

Kent Academic Repository

Full text document (pdf)

Citation for published version

Gillham, Michael and Pepper, Matthew G. and Kelly, Stephen W. and Howells, Gareth (2017) Stakeholder views addressing the development and uptake of powered wheelchair assistive technology. Disability and Rehabilitation: Assistive Technology . ISSN 1748-3107.

DOI

<https://doi.org/10.1080/17483107.2017.1416186>

Link to record in KAR

<http://kar.kent.ac.uk/65424/>

Document Version

Author's Accepted Manuscript

Copyright & reuse

Content in the Kent Academic Repository is made available for research purposes. Unless otherwise stated all content is protected by copyright and in the absence of an open licence (eg Creative Commons), permissions for further reuse of content should be sought from the publisher, author or other copyright holder.

Versions of research

The version in the Kent Academic Repository may differ from the final published version.

Users are advised to check <http://kar.kent.ac.uk> for the status of the paper. **Users should always cite the published version of record.**

Enquiries

For any further enquiries regarding the licence status of this document, please contact:

researchsupport@kent.ac.uk

If you believe this document infringes copyright then please contact the KAR admin team with the take-down information provided at <http://kar.kent.ac.uk/contact.html>

Stakeholder views addressing the development and uptake of powered wheelchair assistive technology

Michael Gillham¹, Matthew Pepper^{1,2}, Steve Kelly¹, Gareth Howells¹

¹Department of Engineering and Digital Arts, Jennison Building, University of Kent, Canterbury, Kent, CT2 7NT, England, UK

²Department of Medical Physics, East Kent Hospitals University NHS Foundation Trust, Canterbury CT1 3NG

Contact:

Michael Gillham Email: M.Gillham@kent.ac.uk

Matthew Pepper Email: matthew.pepper@nhs.net

Steve Kelly Email: S.W.Kelly@kent.ac.uk

Gareth Howells Email: W.G.J.Howells@kent.ac.uk

The authors report no conflicts of interest

Paper word count = 7391

Keywords: Assistive technology, Powered wheelchair, Rehabilitation

Abstract

Purpose

The objective of this research is to identify stakeholder views with regard to the development of effective powered wheelchair assistive technologies more suited to the user and carer needs, whilst also meeting the requirements for other stakeholders, such that developers can be better guided towards producing solutions which have a better chance of getting to the market place and hence to the end user.

Method

A questionnaire was designed to collect the views of all stakeholders and circulated to a statistically representative number of them. The question rating data was then checked for correlation between groups, and within groups, to establish validity.

Results

The 74 stakeholders across the eight classes who responded had a good correlation between each other, with a cross class 'Pearson's correlation' ranging between 0.7 and 0.95, and the 'Fleiss's Kappa reliability of agreement' within each class ranging between 0.07 and 0.36.

Conclusions

This research has identified that all stakeholders should be involved in the development of the technology and that some may benefit in 'role-reversal' to help understand user problems and stakeholder concerns more clearly. Cost was a significant barrier to the uptake of appropriate technology, and training of users and carers was a major issue. Furthermore development should not increase user isolation and the impact on the user must be monitored for 'quality of life'.

Technical support and training should be given to the user and their carers and equipment must be adaptive to meet the changing needs of the user.

Introduction

This research has sought to determine the problems with regard to the development of smart assistive powered wheelchairs such that one mass produced device can be used by a wide range of users, each with individual needs which may change over time. Whilst the principal of involving a wide range of stakeholder in order to identify problems and issues could be applied to the development of other assistive technology we have taken development of a smart assistive powered wheelchair as the core technology with the users and other stakeholders targeted towards this.

According to the UK Government, the term assistive technology is best described as a device which mitigates the effect of an individual's disability, such that the technology substitutes for some biological function which has been impaired [1]. The World Health Organisation (WHO) describes an assistive device as 'equipment that enables an individual who requires assistance to perform the daily activities essential to maintain health and autonomy' and assistive technology as 'an umbrella term for any device or system that allows individuals to perform tasks they would otherwise be unable to do' [2]. The terminologies 'assistive technology' and 'assistive devices' have over time been driven towards meaning assistance which is more user centred, rather than terminologies with a wide definition referring to generic devices such as walking sticks and wheelchairs [3]. More recently the WHO have defined the assistive technology as a subset of health technologies which enable individuals to improve or maintain healthy, independent, and productive lives in a dignified manner whereas without they may become isolated and impoverished. Furthermore assistive products should be purposed to compensate for loss of ability and gradual decline in the individual over time whilst also reducing the burden on carers, health care providers, and welfare [4].

Potential assistive technology users

The availability of the United Kingdom (UK) Census data makes it possible for estimates to be based on up-to-date demographic figures, which quote the UK population in 2011 as 56,075,912. A survey of disability in Great Britain, carried out by the Office of Population Censuses and Surveys (now the Office of National Statistics) in 1989, stated that 13.5% of the adult population of the UK had a disability of some kind, and that, of these, 69% had a mobility problem, these percentages correspond to the absolute figures of 7,570,248 and 5,223,471 respectively. The same source also estimated that 7% of disabled adults, and 10% of adults with a mobility problem used a wheelchair, and that 10% of those wheelchairs were of the powered type [5].

The provision of a powered wheelchair (PWC) can have a significant impact on improving mobility, independence and quality of life. However not all persons who would benefit from the use of an PWC will meet the prescription criteria. For example, cognitive and visual deficit may exclude the individual. Additionally, even when prescribed with an EPW its use can be challenging, especially if the user does not have the required fine motor control for collision-free navigation within the home. Operating a PWC indoors can present the user and their carers with significant challenges. Physical and mental disabilities can also make accurate control of the device a major challenge. Collisions with objects and people can be highly detrimental to the rehabilitation and confidence of PWC users, particularly if the independent use of the PWC is in jeopardy because an unacceptable risk level, which varies from prescriber to prescriber, has been reached.

Additionally, cognitive and physical ability will deteriorate with time for many PWC users. For example, users with Multiple Sclerosis or Motor Neurone Disease will have increasing physical difficulty in accessing and moving the joystick (the prime human machine interface) as well as being able to drive safely. This means that users with progressive conditions will require periodic assessment and adjustment of the PWC configuration in order to maintain independent and safe mobility. These adjustments to the control system mean the user often has to wait several weeks for

appointments with clinicians, therapists, and technicians. The outcome can be that the user loses their independent mobility affecting their quality of life and that of their carers, friends and family. One solution to this challenge is to develop a PWC control system which can measure the changes in user condition. This information can then be used to adapt the PWC control system to more closely match the ability of the user.

State-of-the-art

Over the past four decades considerable research has been published on the application of mobile robotic assistance to improve the quality of life for the disabled user [6]. According to a systematic review by Simpson [6], it was observed that little attention had been paid to user input, user feedback, and user confidence, with negligible consideration of the users' abilities and desires. In order to investigate the importance of understanding those issues, research was carried out by Woods and Watson [7]. They suggested that a 'social constructionalist' approach needed to be undertaken in order to understand the relationship between users' needs and technological requirements and how society views the wheelchair and its user. It was important to question the assumption that the current social and technological solutions must automatically be the best.

There was a broad review of intelligent, or smart, and assistive PWC literature undertaken by Simpson in 2006 [6] and another similar review by Faria in 2014 [7]. There have been some projects which have evolved or continued [8]-[11] and others initiated [12]-[15]; between 2005 and 2013 over 4,000 papers were published; however no mass produced device has yet reached the end user, according to Garcia et al. [16]. They identified three major problems: that most research is undertaken in the Lab without involvement of the stakeholders, in particular the users; the lack of availability of suitable sensors; and lack of a standardised platform.

Another significant issue in the development of assistive PWC technology is the absence of any standard bench testing procedure so that research groups can compare the performance of their

developments. In addition, when evaluating the performance of any assistive system it is essential to prove that the technological device is fit for purpose and safe [17]. Most research has not fully considered these issues [9], [18] and what may be considered by some researchers as appropriate may not be addressing users' needs, or worse may be considered dangerous when applied to real-world applications. Considering the somewhat complex requirements for keeping the individual user in overall control of the actions of the robotic PWC system, most research has concentrated on addressing specific issues rather than attempting to define the wide-ranging problem and work towards a solution which balances the global variables.

We have worked closely with one of the world's major suppliers of PWC control systems, Dynamic Controls Ltd. The manufacturer informed us that the problem is essentially profit and cost such that the larger the market and the simpler the device the lower the cost, in the case of the assistive technology powered wheelchair we find ourselves with the exact opposite: complex unique to the individual, or bespoke, equipment. Dynamic Controls Ltd states that without external funding they would be unable to develop the required technologies; quite simply they would lose money if they did attempt to do so.

The aim of this research

The road to developing assistive technology, which is fundamentally a user specific adaption of some technology, and making it mass producible for a wide range of users is likely to be a very complex and costly one. If, the past 40 years, research into producing a smart assistive powered wheelchair has still failed to provide anything but the most basic line following navigation assistance [19], then the challenge of developing adaptive smart assistive systems will need to be approached very differently. Referring back to the 'social constructionalist' approach we hypothesise that in order to develop a technology that can be adapted, adjusted, and applied to a wide array of user needs, there needs to be a commonly acceptable (amongst all stakeholders) range of functionality which meets the end user's needs and wishes as optimally as possible per unit cost.

This research is an attempt to start at the beginning of the development process by trying to understand the relationship between stakeholders and their views on the development and use of assistive technology. This will identify some of the reasons why the route of developing assistive technology and getting it to the end user appears to be so problematic. There is also clearly a need to identify a methodology which can be used to develop cost-effective assistive technology.

Methodology

Literature is sparse with regard to PWC stakeholder semantics and the variation of difference in definition for each of the stakeholder classes. Therefore, in order to understand the interclass relationship and to obtain some measure of the range of functionality common to stakeholders we devised a simple questionnaire (see appendix A) which we could circulate to relevant stakeholders. The questions were based upon significant experience gained by the authors due their extensive involvement in two European Union projects developing powered wheelchair assistive technology, SYSIASS [20] and COALAS [21]. A follow-on European Union cluster project called EDECT [22] involved the organisation of a stakeholder conference and the undertaking of a user clinical evaluation of assistive technologies. It was during the stakeholder conference that some of the questionnaires were first circulated to collect data in a semi-structured manner, with the stakeholders completing the form themselves having had the questions explained. Data was also collected from stakeholders at the 2016 Naidex exhibition [23] in Birmingham, UK and at the 2016 Independent Living Scotland exhibition [24] where again the questions were explained and the responses self registered.

Questionnaire

The questionnaire was designed with questions worded in such a way as to encourage the stakeholder to reflect on their own opinion, rather than any generally accepted view, by specifically directing the questions at the reader. This was re-enforced with instructions, written and verbal, on

how to answer the questions. There were a total of 12 questions with a rating scale of 1-10, where 1 denotes “no, less, or not much” and where 10 rates as “yes, greatly, very much, or lots”. There was an additional section for responders to add their personal comments, Table 1.

Table1. Stakeholder questionnaire comments

Stakeholder	Comment
User	Within the NHS there is a ‘perception’ that you can be a wheelchair user OR have severe medical conditions.....
User	The academic world is FAR [advanced], but we also have to involve the suppliers, government etc.
User	There are lots of external factors when using a powered chair that I think are hard to measure.
Policymaker	Measuring the quality of life and placing a value on it is vital to make the case for public sector spend and take-up.
Clinician	There sometimes needs to be a compromise regarding what the user wants/preferences and what is actually most suitable assistive technology [for them].
Clinician	Unfortunately statutory NHS standard services are risk led as opposed to service delivery common sense approaches, they focus on one size fits all.....
Clinician	Occupation therapists and [clinical] professionals don’t have enough influence over finances and systems, therefore restricting the service user’s chances of receiving a suitable chair.....
Student	Technology is often available but not made accessible to users because of financial constraints to limit disappoint/frustration [to users].

Questionnaires were handed out in person with an explanation of what was required and why the information was required to the following groups of stakeholders:

- Academic; university or hospital teaching/research.
- Researcher; university or hospital research.
- Student; university or hospital student on relevant nursing/caring/medical course.
- User; those using powered wheelchairs and other devices.
- Prescriber; occupational therapist/other who directly prescribes PWCs/assistive technology.
- Clinician; hospital medics whose patients use PWCs and other devices.
- Carer; person who is involved in the daily care of users.
- Policymaker; someone who has political decision making in hospitals/governing bodies.

Participants were asked to indicate with which stakeholder group in the assistive technology field they were most strongly affiliated. More than a hundred forms were issued and seventy-four stakeholders responded.

Based upon the authors' previous experiences it was decided to ask 12 closed questions to provide a quantitative response. These questions were grouped into four blocks such that each block concentrated on a particular theme. The first block of three questions was designed to determine whether stakeholders understood the role that users play in the development and provision of assistive technology. The second block sought to discover if, by changing roles, stakeholders could better understand the issues and problems faced by each other, with the aim of developing more focused and effective solutions, e.g. designers experiencing what it is to be a user. Question block three investigated the stakeholders' opinions on trust in technology and the dependence people have on finding solutions to all problems through technology, and thus whether technology holds the sole answer to solving user needs. The final block attempted to identify the stakeholders' opinions on why so little research reaches the end user in marketable products; whether it is simply money, effective application, knowledge and understanding of the devices, or all three. The questions, together with a description of the reasoning behind them are as follows:

1. *How much should the user be involved in the development of assistive technology?* This question was designed to determine the stakeholder's views on how much the user should be involved in the development of assistive technology. The notion being that too much involvement by too many can end up with technology 'designed-by-committee' over engineered and overpriced and not fully suitable for any purpose.
2. *How much do you feel that other stakeholders in assistive technology provision understand the end user's point of view?* In this question, we were attempting to ascertain the general feeling amongst stakeholders about how they thought their fellow stakeholders really understood the user's perspective rather than their needs.

3. *When issuing, buying, or prescribing assistive technologies how much do you think the user's wishes and desires are taken into account in that process?* This is an important question which seeks to determine the stakeholder's opinion on the degree of user involvement in specifying the assistance they would like to receive; this would possibly be in conflict with other stakeholder's opinions on what is suitable for the end user.
4. *How much do you think Role Reversal Simulation, giving care givers experience of being a care receiver, would help them to better understand and empathise with the care receiver?*
The reasoning behind this question was to investigate the attitude of all stakeholders to putting care givers into the users' role so that they could better understand the need for and use of assistive technologies, this stems from the frequent discarding of equipment [25] and this attempted to discover if some form of role reversal would be acceptable to help with a better understanding of the device and its functionality in assisting users to function more independently.
5. *If the opportunity for simulation by role reversal was extended to all stakeholders how much do you think that this would help them understand and empathise with one another in the process of developing and providing assistive technology?* Following on from the previous question, this one sought to establish whether stakeholders consider that by all stakeholders being involved in the development of assistive technologies by partaking in role reversal they could better understand the problems and generate better solutions.
6. *How willing would you be to volunteer to put yourself in the user's role if workshops were available?* By this we meant stakeholders being restricted as if disabled and having to use the assistive devices to undertake everyday tasks users need to perform; this question was designed to validate the previous two questions.
7. *Do you think users feel more or less isolated from society when using assistive technology?*
During our previous research, powered wheelchair users had reported to us that the carer's visit was often the only contact they had with other people. Therefore, this question sought

to establish the perception of all stakeholders towards the benefit or hindrance that comes with the reliance upon technology.

8. *Do you feel that technology can solve all the disabled user's problems and enable them to have a satisfactory quality of life?* This question seeks to look at the very optimistic view that technology alone can solve end user problems, and specifically asks whether 'all' problems can be solved. We expected to see from the answers a more personal 'hope' from the users, carers, and other clinical stakeholders and a middle of the road practical reality approach from the technology developing stakeholders.
9. *How far advanced do you think academia is with regard to providing solutions to empower disabled users to a level desirable by users?* Completing block three set of questions we were looking to establish how close stakeholders thought advancements in technology were towards providing effective assistive technology. The result of this question would indicate whether there was any link between the promised technology and available products.
10. *Do you think that cost is the driving force which restrains the development and adoption of new assistive technologies?* Financial constraints are often the root cause for the failure of technologies to be brought to market. However, in the case of the powered wheelchair, having reviewed the literature, the problems seem to be far more complex than are readily apparent. This question hopes to clarify stakeholders' opinions on the issue of whether cost is an issue, the wording being carefully chosen to imply the cost of the end product rather than front end costs such as research.
11. *How important is the need to measure the improvements in the quality of life assistive technology provides?* Previous projects we had undertaken had uncovered a major issue with regard to providing users with suitable technology. This was user empowerment; to use technology to improve their lives rather than burden them or to make them feel negative about their lack of ability. Therefore, this question will establish just how important

stakeholders thought the measurement of improving quality of life was with when developing assistive technology which would then be more likely to reach the end-user.

12. *Should training and coaching for all stakeholders be an important part of the technology development and usage cycle?* It was expected this question would be very highly rated, particularly after encountering this issue in previous projects. It had been reported that technology was often left unused because of the lack of understanding of the user/care in how to operate the equipment, and the absence of technical support.

The final section of the questionnaire provided a comment box to gather open opinions where strongly held views might be expressed that would add qualitative semantic context to the quantitative responses.

Ethical approval

This research was subject to the University of Kent's standard ethical review process for projects involving human participation, and met all of its requirements.

Data analysis

Due to the consideration that the data is nonparametric in behaviour, Pearson's Correlation which measures the linear correlation between two variables [26], and Spearman's Rho gives a measure of nonparametric rank correlation [27], and Wilcoxon Signed-Rank Test [28] employed for analysing matched-pair data based upon difference; were used to test for consistent differences/similarities in agreement between stakeholder groups, whilst we utilised Fleiss's kappa [29] to determine the overall rater reliability within each of the stakeholder groups.

Median, range, mean and standard deviations for each stakeholder group for each question block were compared for data evaluation then presented raw as box plots with the outliers marked as a stand-alone red asterisk, the upper and lower (if data falls outside the central rectangular box)

dotted line ending with a 'T' represents the range of data not considered outliers to a maximum of 3/2 times the height of the central rectangular box. The central box contains data within the range of the 25% and 75% quartiles and the mean of the data range is represented by the solid thick red horizontal line within the central box.

Results

Fleiss's Kappa:

Despite some groups of stakeholders having a relatively low number of participants the result of the Fleiss's Kappa test, given in Table 2, indicates that there is a reasonable agreement within each of the groups for all questions, where zero is no agreement and one is complete agreement. The strongest intra-group correlation was the researchers at 0.36, followed by users then policymakers, with clinicians having the least intra-group correlation tending towards zero.

Table 2. Fleiss's Kappa reliability of agreement

Group label	Fleiss Kappa	Number of raters
Academic	0.073	11
Researcher	0.355	5
Student	0.088	10
User	0.149	9
Prescriber	0.2	5
Clinician	0.014	15
Carer	0.099	11
Policymaker	0.107	8

Question 1:

It may be inferred from the mean value of responses in Figure 1 that the responders/raters wrongly took the question to mean the value of the contribution the user can make towards developing assistive technology rather than 'should' the product development be solely concentrated on being steered by the end user. Although one user, one researcher, and one carer clearly understood the question and gave a middle rating indicating that they thought that the development was a process for the involvement of other stakeholders. Therefore the ratings were very densely centred on the maximum value with one clinician declining to answer this question.

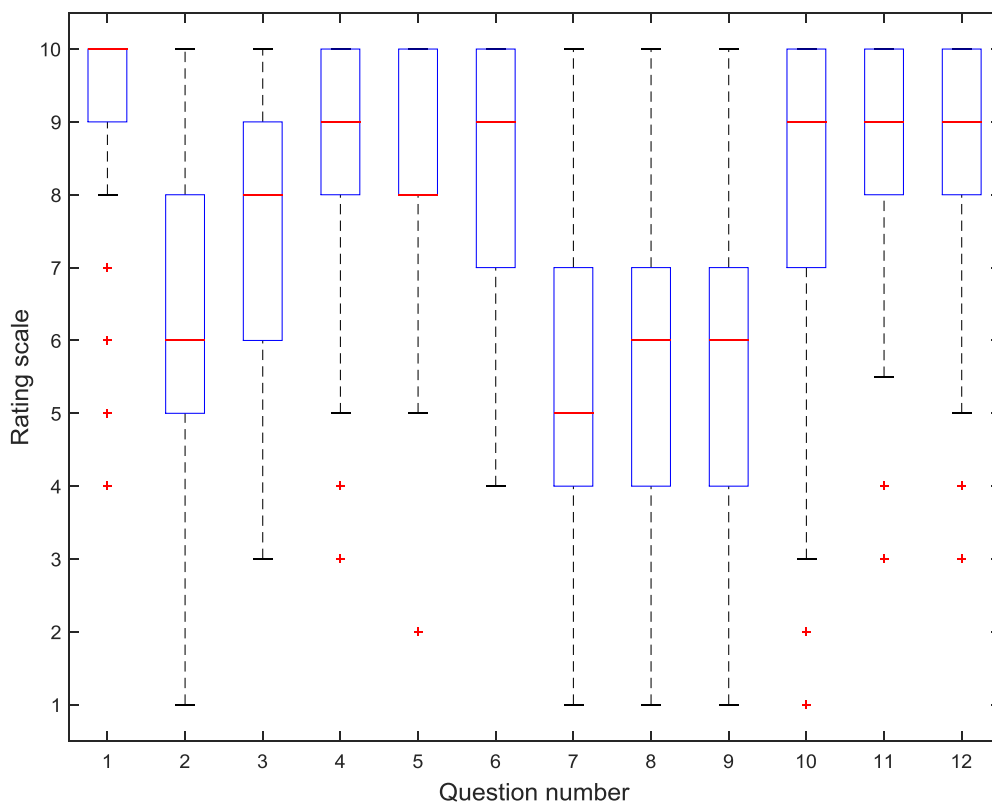


Figure 1. Box plot of ratings for all stakeholders

Question 2:

This question had a very wide range of ratings, the median overall ratings for all groups appears to straddle the middle rating (Figure 2), although the academics (Figure 3), researchers (Figure 4), students (Figure 5), users (Figure 6), and policymakers (Figure 7) were slightly more positive in general than the median for all groups. All stakeholders responded by rating the question.

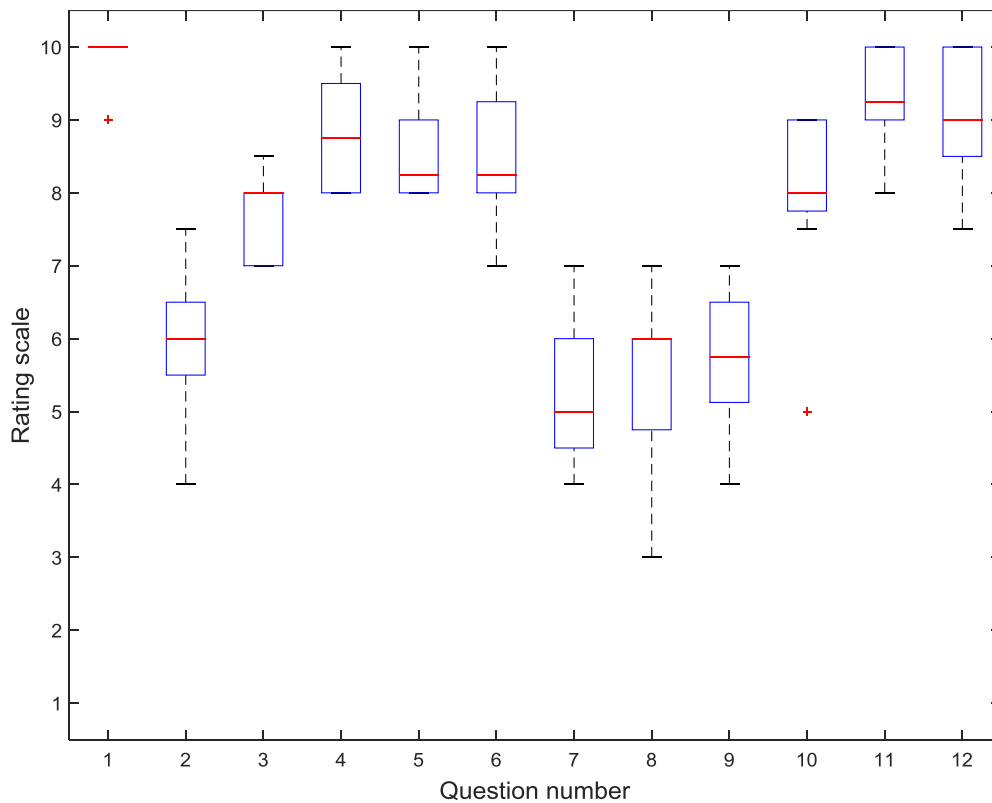


Figure 2. Box plot of mean median rater's rating values for all groups

Question 3:

The prescribers (Figure 8) had a high rating with a low range; the only other stakeholders with similar ratings were the clinical students (Figure 5). All other stakeholders had a very wide range of ratings although generally more positive than question 2, with the all group mean of the medians rating of eight compared to question 2's rating of six. One prescriber failed to rate this question.

Question 4:

The response to this question was for all stakeholders to rate this highly with the mean median rating (Figure 2) just under nine.

Question 5:

The ratings showed that the clinicians, prescribers, and policymakers were rating this question more positively than the remaining stakeholders, particularly users (Figure 6) and carers (Figure 9); this question rated an average median over eight and was closely grouped around that value.

Question 6:

The ratings were a little less compact in the responses to this question but still almost the same overall average median of all groups as were the previous two questions (4 and 5), see Figure 2, making the block of three questions (4-6) results appear correlated. The only question out of the block of three (4-6) which stakeholders failed to answer was this question which was left blank by three users. From one user's comment section it was clear that they not think the question applied to them, although users had been told to simply replace the word user with other stakeholder such as a carer if they were physically able to partake, three users rated the question with a score of ten. The response to this question indicates that the concept of role-reversal to better understand the problems seems to appeal to all stakeholders, however; the meaning/use may need clarification.

Question 7:

The ratings were very wide spread, being based upon stakeholders own experiences. The user group had the widest spread of responses with the clinicians (Figure 10), students, and policymakers having the narrowest. The researchers, users, carers, and students general opinion was that the technology would make users feel less isolated; however the policymakers, followed by the clinicians and then the academics were more sceptical. This was the most unanswered question, two policymakers, one clinician, one user, one student, and four academics left the answer blank.

Question 8:

It was clear from the responses that all of the stakeholders took the question seriously, except one academic and one policymaker who failed to rate. The academics having the most positive rating followed by the younger students, the clinicians, prescribers, and the policymakers were similarly grouped although being generally negative (Figure 7). The answer to this question clearly straddled the midway point with a clear divide between the innovators of new technology and those who need to apply and prescribe the technology to the end user. The question may also need rephrasing.

Question 9:

The students recorded a wholly positive rating in their agreement with the question, followed by the prescribers; in contrast the researchers were wholly negative with their rating of the question. All other stakeholders were scoring around the centre of the range of rating values. One user and one carer chose not to record their answer to the question.

Question 10:

This question seeks to clarify stakeholders' opinions on the issue of whether cost is an issue, the wording being carefully chosen to imply the cost of the end product rather than front end costs such as research. The very high median value of nine for all stakeholders' responses given in Figure 1 indicates a general consensus that end cost is a major issue, although some stakeholders notably the researchers thought otherwise, they were very much spread around the middle of the ratings with their mean at five being slightly negative. The prescribers were the next group to be less sure that cost was the issue having a mean at between seven and eight followed by the user mean at eight. These groups (researchers, users, prescribers) also had a very large spread of ratings compared to all the other groups who were much tightly bound to the upper end of the scale. Only one prescriber failed to respond to this question.

Question 11:

Policymakers and prescribers were closely bound to the upper ratings between eight and ten with a median over nine for both groups. These two were followed very closely by the researchers with a mean of nine and a range of seven to ten. The user group had a mean close to ten with a tight central range between the upper and lower quartiles around the median, although one user rated this category at three, which may indicate that they misunderstood the question or had some other personal reason. The remaining stakeholders all had a much wider spread of ratings although their medians were all above eight in the ratings; this question was answered by all 74 stakeholders.

Question 12:

The results showed the overall stakeholder median rating was the third highest for all questions, and the mean rating for all stakeholders was nine. The academics, researchers, and students had a wider range of ratings with a median generally slightly lower than the other stakeholders. The clinicians, users, and prescribers had high median ratings and were very closely grouped at the more positive end; the policymakers' ratings are closer to the academic ratings, although two policymakers did not answer the question.

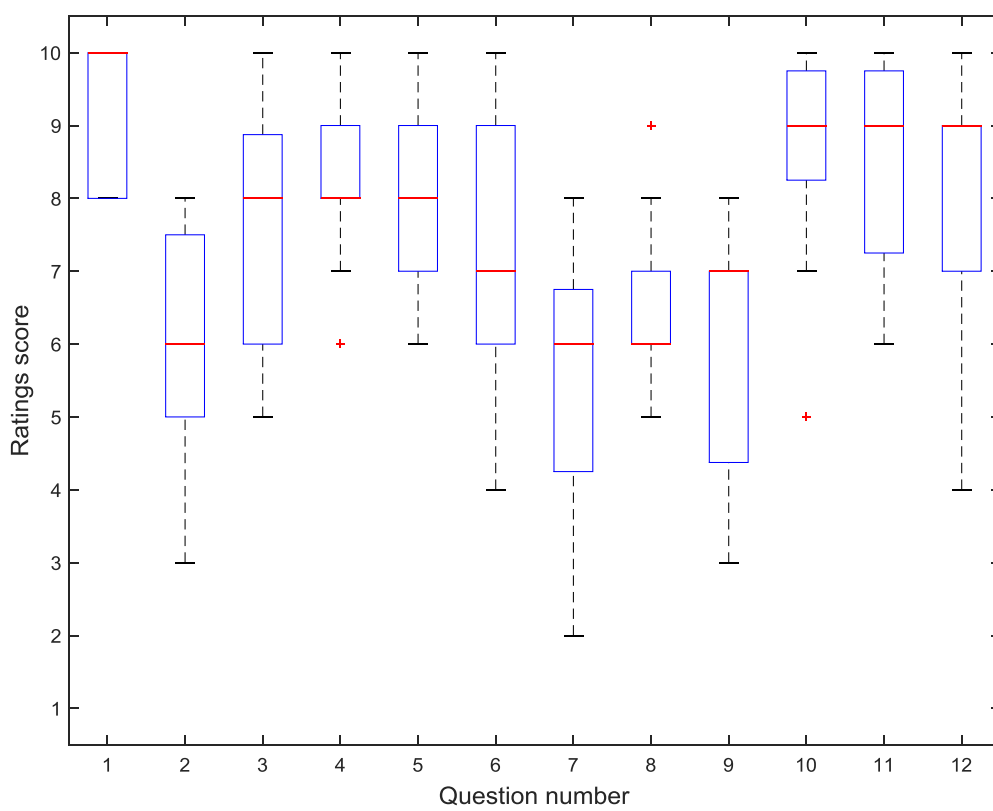


Figure 3. Box plot of academic ratings

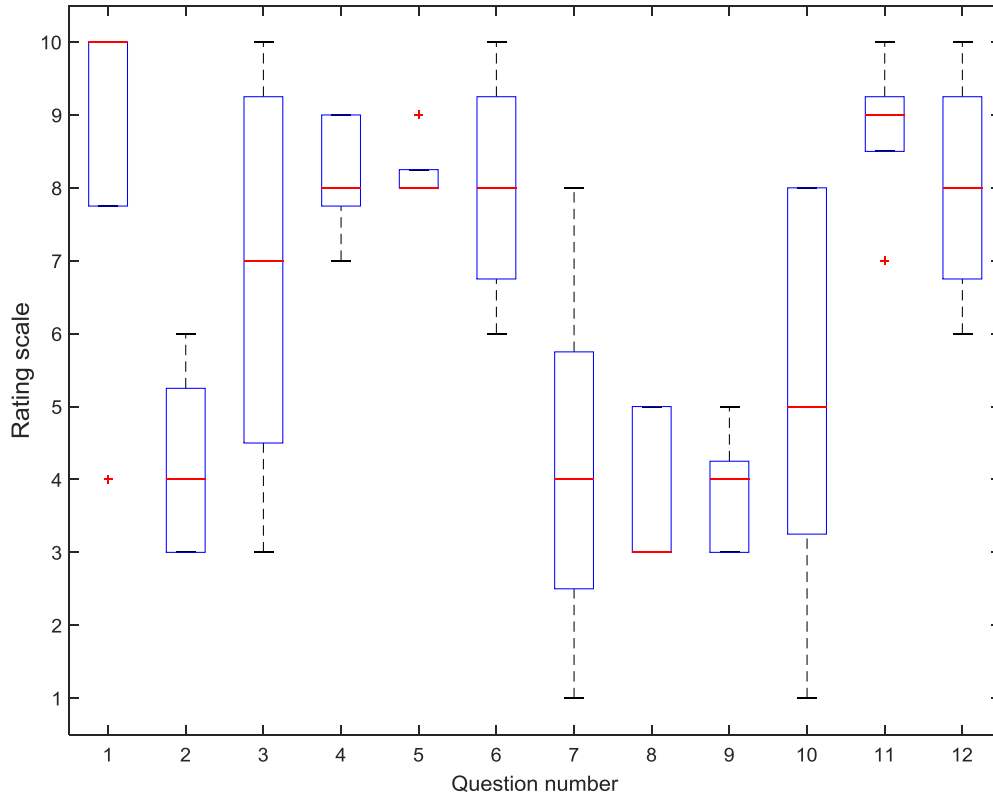


Figure 4. Box plot of researcher ratings

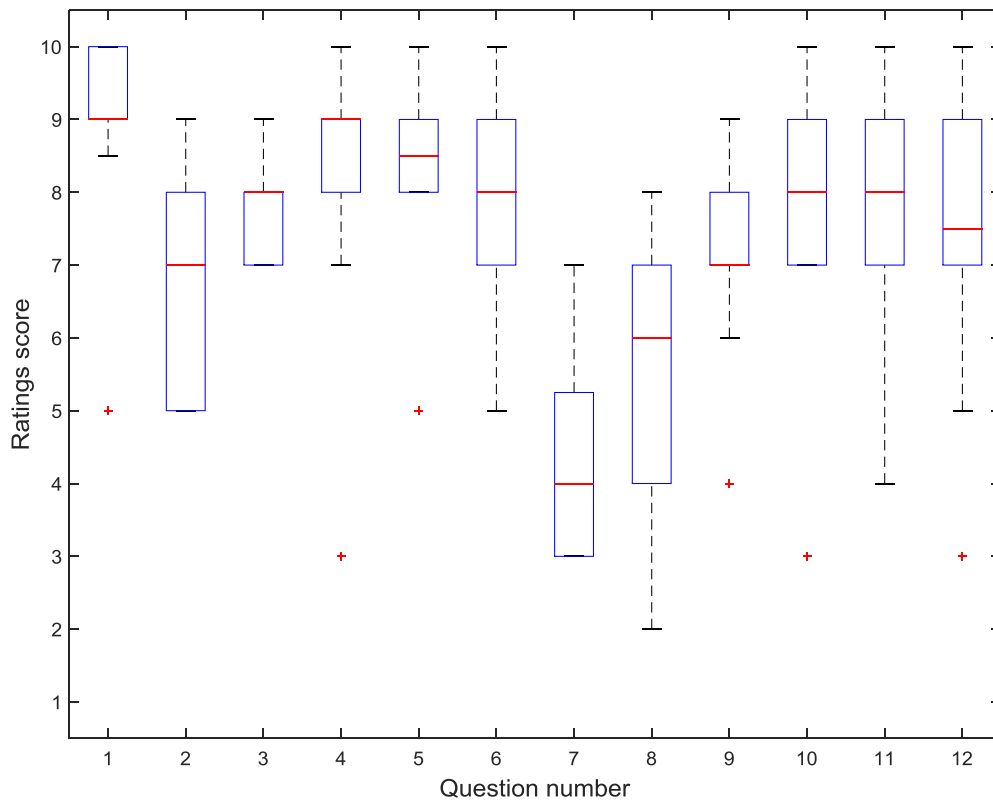


Figure 5. Box plot of clinical student ratings

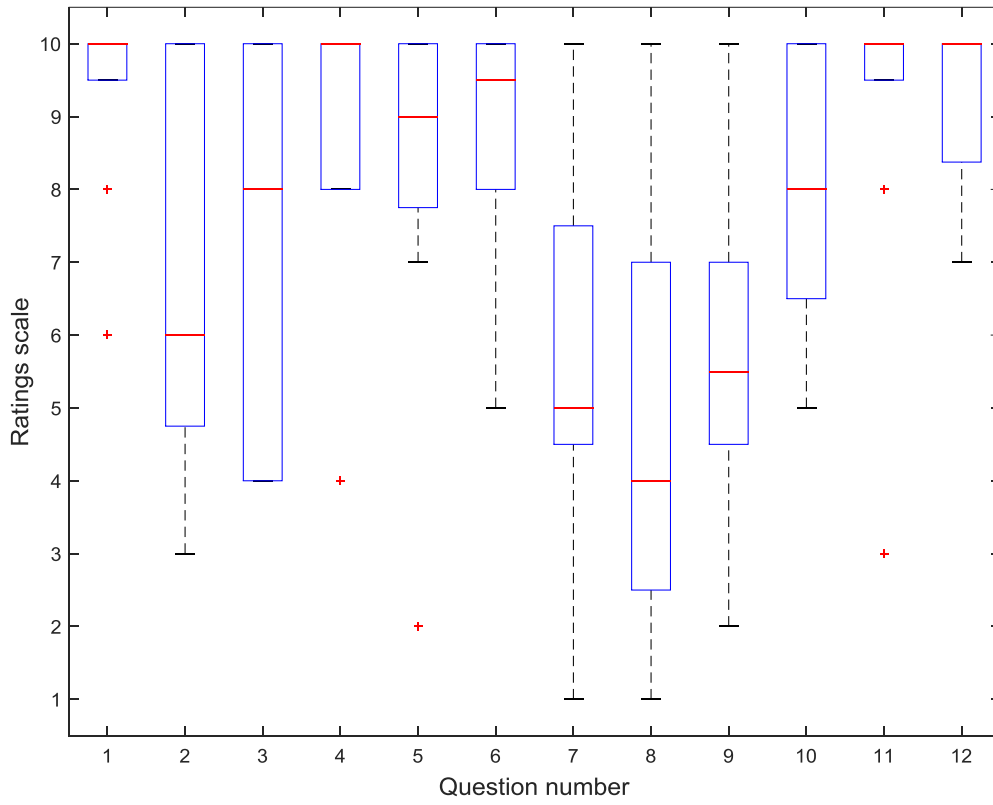


Figure 6. Box plot of user ratings

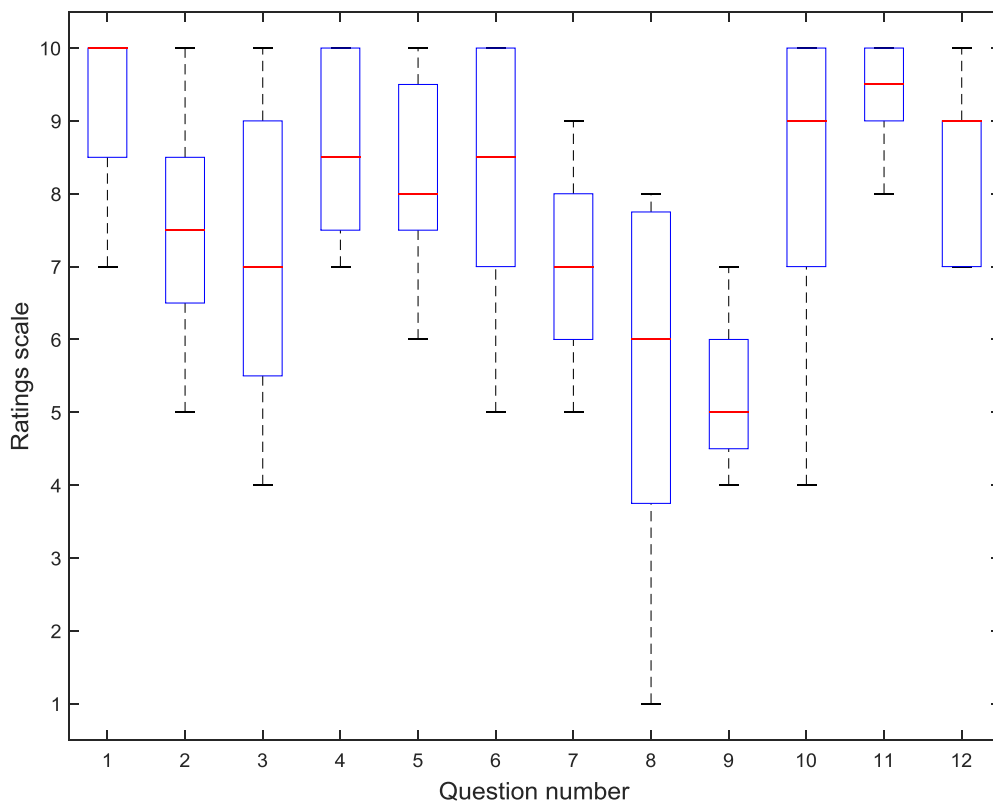


Figure 7 Box plot of policymaker ratings

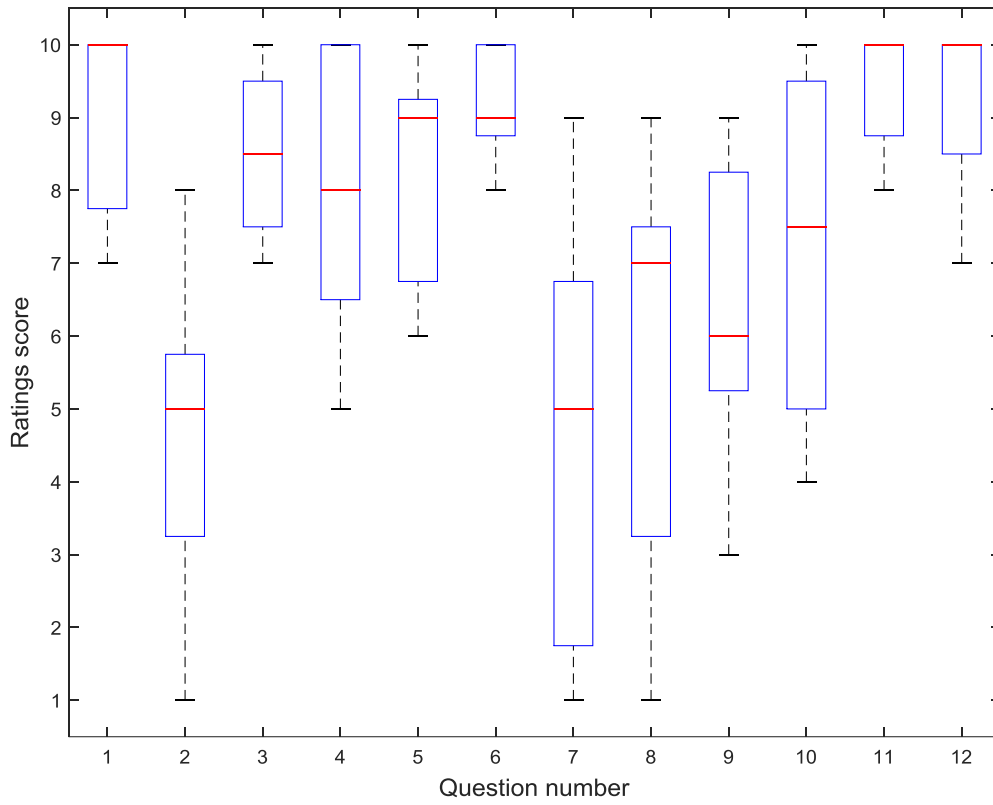


Figure 8. Box plot of prescriber ratings

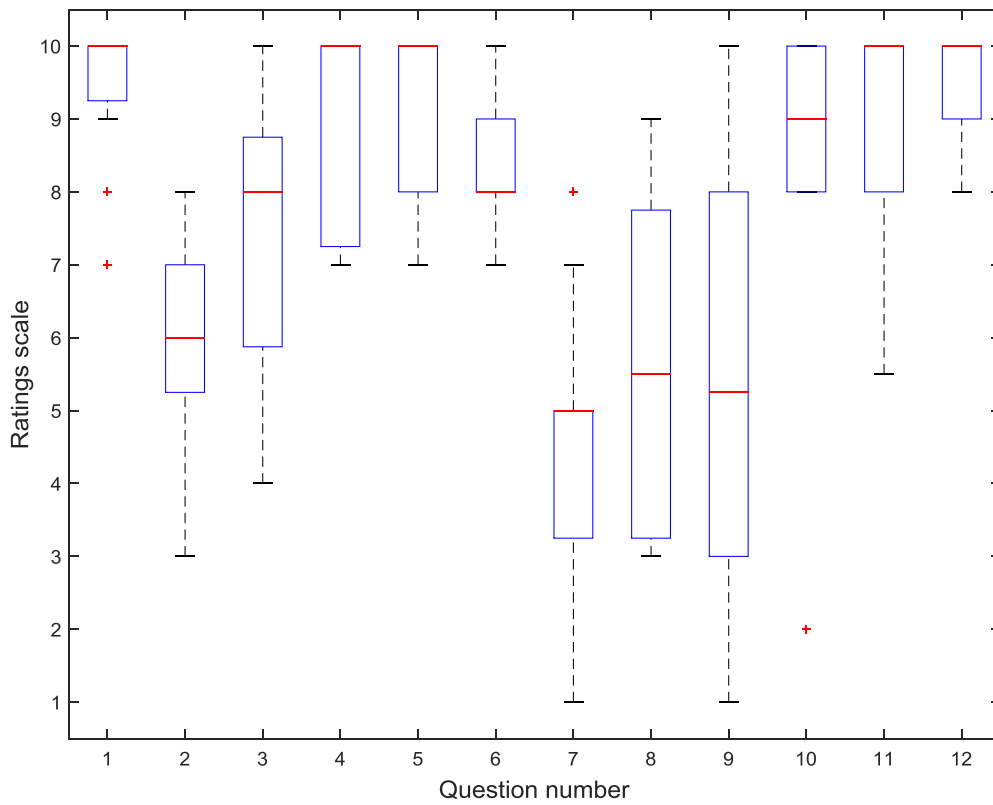


Figure 7. Box plot of carer ratings

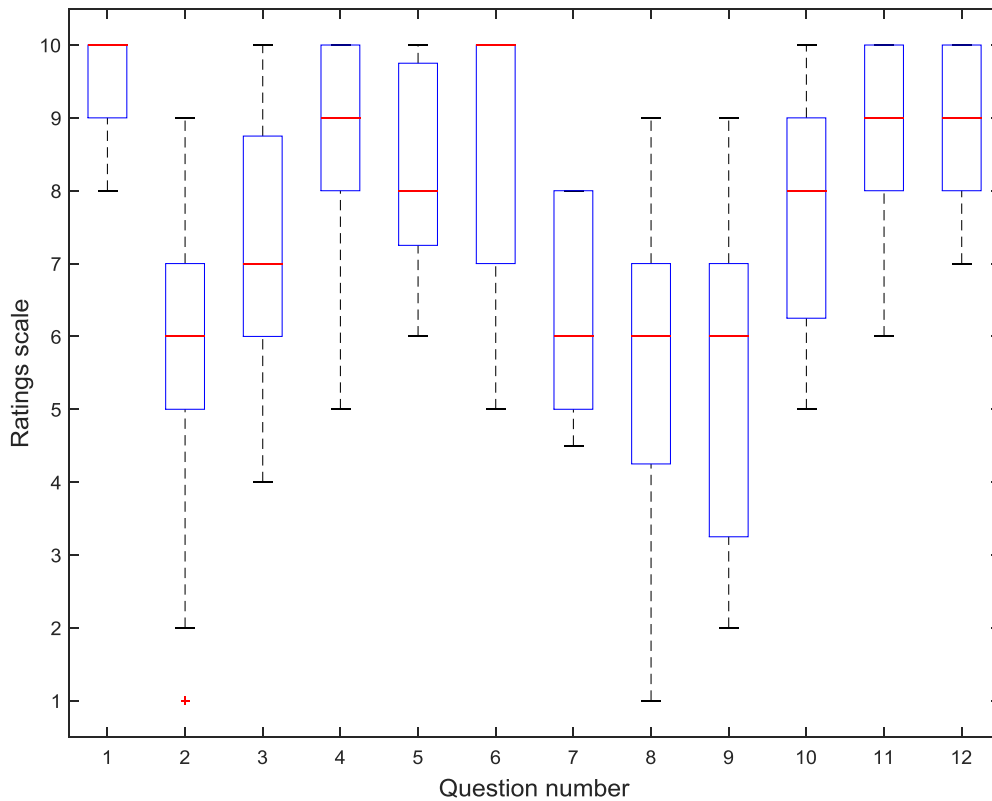


Figure10. Box plot of clinician ratings

Pearson's Correlation:

Academics have better than a 0.81 (Table 3) correlation with users, prescribers, and carers, which demonstrates the general good understanding academics have of the problems faced by the users. The researchers have the closest correlation with the user group at 0.95 followed by clinicians at 0.9, the prescribers 0.89, then the carers 0.88, with the remaining stakeholders all better than a 0.75 correlation. The policymakers clearly have a poor correlation with students at 0.57 and prescribers second worse at 0.7 with a much better correlation between users 0.84, clinicians 0.85, and carers at 0.84. This may however be more of a reflection of the likelihood of the different stakeholder groups meeting each other and interacting.

Table 3. Pearson's Correlation

	Academic	Researcher	Student	User	Prescriber	Clinician	Carer	Policymaker
Academic	1.000	0.782	0.719	0.806	0.808	0.739	0.866	0.761
Researcher	0.782	1.000	0.746	0.946	0.890	0.901	0.882	0.785
Student	0.719	0.746	1.000	0.804	0.705	0.718	0.815	0.573
User	0.806	0.946	0.804	1.000	0.851	0.924	0.940	0.836
Prescriber	0.808	0.890	0.705	0.851	1.000	0.850	0.865	0.699
Clinician	0.739	0.901	0.718	0.924	0.850	1.000	0.842	0.849
Carer	0.866	0.882	0.815	0.940	0.865	0.842	1.000	0.838
Policymaker	0.761	0.785	0.573	0.836	0.699	0.849	0.838	1.000

Spearman's Rho:

According to the results given in Table 4, the group of academics have an agreement correlation rank of ≥ 0.79 with users, researchers, prescribers, carers, and policymakers. Researchers have the highest correlation of agreement with users at 0.94, clinicians 0.91, and prescribers 0.9 and all others greater than 0.79 making them the group with the best statistical fit to all the other groups. The agreement between students and policymakers, and also with prescribers, showed a poor correlation at 0.64 and 0.65 respectively.

Table 4. Spearman's Rho

	Academic	Researcher	Student	User	Prescriber	Clinician	Carer	Policymaker
Academic	1.000	0.798	0.706	0.792	0.805	0.718	0.827	0.829
Researcher	0.798	1.000	0.813	0.943	0.899	0.911	0.870	0.838
Student	0.706	0.813	1.000	0.778	0.650	0.763	0.824	0.643
User	0.792	0.943	0.778	1.000	0.850	0.903	0.909	0.850
Prescriber	0.805	0.899	0.650	0.850	1.000	0.851	0.835	0.753
Clinician	0.718	0.911	0.763	0.903	0.851	1.000	0.779	0.841
Carer	0.827	0.870	0.824	0.909	0.835	0.779	1.000	0.814
Policymaker	0.829	0.838	0.643	0.850	0.753	0.841	0.814	1.000

Wilcoxon Signed-Rank Test:

Researchers have a zero value of 'T' for all stakeholders except students where the value is 10.5 and academics 2 (Table 5). The lower the number in this test, the stronger the correlation between two sets of data; this means that the researchers have a very close statistically significant opinion with all stakeholders except students and academics. The clinicians, clinical students, and carers, seem reasonably correlated with each other having a 'T' value of 12 or 13 between each pairing, the policymakers have a good pairing with clinicians and an even better pairing with academics but a poorer pairing with prescribers and users. Academics have their best pairing with researchers, followed by the clinicians at 7.5, but a worse pairing with the user and prescriber groups. Users have their best pairing with researchers and second best with carers at 5.4 then prescribers.

Table 5. Wilcoxon Signed-Rank Test

	Academic	Researcher	Student	User	Prescriber	Clinician	Carer	Policymaker
Academic		2	14.5	19.5	24	7.5	10.5	10.5
Researcher	2		10.5	0	0	0	0	0
Student	14.5	10.5		18.5	22.5	13	13	21
User	19.5	0	18.5		12	17.5	5.5	31.5
Prescriber	24	0	22.5	12		23	13.5	31.5
Clinician	7.5	0	13	17.5	23		18	12
Carer	10.5	0	13	5.5	13.5	18		23
Policymaker	10.5	0	21	31.5	31.5	12	23	

Discussion

When each group of stakeholders' responses were averaged the range of all the groups when combined had a significant clustering, as shown in Figure 2, despite the wide range of individual ratings within each group shown in Figure 1. This indicates that there is a general trend with the responses to the questions which means we have identified some common ground amongst the stakeholders. Not answering a question could have been due to a respondent's lack of experience in a certain area making them feel unable to give an opinion, lack of understanding of the question or did not feel the question applied to them and so left the question blank.

The response to question one clearly places the concept of user involvement in the process of assistive technology development as being of paramount importance. However from the wide range of ratings to question two, and particularly the common mean trend rating of six (Figure 2), we can

deduce that although individuals may have differing personal experiences that there is a clear lack understanding of the user's point of view, and if we take a similar view on the responses to question three then we can say that the user is not as involved in the entire assistive technology process as much as stakeholders think they should be.

The second block of questions had a distinct objective to determine stakeholder views on the method of role reversal simulation to help them better understand the problems, and whether the concept would be taken up by stakeholders as a methodology. The responses from all raters suggest that the concept is one which would be acceptable, although due to the slightly less enthusiastic response to question six possibly not compulsory.

The responses to the third block of questions (7-9) were wide ranging and the common trend was centred close to the middle rating. Whilst it would be easy to assume that raters misunderstood these questions, or that there was a general middle-of-the-road response, when we examine the inter-group rating ranges there are distinct differences. Question seven asked whether technology would make users feel more or less isolated from society, the responses from the user group closely matched the median range of all the stakeholder groups combined. However there was a distinct split between clinicians and policymakers who thought users would become more isolated and researchers and students who thought that technology would make users less isolated. We surmise that this may be due to age and the younger stakeholders being more comfortable with social media and the wider opportunities for socialising that this brings; conversely older and severely disabled users may not understand or be comfortable using such technology, the professionals being aware of this problem.

Question eight was aimed at determining the simplistic view of whether stakeholders believed technology had all the answers to user's problems. The assumption was that the technologists would have a neutral view around the rating of five to six and for the users, carers and medical professionals to have a higher rating opined that technology can solve 'all' the problems. Although

the technologists were tightly clustered close to centre point as expected, the response from the researcher group was wholly on the negative side of the centre point whereas the academics were wholly on the higher positive side. Most of the other stakeholder groups each had a wide range of ratings, some spanning the whole spectrum of ratings, with their median response at the mid-point. The policymaker median was slightly more positive and the user group median more negative. The responses appear to support our hypothesis suggesting that the problems and solutions might be divided between social and technological and therefore assistive technology development should consider the social impact.

The next question and the last in this third group of questions sought to establish how far advanced different stakeholders thought academia was with progress towards providing solutions to empower users to a level they would desire. The researchers were wholly negative and the students wholly positive with the academics nearly all on the positive side of the centre point. The prescribers were also mainly positive with their median rating of six. All of the other stakeholders were widely ranged but with their medians centred towards the mid-point. The implication here is that academics, prescribers, and the clinical students have a belief that academia is reasonably advanced with regard to providing solutions where in reality, as stated previously, little has been brought to market because of the complex problems which need to be overcome, as the researchers low ratings imply.

Stakeholders mostly rated question 10—does cost restrain the development and adoption of new technology—towards the maximum rating which makes this the second highest rated question after number one. The academics, carers, and policymakers all had a median rating of nine firmly holding the opinion that cost was the driving force. Most other groups had their median rating at either seven or eight with the exception of the researchers who had their median slightly negative at five and their quartile range between three and eight making this group appear to imply that cost was only one factor rather than the driving force, some users, clinicians, prescribers, and policymakers widened their respective group spread of ratings towards the centre point supporting this notion.

The importance of assistive technology improving the quality of life was the basis for question 11 with the users rating median of 10 and the quartile range nine to ten, the researcher's median rating of nine and quartile range eight to nine. Most other stakeholders considered this very important with the quartile upper to lower range for all raters between eight and 10. Therefore all stakeholders accept that quality of life improvement should be a major requirement when developing new technology; however the literature appears to lack this consideration.

Finally question 12 asks whether training and coaching for all stakeholders should be part of the assistive technology development cycle. The responses from all stakeholders was to rate this question towards the maximum value, although not quite as highly as question 11. We postulate that this response is because stakeholder opinions would be based upon their experience of many technological devices failing to function satisfactorily, too complicated to understand, or not suitable for the application and the idea of having all stakeholders involved in the development with the technology explained to them as it progresses whilst also providing ongoing support for them during the usage cycle is thus appealing. Solving the problems posed in this last group of three questions we believe would improve the very negative responses to the third group of questions particularly number eight.

When we analyse the inter-group correlations we might expect that academics would have a close pairing with their researchers and also a good pairing with clinicians, particularly as medical research projects involve collaboration between academics and clinicians. We would also expect academics not to frequently meet users as their researchers would be an intermediary; furthermore they would very infrequently meet prescribers and therefore share even less in common with this group. Researchers have the closest pairing to all groups, which we would expect to be the case, as they are working and communicating with all stakeholders and knowledgeable within the art in a specialised way. Policymakers, academics, clinicians, and researchers are also likely to meet and discuss research projects, particularly in light of funding applications; therefore the pairings shown in this

test are closer between these groups. The policymakers probably have little chance to meet users, carers, and students hence the worse pairings are with these groups. Despite small differences, in general this test has also confirmed that all stakeholders appear to have a reasonably good common understanding of the challenges underlying the questions in the questionnaire.

Conclusions

From this research it is clear that for assistive technologies to be effectively deployed they must, in addition to being suitable for the end user's needs, be supported by providing:

- Specific role reversal or immersion into other stakeholder environments during training to use the technology for prescribers and carers, and in general for all stakeholders when the technology is first being developed in order to better understand the problems.
- Feedback from the user about, and ongoing monitoring of, their quality of life when using the technology, to all other stakeholders, and in particular technicians and clinicians.
- Ongoing training (re-training) and technical support should be readily available to users and other stakeholders to ensure the devices do not become discarded or damaged and remain fit for the purpose they were designed.
- Better social and professional interaction should take place between stakeholders to share knowledge and exchange experiences rather than remain isolated in their respective groups.
- A consideration for funders must be the need for the involvement of all the stakeholders in assistive technology research together with a strong industrial partnership if these devices are to reach the end user.

Furthermore, we conclude that any methodology for improving the uptake of technology into the market place and onto the end user should involve the following:

- engaging assistive technology users, and all other stakeholders, in regular discussion to determine the problems that require solutions, and also iteratively evaluate these solutions during development phases of the equipment;
- establish if there is a grouping of many user problems which can be solved by one type of adaptable and adjustable device;
- determine the number of users and undertake a typical marketable device cost-benefit analysis with involvement of the manufacturer;
- obtain public funding with a manufacturer in partnership to undertake the research;
- involve all stakeholders in the development and evaluation of the device.

Finally, we concluded that the device should:

- decrease user isolation;
- be capable of being monitored for determination of the improvement in the quality of life;
- have ample technical support and training;
- be cost effective;
- be adjustable and adaptable to a wide range of users;
- be easily operated by anyone;
- have a suitably adjustable and adaptable interface if necessary.

Disclosure statement

The authors report no declarations of interest.

Acknowledgements

The work has been supported by the Wellcome foundation trust under Pathfinder Award 109739/Z/15/Z entitled *A synergetic adaptive non-intrusive-navigation assistance system empowering the disabled, elderly and infirm powered wheelchair user'* (SANAS).

References

1. Assistive technology: definition and safe use. Accessed 22 June 2017. Available from: <https://www.gov.uk/government/publications/assistive-technology-definition-and-safe-use/assistive-technology-definition-and-safe-use>
2. WHO | Ageing and Health Technical Report Vol.5 Published 2004. Available from: http://www.who.int/kobe_centre/publications/Ageing_Tech_Report_5/en/
3. Sanford, JA. Universal design as a rehabilitation strategy: Design for the ages. Springer Publishing Company 2012. Accessed 22 June 2017. Available from: <http://www.springerpub.com/universal-design-as-a-rehabilitation-strategy.html>
4. Disability facts and figures [Internet]. Accessed 22 June 2017. Available from: <http://odi.dwp.gov.uk/disability-statistics-and-research/disability-facts-and-figures.php>
5. Simpson RC. Smart wheelchairs: A literature review. *Journal of rehabilitation research & development*. 2005;42(4)
6. Faria BM, Reis LP, Lau N. A Survey on Intelligent Wheelchair Prototypes and Simulators In: *New Perspectives in Information Systems and Technologies, Volume 1*. Springer; 2014; p. 545-57.
7. Bourhis G, Sahnoun M. Assisted control mode for a smart wheelchair. In: *Rehabilitation Robotics, 2007. ICORR 2007. IEEE 10th International Conference on; 2007IEEE; 2007*. p. 158-63.
8. Garcia JC, Marron M, Ureña J, Gualda D. Intelligent wheelchairs: Filling the gap between labs and people. *Assistive Technology: From Research to Practice: AAATE 2013*. 2013; 33:202.
9. Parikh SP, Grassi V, Kumar V, Okamoto J. Integrating human inputs with autonomous behaviors on an intelligent wheelchair platform. *Intelligent Systems, IEEE*. 2007; 22(2):33-41.
10. Zeng Q, Teo CL, Rebsamen B, Burdet E. A collaborative wheelchair system. *Neural Systems and Rehabilitation Engineering, IEEE Transactions on*. 2008; 16(2):161-70.
11. Montesano L, Díaz M, Bhaskar S, Minguez J. Towards an intelligent wheelchair system for users with cerebral palsy. *Neural Systems and Rehabilitation Engineering, IEEE Transactions on*. 2010; 18(2):193-202.
12. Braga RA, Petry M, Moreira AP, Reis LP. Concept and design of the intellwheels platform for developing intelligent wheelchairs In: *Informatics in control, automation and robotics*. Springer; 2009; p. 191-203.
13. Carlson T, Demiris Y. Collaborative control in human wheelchair interaction reduces the need for dexterity in precise manoeuvres. In: *ACM/IEEE HRI-08 Workshop on Robotic Helpers; 2008; Amsterdam, The Netherlands*. 2008. p. 59-66.
14. Braga RA, Petry M, Reis LP, Moreira AP. IntellWheels: Modular development platform for intelligent wheelchairs. *J Rehabil Res Dev*. 2011; 48(9):1061-76.
15. Garcia JC, Marron M, Ureña J, Gualda D. Intelligent wheelchairs: Filling the gap between labs and people. *Assistive Technology: From Research to Practice: AAATE 2013*. 2013; 33:202.

16. Yanco H. Evaluating the performance of assistive robotic systems. NIST SPECIAL PUBLICATION SP. 2002:21-5.
17. Nisbet P, Who's intelligent? Wheelchair, driver or both? In: Proceedings of the 2002 IEEE International Conference on Control Applications; 2002; Glasgow, Scotland. 2002
18. Smile Smart Wheelchairs <https://smilemart-tech.com>
19. Kokosy A, Floquet T, Hu H, Pepper M, Sakel M, Donzé C. SYSIASS—an intelligent powered wheelchair. In: International Conference on Systems and Computer Science (ICSCS) 2012
20. Ragot N, Caron G, Sakel M, Sirlantzis K. Coalas: A eu multidisciplinary research project for assistive robotics neuro-rehabilitation. In: IEEE/RSJ IROS Workshop on Rehabilitation and Assistive Robotics: Bridging the Gap Between Clinicians and Roboticians, Chicago, USA; 2014
21. Empowering Disabled People through Ethics in Care and Technology (EDECT). Available from: <http://edect.weebly.com>
22. Naidex. <http://www.naidex.co.uk>.
23. Independent Living Scotland 2016. <http://www.independentlivingscotland.org>
24. Scherer MJ, Sax C, Vanbiervliet A, Cushman LA, Scherer JV. Predictors of assistive technology use: The importance of personal and psychosocial factors. *Disabil Rehabil* [Internet]. 2005; 27(21):1321-31.
25. DeLong ER, DeLong DM, Clarke-Pearson DL. Comparing the areas under two or more correlated receiver operating characteristic curves: A nonparametric approach. *Biometrics* 1988: 837-45.
26. Conover WJ, Iman RL. Rank transformations as a bridge between parametric and nonparametric statistics. *The American Statistician* 1981; 35(3):124-9.
27. Woolson R. Wilcoxon Signed-Rank test. *Wiley encyclopaedia of clinical trials*. 2008
28. Fleiss JL, Cohen J. The equivalence of weighted kappa and the intra-class correlation coefficient as measures of reliability. *Educational and psychological measurement* 1973; 33(3):613-9.