff, to develop testable prototypes based upon the sketches, images, and interview material obtained. The aim will then be to produce user-inspired, after-market, applications that improve usability, comfort, and aesthetic appeal, and enhance wheelchair and assistive device interaction for all.

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