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RESEARCH ARTICLE

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Enabling by voice: an exploratory study on how interactive smart agents (ISAs) can change the design of environmental control (EC) equipment and service

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ABSTRACT

Aim: Well-designed assistive devices improve the quality of life of individuals with severe and permanent impairments and reduce the burden on their caregivers. This study investigated whether interactive smart agents (ISAs) are effective in supporting individuals who are affected by neurological conditions causing severe mobility issues, and the factors aiding ISAs' adoption.

Materials and Methods: The North Thames Regional Environmental Control Equipment Services (NTRECES) supported this study by recruiting service users (people with severe mobility impairments due to neurological ailments) in the study. Health Research Authority approval was obtained (255096). NTRECES prescribes medical-grade environmental control (EC) devices, unlike smart speakers (ISAs). Research on ISA adoption by NTRECES users could support prescribing ISAs as assistive EC devices in the future. Through secondary research and exploratory primary data, this user-centred study developed an initial technology adoption model, subsequently revised in light of the insights from a multi-point qualitative primary research.

Conclusion: This research uncovered that novelty, ease of voice interaction and its entertainment value play a key role in the adoption decision. Willingness to overlook reliability, privacy and security attributes was identified, providing that the service users had back-up devices for security and privacy critical tasks. The originality of this work consists in the development of a technology adoption model tailored to consider the characteristics of service users with severe physical disabilities and the attributes of ISAs technology. The research contributes to the discussion on contextual factors and technology design features that may improve the inclusivity of ISAs and their use as medical devices.

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KEYWORDS
Assistive technologies; interactive smart agents; technology adoption; user-centred design

> IMPLICATIONS FOR REHABILITATION

This manuscript represents original research conducted in the field of design focusing on User Centred Design in Assistive Technology. We believe that our findings significantly contribute to the understanding of Human Behaviour and Assistive Technology Adoption, which aligns closely with the scope and interests of your esteemed journal.

1. Interactive smart agents (ISAs) like Alexa can be integrated with assistive technologies to support individuals with disabilities. For example, ISA devices can help those with mobility impairments control their environment or access information hands-free.
2. Our study employs qualitative methods to investigate adoption of voice based smart agents as assistive technology devices. Through rigorous thematic analysis, we have proposed a new assistive technology adoption model based on theory of planned behaviour (TPB).
3. The new model provides valuable insights for designers and manufacturers to tailor ISA devices to better meet the needs of users with severe mobility impairments. This can result in the improvement in their quality of life, less reliance on caregivers and increased independence. In addition to that, new venues of employability and entertainment can also be explored.
4. The key constructs influencing behavioural intention include Attitude, perceived behavioural controls (PBCs), subjective norms (SNs) and a novel addition, voice Interaction experience. Various factors such as voluntariness, openness to innovation, disposable income, disability, familiarity with technology, technical

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support, trust in advice, among others, influence these constructs. The modified model integrates emerging themes from data analysis, including the addition of disability as a factor and modifications to existing factors like income. The research extends TPB by including voice interaction experience as a significant factor in behavioural intention. Additional factors affecting users' attitude, perceived controls, norms, and voice interaction experience are identified and incorporated into the model, enhancing its comprehensiveness. Certain factors previously identified in technology adoption theories may not hold the same influence in this context, while others remain consistent or are adapted to suit the specific needs of users with severe mobility impairments.

We believe that these contributions are particularly relevant and valuable to the readership of "Disability and Rehabilitation: Assistive Technology".

Introduction

People with neurological ailments suffer from severe mobility impairments. The National Health Service (NHS) *via* the Regional Environmental Control Equipment Service (RECES) provides assistive technology and maintenance to enable the level of independence that can be afforded. Common technology that RECES service users receive are EC devices. EC devices enable the performance of daily tasks such as controlling the TV, turning on/off lights or air conditioning. The most common interface that enables the control of EC devices is called a switch (Figure 1) that enables option selection from a menu *via* a single button.

The interface can also be operated by eye movement, head pointer (Figure 2) or by a suck and puff device that user controls with their breathing (Figure 3).

With the progression of neurological conditions, such as multiple sclerosis, and in the case of severe spinal cord injuries, patient's movement is extremely limited, and the control of EC devices becomes increasingly difficult [1].

Since 2017 Interactive Smart Agents (ISAs), also known as smart speakers, have become widely available on the market at modest retail prices. ISAs continuously listen to their surroundings for the "wake-up word" which initiates the recording of the user voice command. The voice command is transmitted *via* the internet and processed remotely leading to a response to the users. ISAs can search for information online and can also operate other devices that are connected through Wi-Fi. Through effective and rapid training ISAs learn to process commands in natural language making the interaction frictionless. Users with severe mobility or affected by deteriorating neurological conditions do not find it problematic to

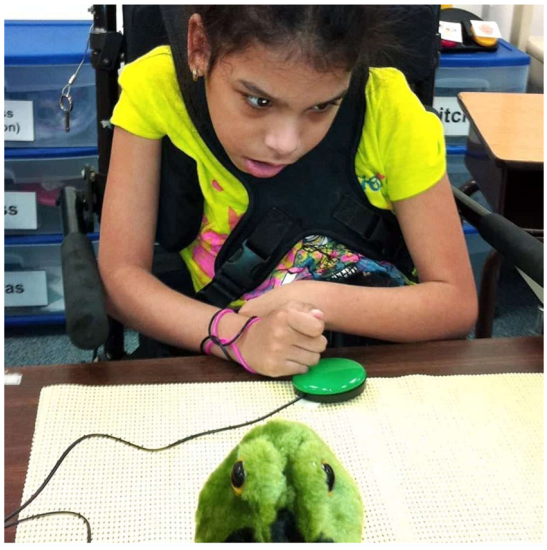

Figure 1. Switch or buddy button, operated *via* click of the button (https://www.smilesmart-tech.com/product/buddy-button/).

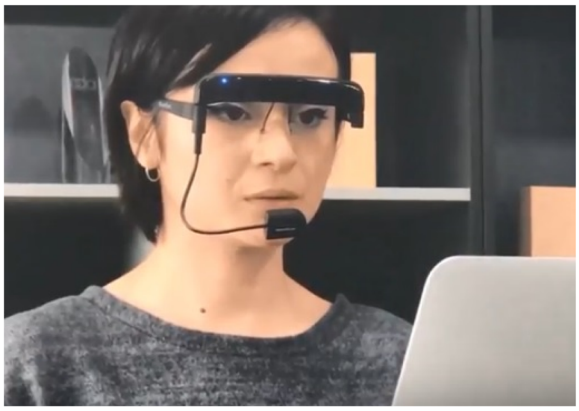

Figure 2. Head mouse, controlling the mouse by head movement. (https://www.assistivetechnologyservices.com/headmouse.html).

Figure 3. Integra mouse, operated *via* suck and puff (https://www.mkprosopsis.com/hardware/IntegraMouse.htm).

use their voice, and this makes ISAs a more suitable alternative to EC devices that are cumbersome to use or unfeasible due to patient deterioration.

The literature on the use of ISAs as assistive technology is rather limited [2] studied the use of ISAs in care home settings where they were found to be an effective means of support to the residents due to their simple installation and low cost [3] examined the use of ISAs among visually impaired people who preferred the voice interaction allowing the control of multiple devices with a single control [4] found that the ease of use and utility of ISAs made ageing users with co-morbidities feel more productive and independent. Moreover, this study identified that users' characteristics such as age, technical skills, perceived privacy and overall health status, were relevant in the adoption of ISAs [5] investigated technology adoption in older adults with visual disabilities and concluded that factors such as usability, safety and accessibility have a key role in the adoption of assistive technology. Smith et al. [6] identified how smart speakers can be used to enhance the life quality of people with intellectual disabilities, highlighting themes such as (1) social value, (2) entertainment, (3) perceived agency, (4) challenges, perseverance, training/support needs playing a vital part. Esquivel et al. [7] provide a comprehensive discussion of how people with impairments can use voice assistance technologies to live independently and participate in the community. This study provides a solid foundation in pointing out the barriers like cognitive load and privacy concerns, which play a part in the usage and adoption of smart speakers.

In order to understand what other factors can affect technology adoption especially within users with disabilities, similar literature was explored. For example, a recent study by Kim et al. [8] presents a modification of the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2). This study points out that there are additional factors, such as social influence, performance expectancy, facilitating conditions and hedonic motivation, to consider when in the adoption of technology by users with disabilities. This research is set to further explore the factors that affect the adoption of an emerging technology, ISAs,

that due to their natural voice-based interface, may represent an innovative, intuitive and cost-effective alternative to current ECs.

In the next section, the article contextualises the services provided by RECES by describing the RECES unit in West London (UK), involved in this research, its jurisdiction and the technology normally prescribed to its service users. In the Methods and Tools section, the research design is justified. Following, a model of adoption for ISAs devices as assistive technology is presented together with emerging themes that the qualitative study revealed. The discussion frames the findings within the current literature, and in the conclusion, highlight lessons learned, and direction for future work.

The Regional Environmental control Equipment service in North-West London

NTRECES is part of a nationwide NHS-based service, RECES. It is based at Hillingdon Hospital and serves the north-west London region. It has around 834 service users who are affected by some 22 different conditions [9]. The NTRECES is headed by a service manager, and the team comprises of 3 occupational therapists (OTs) who assess the service users and monitor their use of ECs, 2 support engineers who install and maintain the ECs and provide technical support, and management and administrative staff who book assessments and monitor appointments, keep track of finances, and maintain patients' records. Service users are normally assessed at home, soon after hospital discharge, or when referred by their General Practitioner (GP), or OT, and sometimes they are assessed in the rehabilitation ward when they have been readmitted following worsening symptoms. The assessment normally consists of a home visit where a demo of available ECs is carried out by one of the OTs or engineers. The type of EC device issued depends upon the characteristics of the service users, e.g., their health, their surroundings, and the degree of control they wish to exercise with the EC, e.g., communication requirements, front door control, and other peripherals. The outcome of each assessment is the prescription of an EC device. After approval, an engineer carries out the installation and illustrates to the patient how to use the device. The EC device manufacturers provide technical support in case of malfunctioning. A review meeting 2 weeks after the installation assesses whether changes are required. An annual review is the standard process for existing service users. On an average NTRECES spends approximately £4000–£7000 per service user [9].

Traditional EC devices are medical devices approved by the UK and the European Medical Device Regulation (MDR). The approval process makes sure that the ECs meet all regulatory requirements related to product safety and performance. On the other hand, ISAs do not hold a medical device status and, moreover, are internet-based technology with inherent risks related to privacy, confidentiality and service reliability. Whilst they offer users a more natural interaction that saves time and does not require additional input devices, like the Switch, they pose concerns that need further investigation.

Objectives

This research aims to complement and consolidate a model of technology adoption of ISAs by service users with severe disabilities, specifically:

- Improve the understanding of technology adoption of mainstream technology as assistive devices.
- Support decision-makers in assessing the potential benefits of prescribing ISAs instead of traditional ECs.

Methods and tools

The study applied deductive and inductive reasoning in the research design strategy. Figure 4 depicts the research design strategy. Exploratory ethnographic research (phase 1) combined with literature review on technology adoption models (phase 2) informed the selection of a blueprint for the adoption model. Further research on factors influencing technology adoption led to identifying research propositions (RPs) that were organised in the initial research model (phase 3). A qualitative study including primary data collected *via* semi-structured interviews (phase 4) enabled the review of the

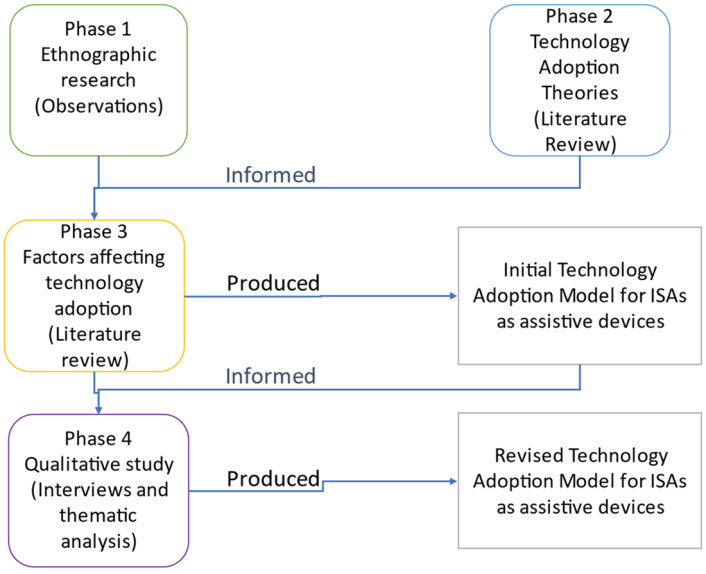

Figure 4. Research design.

initial research model of technology adoption. A similar methodology has been followed by Yang et al. [10], however, the final validation of the model in the said study was done *via* quantitative research methods.

Ethics

Due to the nature of the research and the involvement of NHS staff and patients, the research team sought approval by the Research Ethics Committee (REC) of the Health Research Agency *via* the Integrated Research Application System (IRAS). The application was approved with the following protocol details: Project ID: 255096 REC Reference: 19/LO/1905).

Phase 1: Initial ethnographic observations

An initial ethnographic study took place to explore the user assessment with a particular attention to the service as experienced by NTRECES staff and service users. To avoid any interference with the service provision a non-participant observation protocol was selected. Prior to the observation and in line with ethnographic methods [11], the researchers familiarised with the NTRECES team, place of work and the service user assessment process, specifically the assessment form and the service user referral, which include details of the individual's health and care arrangements over a course of 1 year. Researchers attended services users' visits at the rehabilitation ward and at their place of residence during the year. The observations revealed a growing interest in ISA devices among service users who, being accustomed to control their smart phone through voice interface, pressed for similar control interfaces instead of the prescribed ECs. The exploratory study guided the literature review on the factors that may influence technology adoption and contributed to define the RPs (phase 3). The ethnographic study was also essential in familiarising the researchers with the context of NTRECES service provision, the type of prescribed ECs, the neurological conditions suffered by service users, and their impact on everyday life. An understanding of these notions enabled the researchers to have more effective exchange with the participants during the interviews (phase 4).

Phase 2: Review of technology adoption theories

The field of technology adoption is crowded by several theories, such as the Matching Person and Technology (MPT) model [12], the technology acceptance model (TAM) [13], and the UTAUT [14]. These

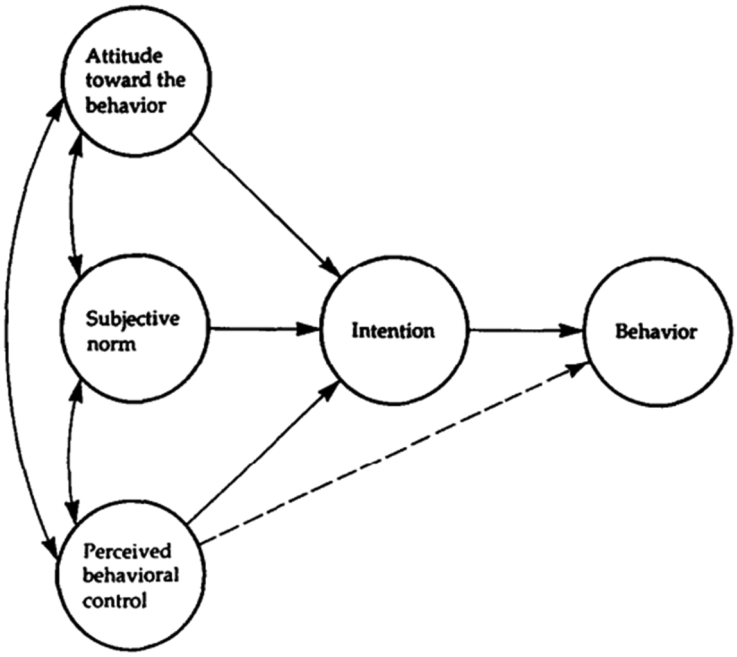

Figure 5. Theory of planned behaviour (3: 182).

theories along with models of human behaviour, e.g., the Theory of Reasoned Action (TRA) [15] and the theory of planned behaviour (TPB) [15] have been used to understand technology adoption.

TPB is centred around the tenet that individual's *Attitude*, *Subjective Norms* (SNs) and perceived behavioural controls (PBCs) influence behavioural intention and that this, in return, affects individual behaviour [15,16]. Figure 5 depicts the key components of TPB whereby Attitude "refers to the degree to which a person has a favourable or unfavourable evaluation or appraisal of the behaviour in question" (3:188), SNs "refers to the perceived social pressure to perform or not to perform the behaviour" (3:188), and lastly, PBCs are considered to "reflect past experience as well as anticipated impediments and obstacles" (3: 188).

Most technology adoption studies applied variations of the TAM or UTAUT theories to understand how emerging technologies are adopted. Given the applicability and relevance of TPB to diverse contexts of human behaviour [16,17], TPB was selected as the blueprint for the adoption model proposed in this study. However, a straightforward application of TPB without considering the uniqueness of ISAs and of the characteristics of the service users with severe disability of this study may have been limiting. In line with other scholarly adaptations of the TPB model [10,18] and technology adoption studies using TAM and UTUAT for emerging technologies [19,20], this research proceeded to investigate how a bespoke model of adoption of technology could be conceived starting with the conceptual framework offered by TPB.

On average one third of all assistive technology get abandoned due to multiple factors that are linked to social acceptance, technology aptitude and performance [12,21]. Previous research [22] has identified that variables contributing to adoption of Voice User Interface (VUI) are the context of use, the type of task to be conducted and the user characteristics. Moreover, as noted by Lopatovska and Williams [23] due to the innovative nature of the technology and the unique interface modality, ISA may be attributed characteristics of anthropomorphism, leading to emotional attachment and recognition, and possibly the assignment of agency.

Some studies have been carried out to understand specifically the adoption and acceptance of ISA devices [24], however, this research has focused on fully able users. On the other hand, some studies can also be found where the use of smart speakers by people with disabilities is investigated, for example Masina et al. [25]. These studies demonstrated that smart speakers are a cost-effective substitute for assistive technologies and have positive impact on the daily lives of people with disabilities.

The extant literature has some contributions to make towards the understanding of technology adoption behaviour by users with disabilities for example [2–5], and remarked that although these new technologies provided an easier way to control the environment or access information, there are specific issues to be considered in the technology adoption and use. These included security and privacy concerns, financial considerations and technical know-how.

Phase 3: Factors affecting technology adoption and initial proposed conceptual model

An in-depth review of factors influencing the adoption of technologies, particularly ISA devices as assistive technology, was carried out in phase 3. This included multiple meeting online and in person within the academic researcher team as well as the clinical team in The Hillingdon Hospital, over a period of 1 year. This enabled to identify a set of RPs that were organised following the macro structure of TPB (Figure 5) in an initial proposed technology adoption model for this research (Figure 6). The factors influencing technology adoption in this initial proposed model are grouped in constructs as followed:

- User Characteristics factors in addition to those identified in the original TPB [15].
- Attitude.
- PBCs.
- SNs.
- An additional set of factors linked to the quality of the interaction with the ISAs and defining the construct of voice interaction experience.

Figure 6 illustrates the main constructs in the model, the functional relationships between constructs, and their directionality. The figure also lists the factors under the construct of User Characteristics. The numbers in parentheses indicate the RPs developed from each relationship and analysed in what follows.

Development of the data collection tools

Phase 4 operationalised the RPs identified in the initial technology adoption model in interview questions (listed in Appendix 1) (Figure 6). The interviews, conducted online due to the pandemic, consisted of three parts:

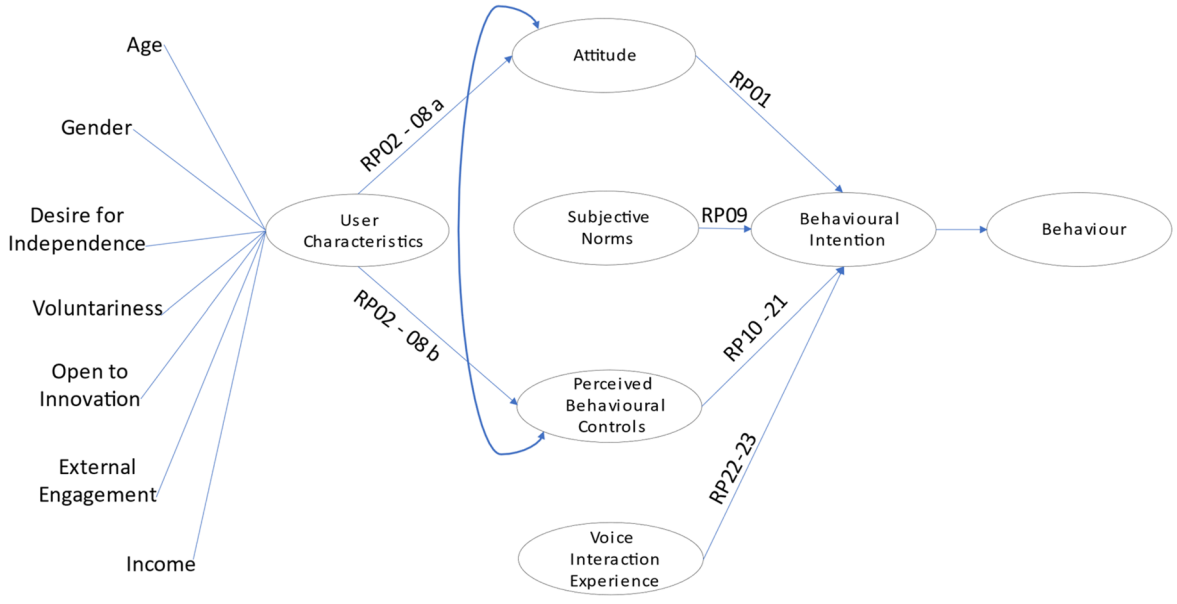

Figure 6. Initial technology adoption model (adapted from [26]) resulting from phase 3 of the research methodology.

- Part 1, an introduction to understand the service user personal experience of the EC devices they used, and health and social circumstances, and the general independence and quality of life.
- Part 2, a set of 68 questions were asked from the participants to evaluate the RPs of the proposed technology adoption model (September–November 2021); Participants were offered to break the interviews in two parts if they felt they were getting tired or needed a break.
- Part 3, an open-ended discussion to gather additional insights and feedback from the participants.
- Part 4, after the interview, the participants reviewed a demo video to demonstrate the functionalities provided by smart speakers. This was accompanied by a short survey to gauge the study participants feedback regarding the different functionalities of ISA devices.

RPs (04–23) were operationalised by at least three questions each. This is because at least three distinct observations for each RP ensured more reliability in the results [27]. An example of how RPs were operationalised in interview questions is reported below:

RP05a: Voluntariness to try a new technology have a positive intention to adopt ISA device.

Interview questions to capture insights on the RP:

1. How did you learn about EC service (NTRECES)? Was it recommended by someone?
2. Can you tell me how the EC service was prescribed for you?
3. How did you feel about the EC device before it was installed in your home?
4. How do you feel about it now?
5. How did you go about learning to use it?

These questions gave an insight into the method of prescription of the EC device to the participant and whether the participant initiated the request of the device or received it after a clinical referral. This information was than compared with their current usage of EC devices to check whether the motivation to procure a device had an effect on the use of the EC device. So, if a participant is motivated to procure an ISA device it might reflect positively on their adoption of ISA devices.

Constructs and specific research propositions

In this section the constructs of the initial adoption are explained alongside the RPs identified within each factor.

Attitude

If a user has a positive attitude towards a certain behaviour or towards adoption of a certain technology, then the user develops a positive intention towards said behaviour [13,15]. Scholars demonstrated that a positive user attitude leads to the adoption of smart speakers [19]. Similarly, here it can be stated that:

(RP) 01: Positive attitude towards ISA devices is associated with the intention to adopt them.

User characteristics

Users' personal characteristics are individual attributes of socio-demographic nature and play a significant part in the uptake or abandonment of technology [12,28]. User characteristics can have a positive or negative impact on attitude. Similarly, they can influence the perceived ease or difficulty of performing the said behaviour, that is the PBCs. However, these constructs cannot influence SNs as they relate to the people and the environment surrounding the users, which cannot be influenced by the characteristics of the user. As seen in UTAUT [14] and UTAUT2 [29]. User characteristics include: age, gender, desire for independence, voluntariness, open to innovation, external engagement and income.

Age

Age has been a very important variable in studying technology adoption. Older adults are generally considered technology laggards, but this is not always the case [30]. During the ethnographic study, it

was observed that age seemed to play a part in the enthusiasm users demonstrated for new technologies. Older users perceived new technologies difficult to use, in part due to lack of familiarisation and due to sensory, motor and cognitive changes affecting the learning process [30]. This may still be valid with people with severe mobility impairments; therefore, it is proposed that:

RP02a: Older age has a negative effect on the attitude towards intention to adopt ISA devices.
RP02b: Older age has a negative effect on PBC.

Gender

According to previous studies, women are less likely to adopt a new technology than men [31]. Moreover, women have less confidence in their abilities to use new technologies [32], consequently affecting their perception of ease in adopting new technologies. Whilst this trend is changing, the proposed model accepts this hypothesis as valid also for ISA and states that:

RP03a: Females have a negative attitude towards the intention to adopt ISA device.
RP03b: Females have a negative effect on PBC.

Desire for independence. According to previous studies [33], one of the characteristics of successful adoption of assistive technology is that the user has a desire for independence. Users who wish to do more through the use of technology to attain independence, have a higher chance of adopting an assistive technology to help them achieve their goals. In this study, it was assumed that desire for independence affect positively the users' attitude to adopt the ISA device. Similarly, a desire for independence will also influence the perceived ease or difficulty in adoption of ISA devices. Moreover, the desire to be independent can motivate the user, hence reducing anticipated difficulties. The following therefore can be said:

RP04a: Desire for independence positively influences attitude towards intention to adopt ISA device.
RP04b: Desire for independence has a positive effect on PBC.

Voluntariness

People who are willing to try new technology tend to have a positive attitude towards it contrary to people on which technology is imposed. According to Agarwal and Prasad [34], voluntariness is a significant factor in users' adoption of technology. In parallel, the user's willingness to adopt a new technology reduces the perceived barriers towards adoption. It is proposed that:

RP05a: Voluntariness to try a new technology have a positive attitude intention to adopt ISA device.
RP05b: Voluntariness to try a new technology have a positive effect on PBC.

Open to innovation. Individuals who are more receptive to new solutions and ideas and want to try new things tend to have a more positive attitude towards technology. This is known as openness to innovation [35]. Users with a higher degree of innovativeness tend to be early adopters of technology [35]. Similarly, users who are more open to new ideas and technology will also perceive the adoption of new technology to be easier.

RP06a: Openness to innovation leads to a positive attitude towards intention to adopt ISA device.
RP06b: Openness to innovation has a positive effect on PBC.

External engagement

Whilst shadowing the NTRECES staff during patient visits it was observed that, patients who have higher external engagement, for example, work, hobbies, support groups, etc., have a positive attitude towards technology. They viewed technology as means to support their various activities, which access is otherwise limited due to their mobility impairments. The presence of external peer support available for help also acts as a factor reducing the perceived difficulty in technology adoption.

RP07a: Users with higher external engagement have positive attitude towards intention to adopt ISA device.
RP07b: A higher level of external engagement has positive effect on PBC.

Income

Users who have higher disposable income and higher purchasing power find it easier to adopt a new technology as compared to users with lower purchasing power. Individuals with higher income can also afford to pay for services that facilitate adoption, providing a higher degree of control [36]. The resulting RPs are:

RP08a: Users with higher income have a positive attitude towards intention to adopt ISA device.
RP08b Higher income has a positive effect on PBC.

Subjective norms

According to the TPB, the opinions and beliefs of people who are important to the user, SNs, are vital in forming one's intention. Yang et al. [10] established in their study that if the users perceive that the people who are important to them think they should use smart home services then it may result in the intention to use smart home services. As ISAs enables the control of peripherals in line with smart home functionalities, it is suggested that:

RP09: There is a positive relationship between SNs and the intention to adopt ISA devices.

The factors included under the SNs constructs have been revised in this proposed model to reflect those who may have an influence on the adoption of technology. These are reviewed below with their respective RPs.

Family and peer pressure

In addition to the group of people providing care to the service users, there are also friends, family and associates (support group, clinical staff), whose opinion can be significant. In a study conducted by Luijkx et al. [37], the influence of family members in the selection of technical devices and their usage was determinant. In most cases, spouses, children and grandchildren played a vital role in the selection and purchase of a device. Therefore, this model proposes:

RP09a: Social peer pressure positively affects the intention to adopt ISA device.

Trust in NTRECES advice

Due to NTRECES staff professional experience and knowledge of technology, their opinion of and their advice affect the decision-making process of the potential users. It is, therefore, reasonable to deduct that if NTRECES decided to include ISAs in their set of prescribed EVs and to suggest them to the service users, this would influence their attitude. Therefore, it is proposed:

RP09b: Trust in NTRECES advice positively affects the intention to adopt ISA device.

Care support system

The group of participants in this study receive care and support for their daily living by their family, statutory care service, or by privately funded caregivers. It was observed in the exploratory ethnographic research that the views and opinions of the caregivers can influence the user's opinions and attitude.

RP09c: If caregivers are enthusiastic towards ISA devices, this has a positive effect on the intention to adopt ISA devices.

Perceived behavioural controls

PBCs are the users' perception of the degree of difficulty to perform a certain behaviour, i.e., the use of ISA devices. This perception is based on the individual's previous experience and anticipated obstacles [15].

In existing literature, PBCs have been demonstrated to have a positive effect on behavioural intention [15]. In line with previous work, the model here proposes that:

RP10: PBC is positively associated with the intention to adopt ISA devices.

Extending and applying the definition of PBCs by Ajzen [15] to the context of this study, several factors that constitute PBS have been identified. These are listed below with their respective RPs.

Familiarity with technology

Some studies investigated the effect of familiarity with technology upon the usage of a certain device, for example smart watches [19]. Similarly, through initial observations it was noticed that patients with an existing familiarity with technology were more open towards newer devices' options and functionalities, perceiving the devices easier to use. This results in:

RP11: There is a positive relationship between familiarity with technology and intention to adopt ISA device.

Technical support network

One of the reasons for high abandonment of assistive technology is its lack of customisation and integration [12]. Users find it difficult to install and customise their assistive devices, on their own, hence leading to rejection and abandonment This can be mitigated by the presence of a technology support network around the users, hence reducing the obstacles in the way of adoption. This is captured by the following:

RP12: A strong technical support network has a positive effect on the intention to adopt ISA device.

Residence type

The type of living space, specifically whether it is privately owned or social housing, can have an impact on the intention to adopt ISAs. According to the staff at NTRECES, sometimes there are obstacles in installation of peripheral devices due to the residence being owned by the local Authority. This impacts the ability to maximise the use of an ISA and therefore represents a hurdle towards forming an intention to adopt technology. The resulting RP is:

RP13: Users' residence owned by a housing association or local authority negatively affects the attitude towards the intention to adopt ISA devices.

Lack of access to the open market

Due to physical constraints imposed by disabilities, it is often logistically difficult for the users considered in this study to directly explore the new technological devices available on the market. Although they might get information about new devices through the internet, print media and television, they have limited ability to physically interact with devices, and this opportunity is generally offered when friends and family or the clinical staff of NTRECES bring the device(s) to them. The user's exposure is limited both in product range, as they cannot explore the full variety of the devices on sale, and in product knowledge depth, as their physical interaction is limited and mediated by a third party. Therefore, it is reasonable to assume:

RP15: The lack of access to the open market has a negative effect on the intention to adopt ISA devices.

Perceived ease of interaction

One of the discerning features of ISAs is the interaction through voice. Existing ECs use a "one click switch" method to interact with the devices. The switch method is lengthy and cumbersome, whereas interaction through voice can be easy and natural. As mentioned by Davis [13], perceived ease of use (PEoU) directly drives the attitude towards intention to adopt technology adoption. Similarly, the perceived ease of interaction (PEoI) affects positively the attitude towards the adoption of ISA device (idem).

RP16: PEoI leads to positive attitude towards intention to adopt ISA device.

Perceived reliability

Assistive technologies need to be reliable in emergency situations [12] and their fallibility is unacceptable by vulnerable users. This results in:

RP17: Higher perceived reliability leads to intention to adopt ISA device.

Perceived confidentiality

ISA devices are continuously listening to the users so that they can respond swiftly to the wakeup word. This creates challenges with regards to user confidentiality and consequently it requires a higher degree of trust in the manufacturer who can access and manage user personal data, i.e., audio streaming [10] identified that perceived confidentiality is a key characteristic that affords intention to adopt. This therefore results in:

RP18: Higher perceived confidentiality in the technology and the manufacturer data management governance positively affects the intention to adopt the ISA device.

Perceived security

ISAs devices and their peripherals, e.g., other devices controlled by the ISA, are connected through the home Wi-Fi network. However, there is always a possibility that these devices can be hacked, resulting in malicious entities having access to confidential information. This was identified as a perceived risk among able-bodied users of ISAs [18]. Jutai and Day [38] also reinforced that perceived risk is further amplified by the vulnerability of the service users with disabilities. Therefore, it is reasonable to state:

RP19: A technology with a perceived higher security level has a positive impact on the intention to adopt.

Perceived usefulness

Perceived usefulness is the ability to accomplish more with the use of technology [33]. Perceived usefulness is considered in the TAM [13] to directly influence users' intention towards the adoption of technology. Hence:

RP20: The higher perceived usefulness of the ISAs leads to a positive intention towards its adoption.

Perceived trust in service provider

The internet is a vital component for ISAs to function properly and effectively. Past research stresses the fear that users have when using the internet as they feel exposed to malicious entities and their information may not be secure [39]. The need to trust the internet service provider is further exacerbated in this study as users are vulnerable and potentially more at risk of internet breaches that may reveal their personal data, e.g., address and circumstances. Therefore, it can be stated:

RP21: Perceived trust in the internet service provider leads to a positive intention towards adoption of ISAs.

Voice interaction experience

The natural language interaction that users can have with ISA, may be significant in informing the users adoption of the technology as it may create emotional attachment to the device and may lead the user to attribute agency to the device. Both these effects of natural language interaction may be key in the adoption of ISAs.

Recognition and assignment of agency

It is natural for people to treat things that talk back to them as humans [40]. Research has identified that perception of anthropomorphism in technology will result in increased credibility, reliability and perceived usefulness of the technology hence leading to a positive behavioural intention [41]. This research extends such consideration to ISAs adoption and states.

RP22: The identification and assignment of agency to ISAs will positively affect the intention to adopt them.

Emotional attachment

The functional aspects of the users' experience with technologies encompass hedonic characteristics such as the pleasure and emotion that the experience may generate [42]. Due to the interaction with ISA being based on natural language, it is assumed that there will be a higher probability to create an emotional attachment to the device, therefore:

RP23: The greater the emotional attachment to the ISAs, the stronger the intention to adopt the ISA device.

Phase 4: qualitative contextual study

The choice of research methods is often a function of the researcher's world views and of the nature of the problem to be studied [43]. However, due to the mobility impairments of the prospective participants, which excluded certain data collection methods such as focus groups and diary studies, and because this study took place during COVID-19 pandemic, which prevented face-to-face contact to safeguard the participants, this research had less freedom in methodological choice. Online semi-structured interviews and subsequent questionnaires (see Appendix 2) replaced the initial visits to the participants' home aimed to directly observe the use of ECs and to undertake qualitative interviews. Using a multi-point data collection approach, it was still possible to collect context rich data.

A total of 28 NTRECES service users were contacted and 15 were selected to take part in the study. The participant's inclusion criteria for the study were: (i) the participants desire to use new devices, (ii) the quality of their voice was reasonable and (iii) the participants had full mental capacity. Our colleagues at NTRECES helped us with shortlisting participants that fit the inclusion criteria, due to their familiarity with service users. However, due to arising personal and health reasons, a total of 11 participants were finally interviewed (7 males and 4 females) over the period of 5 months. The average age of the participants was 56 years old, with 3 participants being younger than 50 years old. All participants were registered with NTRECES and had been previously issued with EC devices. Some of the participants (5) had a privately owned ISA device, which they used for leisurely purposes and not as a replacement of their EC device. Each of the participants was diagnosed with neurological conditions resulting in severe mobility impairments such as spinal cord injury (SCI), multiple sclerosis (MS), scoliosis leading to osteogenesis.

Data analysis

All video and audio recordings of the interviews were analysed and transcribed. Answers from the survey were also added to the transcripts. In the first iteration of data analysis with the help of NVivo, a

structured top-down approach was used for coding the data of part 2 of the interviews which operationalised 20 RPs (3 RPs were related to demographic data that was provided beforehand by the NTRECES). Using the proposed research model as a guide, data excerpts were assigned to codes, each referring to a separate RP. The 23 codes contributed to the four main constructs in the TAM proposed (user characteristics, SNs, PBCs and voice interaction experience). In the second iteration of data analysis, an inductive approach was used for coding the data of parts 1 and 3 of the interviews. This resulted in the identification of themes not specified by the initially proposed model.

Findings

Revised ISA's adoption model

This section presents the findings of the qualitative contextual study (phase 4) centred around the proposed TAM (Figure 6), specifically the four key constructs that this research has identified, namely User Characteristics, SNs, PBCs, and Voice Interaction (for complete list see Appendix 3). A final section is dedicated to the discussion of emerging themes from the semi-structured interview with service users. The Revised ISA's adoption model is presented in Figure 7.

User characteristics

While discussing barriers in the use of technology with the participants, age, gender, desire for independence, voluntariness, openness to innovation and external engagement did not appear to be a factor in the adoption of technology. The barriers faced by the participants in the adoption of technology were mostly related to their diagnosis and finances. Hence, RP02b, RP03b, RP04b, RP05b, RP06b and RP07b were discarded.

Participants in the study had an average age of 56 (standard deviation 15), 7 male and 4 females. All 11 participants regardless of their chronological age or gender, used a variety of technological devices and demonstrated their willingness to learn about new technologies including ISA devices, hence RP02a and RP03a were discarded.

Regarding the desire for independence, participants felt differently about what being independent meant. According to participant 4 "It [AN: ISA device] gives me some semblance of independence back,

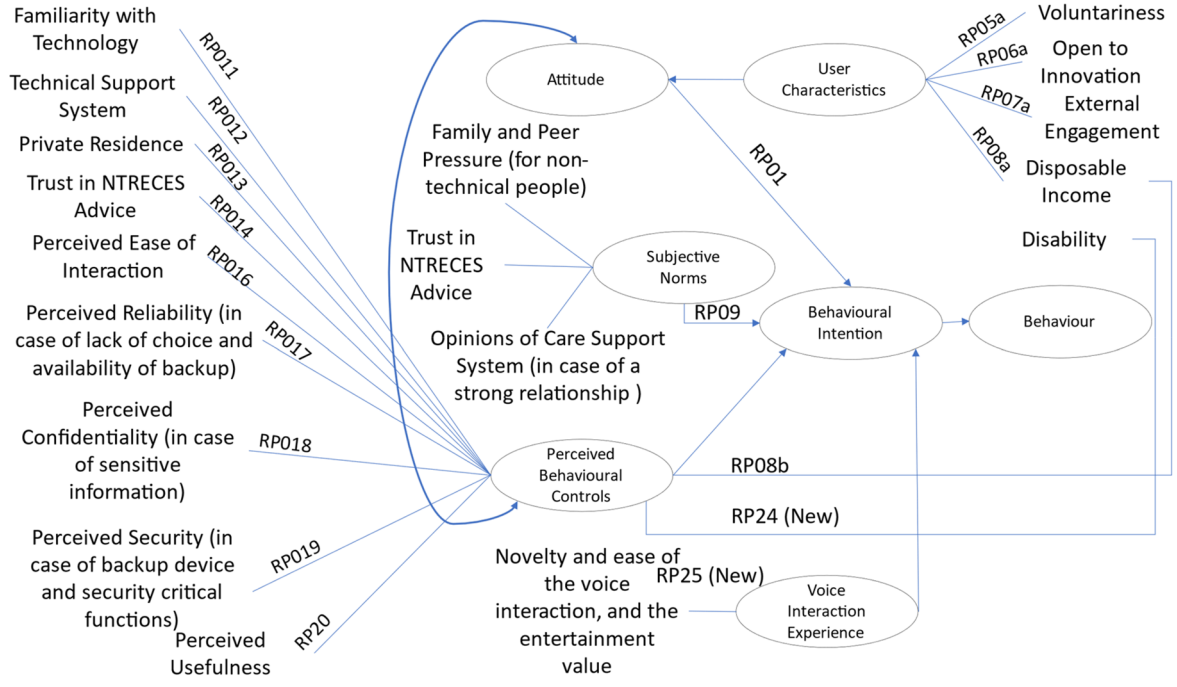

Figure 7. Revised technology acceptance model for ISAs.

in addition to the EC devices because I am in control. Independence is being controlled. If I want to read a book, I read a book. If I want to listen to music, I listen to music. If I want to sing a song, I'll sing a song". However, independence to participant 4 meant something more: "I would probably say to you I don't really have any [AN: independence]. [.} yeah I'd like my body back and I can't have that, so I'm not going to be able to be independent.". Hence, despite differences in opinion regarding independence, this did not affect the participants' decision to show willingness to use ISA devices. So, RP04a was discarded.

Voluntariness and intention to adopt (RP05a) was determined by prompting participants about their referral process and collaboration in the prescription of an EC device. None of the participants were forced to use EC devices and all except one were still using them. Hence, RP05a was confirmed for the modified model after analysis.

Similarly, participants were asked about their thoughts regarding new solutions, ideas and technologies to assess RP06a (openness to innovation and intention to adopt). In this study all participants demonstrated openness to innovation to varying degrees from very open to not open at all and it in turn influenced their willingness to use ISA devices. Participant 11, for example, demonstrated a higher degree of openness. Talking about purchasing new devices participant 11 said: "the latest as soon as I can get hold of it [AN: new devices on market". When questioned about if he had already purchased a smart speaker, participant 11 replied "I have 4, one in kitchen, one in bedroom, one upstairs and one with my carer…". Hence it was observed that participants with higher degree of openness to innovation were more willing to adopt an ISA device. Hence RP06a was confirmed.

All the participants of this study had external engagements either virtually or face to face. This was in the form of paid or voluntary employment and social and cultural activities. However, they felt disconnected from the outside world due to COVID-19 lockdown and due to the progression of their disease. Despite this sense of disconnection from the external physical world the participants demonstrated a high interest in using an ISA device in the future to better connect and communicate with people they worked and socialised with. On this basis, RP06a was included in the revised model.

On the other hand, RP08a (income and intention to adopt) and RP08b (income and PBCs) were altered to change the income construct to disposable income.

During the data analysis, it became evident that it was the disposable income that dictated the participants' spending behaviour, including the purchase of new devices. Participants who had jobs but had dependents at home showed different spending behaviours to ones who were retired and had no dependents at home. For example, participant 04 had good disposable income and he had a variety of new devices at home including multiple smart speakers, iPad and Wi-Fi security cameras. Whereas participant 03, with low disposable income even gave away a gifted smart speaker as she thought she would have to spend money on installation and buying a peripheral. Having lesser disposable income acted as a barrier towards purchase and installation of new technological devices. For example, some participants also felt that due to their disability they are unable to carry out some complex installations and unable to hire professionals due to financial constraints. According to participant 6 "The problem is more…Who is going to fit it up? Who's going to put it up? I mean, I'd much rather have had a proper CCTV system. But it would be expensive. You probably end up having to use a professional company, which would have been thousands of pounds. Whereas for a couple £100 I got blink cameras. And they were easy to put up with because I don't have to source power for them". Hence, RP08a and RP08b were altered and included in the modified model.

Subjective norms

When participants were asked if they took advice from their friends and family before making a technical purchase, their replies varied. Some participants revealed that they asked for advice, while others claimed to be the technical person in the family who gave out advice instead. So, it appeared that the advice of family and friends mattered if the person is not technically oriented themselves. When the participants were asked about their process of buying technical devices their responses varied depending upon their technical expertise. For example, participant 02 said: "I like to search on the website looking at the reviews and also I may ask my nephew who knows more about this sort of device". On the other hand, participant 10 who was tech savvy said: "In my family in my circle of friends I am the technical guy, it

is more likely that they contact me for help". On this basis RP09a (Family and peer pressure and intention to adopt) was altered to RP9a: For the participants, who lacked technical expertise, family and peer pressure (advice) did play a positive part in the intention to adopt an ISA device.

The participants trusted the advice of NTRECES staff and would consult them before making a technical purchase regarding assistive technology. According to participant 06: "to be honest, a lot of trust [AN: for NTRECES staff advice]. So, what I've got is 1,000,000 times better than not having anything. I'm very grateful for what their systems have given me".

Hence RP09b was confirmed for the revised model.

When the participants were questioned about whether they considered the opinion of their caregivers before making a technical purchase, it was revealed that not all participants enjoyed a positive or meaningful relation with their caregivers. Participants who had a strong relationship with their caregivers appeared to give weight to their advice before making any purchase. For example, participant 10 said: "My carers have become friends. We might have a discussion about it [AN: purchase decision]. Yeah, I may ask them for their opinion." Whereas participant 06 was of the opinion that: "But all the carers were so hopeless. I mean there was no, not joking. She didn't know how to peel a carrot…." Hence RP09c (Opinion of Caregivers and intention to adopt) was altered to RP09c: Depending on the strength of the relationship of the participant with the caregiver, opinion of the care support system will positively affect the adoption of an ISA device.

Perceived behavioural controls

All the participants were familiar with technological devices and used them in everyday life. Participant 4 worked in finance and used computers for work. According to her "I've used computers for many years. So, I knew what the functions do [are]". Similarly, participant 7 said "My background is in technology. I used the computer all the time. Most of the technology was reasonably easy for me to use". In line with these findings and extending their confidence with technology to a new group of technology devices, the participants were eager to explore new devices and solutions for environmental control (EC). Hence RP11 was confirmed.

To understand the technical support system participants had, they were questioned about their recent experience regarding a technical device purchase, its installation and learning. All the participants in the study had a technical support system in place, albeit of different kinds. For some participants technical support is more accessible if they themselves are tech savvy or their family or friends can provide the technical support. Whereas for some participants, technical support, would be a professional service they had to pay for. Despite, the difference in access to technical support, 10 out 11 participants showed positive intention towards adoption of ISA device, when enquired about it. This intention could be due to the fact that, the participants were of the view that functionalities provided by ISA devices are more than the EC devices for example participant 04 used the smart speakers for online shopping, looking up information and playing music, which were not possible on the EC device. Participant 06 gravitated more towards amazon-based devices as he found the installation simpler, which could be managed by his caregivers, so he did not have to hire professionals. Participant 02 was confident about using extended functionalities of ISA devices as he believed his nephew will help him out with the installations. Participant 06 also stated that he is not concerned about the security and privacy risks related to ISA devices as he does not talk about any security critical things. These findings suggest that RP12 can be confirmed for the modified model.

In this study information about the participants' residence is collected as part of the participants demographic data. All the participants live in independent residences (6 participants live in a house, 1 in a bungalow, 3 in a flat and 1 in an annex). None of the participants lived in a council owned property. All the participants were able to install devices in their houses without permission from any of the local housing authorities. When asked about the adoption of ISA devices, only one of the participants felt that there will be issues related to the installation of peripheral ISA devices. So, within the constraints of this study not having participants residing in social accommodation, it is feasible to rephrase RP13 to state that residing in private residences positively affects the users' attitude towards intention to adopt an ISA device.

All participants shopped online. In addition, some participants were able to access shops in person but had stopped that due to COVID-19. According to participant 5 "I always get from Amazon because they're very good. Thirty days to make your mind up. If you don't like it, you can just send it back". So, they do not feel the need to go out to try the device physically at the shops. Participant 04 pointed out how the smart speaker suggested things that she could purchase or benefit from, which in her opinion was a good feature. Participant 06 even got his weekly shop delivered *via* online shopping and if something is missing, participant 06 just orders it from amazon instead, he feels that it is very convenient, especially since after COVID-19. Hence RP15 was discarded and not included in the modified model.

To determine the participants PEoI about different technological devices, including EC and ISA devices, the participants were questioned about which technology and methods of interaction they find easier to use. Seven out of eleven participants believed they found voice interaction relatively easy. For example, participant 2 preferred voice interaction because according to him, "anything for which I don't need to press a button is easier". The rest of the 4 participants were either neutral about their views on ease of interaction or stated that it depends on the kind of system you are interacting with. So, RP16 was confirmed for the modified model.

Participants in this study were asked about the technological devices they use daily and how reliable they think they are. All the participants were of the view that ISA devices, due to their dependence on the internet, are not very reliable. Despite acknowledging that ISAs devices can only work if supported by Internet services, 10 participants replied positively about using ISA devices in the future. It is interesting to note that the decision to choose a device which is relatively unreliable for the participants involved in this study and representing service users with severe disabilities, is affected by other factors, namely the lack of choice caused by an advancing disease that hinder the use of other control channels, and the availability of backup device for emergencies, which can moderate the perceived unreliability of ISAs. According to participant 04 "if there's some emergency and I haven't got anybody here… I don't know what to do …. how do I press the button on it [AN: emergency pendant], they should do something voice-activated". Moreover, according to participant 09 when she needs to call her carer during the night, she has no choice but to use voice: "I'm unable to reach, so I have my phone propped up in front of me, but my glasses are off so I can't even use my phone…". Although most participants were willing to adopt the relatively unreliable ISA devices, it does not mean that reliability is no longer a factor in their attitude towards intention to adopt an ISA device. Given the importance participants gave to reliability of the EC devices it can be inferred that perceived reliability does affect the attitude towards the intention to adopt ISA devices, but that other factors such as lack of choice and availability of backup devices may have mitigating and moderating effects. Therefore, the rephrased RP17 is that perceived reliability does affect the attitude towards intention to adopt ISA device, but other factors such as lack of choice and availability of backup device should also be considered.

The participants were asked about their concern regarding the breach in confidentiality when using different Internet-based services, such as shopping and online banking. They were also asked about their trust in Tech giants like Google and Amazon as they provide most of the platform for the said services. In addition, participants were asked about how they felt about the confidentiality that ISA devices would afford and extra security features that could make them safeguard privacy better. All participants did not trust the tech giants with their information. Despite that, all participants except one were eager to use ISA devices. It indicates that additional factors such as significance of information, as well as benefits of the ISA device versus breach of confidentiality should be considered when analyzing perceived confidentiality. For example, participant 06 was talking about the nature of his conversations around Amazon Alexa, "Are they [AN: Amazon] really going to be interested? You know? I mean, if I was an international spy or terrorist or bank robber, then maybe I'd be a bit more concerned, but I'm none of these things so….". Hence, RP18 is now modified as, perceived confidentiality does not affect intention to adopt an ISA device negatively, unless other factors such as significance of information, as well as benefits of the ISA device versus breach of confidentiality are considered.

The participants were asked about their view regarding the perceived security of ISA devices and what security issues they might have. The participants were aware of how certain functionalities provided by the ISA devices can be security critical. For example, participant 1 did not like the idea of using Alexa to control the car. According to him "If you've got some idiot outside trying to get your car [AN:

car with built in Alexa], they managed to get to the Alexa, they could access it by that [AN: Alexa] anyway". Despite these reservations, all the participants were positive about using ISA devices in the future. Similarly, to the case made for RP17, and despite the participants feeling that ISA devices were not secure (7), participants revealed their limited choices caused by their advancing disability or their limited access to controls given their physical lack of mobility. Such limitation leads to lack of usable technology alternatives and this in return, moderates the perceived lack of safety of ISA devices among the participants. For example, participant 8 said "I already use apple, so we know our data is out there. I am a WhatsApp user, and there are issues around WhatsApp. So, it doesn't overly concern me to be on this [AN: ISA device]. And I think you're gonna have to compromise somewhere. and I'm just looking into something that's gonna really improve access around my home for me really…".

Participant 9 shared that she has placed her smart speaker next to her TV: "I think you have to weigh what's most important to you, and being able to have that independence and control is a lot to me than personal data".

Participant 10 was also concerned about security but being very tech savvy, he was of the opinion that there is a lot that can be done to achieve higher security than to stop using it altogether.

Participant 2 was already using Alexa for medicine reminders but when inquired about security issues regarding ISA devices, they replied that there could be issues especially regarding online shopping.

On the other hand, participant 04 who used Alexa as well as Google Home for online shopping and information retrieval was not concerned about security risks, "I usually got somebody else here in the house. That's why I don't worry about that [AN: security risk, somebody hacking into smart speakers]".

Similarly, the participants realised that it is possible to use only those features of ISA devices which are not security critical. For example, smart locks or car controls. So, in the light of the current findings, RP19 can be altered that perceived security negatively affects the attitude towards intention to adopt an ISA device, when the user does not have a secure alternative device or if the device is being used for security critical functions.

The participants were questioned about how their life has improved after the prescription of EC devices to understand what extra functionalities ISA can provide to them. The participants in this study (10 out of 11) also recognised the usefulness of the ISA device, whether they were already using it or not. Participant 03 felt that she had all the technology she needs for all the functionalities right now. All the participants except one were positive about using the ISA device in the future. For example, participant 11 said "… next to my bed at the minute I have a light switch, but if I haven't got a light switch next to me and if I could have an Alexa which is connected to a smart light bulb or something and then that kind of gives me independence 'cause when I'm in bed. I won't be able to get up and turn the light off…". Similarly, participant 09 is only able to use voice-enabled control during the night when she needs to call her carer, and she is unable to reach her phone. Moreover participant 04 whose disease is progressing now and is having difficulty in pressing buttons, is finding using her voice to interact with various smart speakers around the house much easier and more useful. Hence RP20 can be included in the modified model.

Given the reliability of ISAs on internet services, the participants were asked about what factors played a role when selecting an Internet service provider Most of the participants were not concerned about quality of the service or safety features, whilst the cost of the internet service seemed to be pivotal in their decision. This was also the most important factor for the families of the participants who often made a purchasing decision on their behalf. This cost-driven strategy may be the result of a non-essential use of internet services as current EC devices do not make use of an internet connection. Only two participants were concerned about the quality of the internet, participant 06 and participant 10. Both of these participants had multiple smart speakers, and other smart home devices on the internet. Hence, they made sure that the speed of the internet is fast, and it can cater to a greater number of smart devices connected to the Wi-Fi. These observations suggested that RP21 needs to be discarded and not included in the modified model.

Voice interaction experience

This research explored an additional construct in the proposed initial adoption model, namely the experience with the ISA achieved through voice interaction. Participants were asked whether the interaction with the ISAs resembled that with humans. Participants (7 out of 11) generally recognised that ISAs

respond like humans do when they understand the questions being asked, but the lack of emotional connotation in the ISAs response was clear to the participants. In support of this participant 6 said "It answers you a lot like humans would answer you. It doesn't always connect the emotion though. It doesn't always, you know, understand you correctly. It doesn't really get me upset or angry. So, it's still a machine". To further confirm the point that participants see ISAs as machines it was noted that 5 participants used the pronoun "it" when referring to a smart speaker. According to participant 3, "Attributing a personality to a box of tricks (AN: ISA device) is analogous to giving your car a name and believing it has a personality. I have never done either". On these observations, RP22 (the role of recognition and assignment of agency to Isas and the impact on intention to adopt) was refuted.

As part of exploring whether the experience with ISAs could have a positive effect on the intention to adopt, the participants were asked about aspects of the interaction that could characterise an emotional attachment with the technology.

Participants were clear that they had formed no strong emotional attachment to it but that for some older and vulnerable people this could become a problem. Participant 08 said: "if the technology is being in a way to fill that human void. Then I think it will start creating more segregation, exclusion from society then, that's problematic".

The participants acknowledged that the interaction possible with ISAs is different from those afforded by traditional EC devices. For example, participant 6 said "I have great fun just sometimes talking at it and saying very controversial words like explosives and AK47". Other participants used the ISA device for entertainment purposes too. According to participant 4 "I use some games, quizzes, everything. And I listen to the radio on it". The association of fun with the ISAs made them more desirable compared to the EC devices.

In the light of these findings, RP23 is altered to state that: the entertainment value and novelty in the personalisation of the voice interaction positively affects the attitude towards adoption of an ISA device.

Emerging themes

During the analysis of the data, in addition to the codes identified in the proposed model, several other themes also emerged. These themes include factors such as inclusion of mobility impairment or disability as a user characteristic, universality of technology, replacement of human contact and cost of technological devices. As these emerging themes can have overlap with PBC themes, so a future recommendation can be to merge these themes with RPs to further modify the adoption model.

Mobility impairment or disability as user characteristics

During the interviews one thing that almost all the participants pointed out is the impact of their mobility impairment or disability on the perceived difficulties in using different types of technological devices.

Participant 1 was worried about the variability of his voice quality, which could result in non-recognition by the devices (especially in case of voice verification by banks phone services). Participant 1 said, "I'm a bit worried about my voice. When I give the voice to a machine? Is it gonna say, not recognizable, wrong thing"?

Participant 4 said, "I have thought about getting those emergency buttons or pendants bracelets? But then how[AN: increased loss of mobility]? I had them but then I couldn't press the button".

According to participant 7, "Because of my illness, I can't always stay in the same position. Because every time I use it [AN: eye gaze, mouse controlled by eye movement], you have to re-calibrate."

Participant 9 was apprehensive about using new devices as she has almost no mobility left in her hands. According to her, "So one of the reasons I used HomeSense [AN: EC device] is to call my carers during the night. But I need to do that from my phone [AN: phone acts as EC controller]. I'm unable to reach, so I have to have my phone popped up in front of me".

Participant 10 had similar issues, whilst talking about video game controllers, according to him, "I've got limited hand function, so I need certain adaptations".

In the discussion of the user characteristic variables, it is mentioned repeatedly that mobility impairments or disabilities of the user had an effect on PBCs. However, none of the RPs explicitly explore mobility impairment or disability for its effect on PBCs. Hence in light of the findings, it is recommended that mobility impairments have a negative effect on PBCs.

Technology for all

Another interesting theme that came to light during the data analysis was the universality of technology. During the interviews, some of the participants talked about the marginalisation of facilities and technologies designed for the disabled people. They were of the view that everything should be designed universally, catering for people, regardless of their disabilities. Technology designed for all would be more readily available at a lower cost, making its adoption easier for people with disabilities. Hence, an inclusively designed technology would have a positive effect on the attitude towards its adoption.

For example, participant 1 pointed out the condition of disabled toilets in hospitals. According to participant 1 "If I really needed to go to a toilet, it's no good in any hospital that I know of. There are no electric toilets in any hospital but the whole of Japan has one in every house. The hospital I go to has two disabled toilets. In the 10 years I've been in, I've never known the two to be working and a lot of times they're both out of order. But I mean if you were in Japan then everything is like that [AN: accessible for all]. The whole of National Health has been changed for big people. If you go into a waiting room now, you'll find double size chairs and you have got double-sized wheelchairs. And I'm sorry, but they don't do it for the disabled, they don't do it on the voice side, and they don't do it for sight."

Similarly, participant 8 said "I'm noticing a lot of the technology that disabled people are using is what we are seeing [AN: in the mainstream]. I think the problem is that we have made technology medical and medical technology is never going to be mainstream [AN: only limited for the use of patients]. Technology should be seen as universal, and I think what draws me to Apple is Apple made it accessible for everybody. They did n't do it in a way that's only going to benefit non-disabled people. We think technology is not medical, It shouldn't be seen in that way. It should be saying like let's improve everyone's lives, like we saw with door opener [AN: Mechanical door openers] which has now become mainstream. So as soon as a technology becomes something that is not medical, the price becomes reasonable too".

So, taking into consideration the thoughts shared by the participants it can be stated that medical devices are not designed with the same attention to the users and because of a niche market there is not enough development towards making it more universal.

Replacement of human contact

ISA devices interact with the users using natural conversation style. These devices respond to the voice-based queries emulating human voice. Some participants in this study were apprehensive regarding this feature of the ISA devices. According to them, the conversational feature of the ISA device can make a user confuse the device for an actual human. They also pointed out that the ISA device may pose the risk of replacing human contact. According to the participants, using the ISA device in such a way can lead to further isolation of an already vulnerable population.

According to participant 9 "I actually think that it [AN: treating ISA device as a conversational partner] would be detrimental to the function. I think that it can really be dangerous in the future. If people used those devices for conversation and human interaction".

This point was further emphasised by participant 8. According to her "I'm aware that if people are using assistive devices for communication, it is important to have a human sound. But I'm very mindful that we don't see technology as replacing human contact". She further goes on to say that "If the technology is being implemented in a way that is going to be assisting, empowering, and liberating then that's different in my experience. If it is been implemented in a way to fill that human void, without even thinking about how much is creating more segregation, exclusion from society then, that's problematic". In summary, the perceived replacement of human contact can negatively affect the attitude towards the adoption of a technology.

Cost of technological devices

During the interviews, participants mentioned the cost of using ISA devices to control the electrical equipment around their house. There was apprehension and lack of information about the actual cost

of the ISA device, its peripherals and their installation. This lack of information can lead to a hindrance in the purchase and adoption of ISA devices. Hence, perceived cost of technological devices can have a negative effect on the adoption of ISA devices.

The participants were unaware of the cost of the EC devices provided to them by the NHS service and therefore a fair comparison with the cost of an ISA device could not be made by them.

Discussion

Modified model

The underlying assumption of this research project was that the factors that influence users' behaviour may directly impact the design of the technologies in both their functional and non-functional requirements and may suggest improvements in the service provided by RECES in the UK. The initial research model was based on TPB and initial ethnographic observations. The initial research model was then evaluated using the data collected during the research. After analysis, this research has arrived at an updated and modified model as presented in Figure 7.

It is supported by the data collected in this study that in addition to the main constructs of TPB (attitude, PBCs and SNs), voice interaction experience also plays a role in determining the behavioural intention of the user.

It was concluded that voluntariness, open to innovation, external engagement and disposable income and disability are the factors of user characteristics that affect the attitude, which in turn influences the behavioural intention, which ultimately affects the behaviour to adopt an ISA device. The factor income has been modified to disposable income to reflect the results from the data analysis. Moreover, disability is a new factor that is added to the model based on the emerging themes in the data.

Moreover, the factors that make up PBCs are familiarity with technology, technical support system, private residence, trust in NTRECES advice, PEoI , perceived reliability (only in case of lack of choice and availability of backup), perceived confidentiality (only in case of sensitive information), perceived security (only in case of backup device and security critical functions), perceived usefulness, disposable income and disability. Two new factors, disability and disposable income have been added as emerging themes from the data.

In regard to SNs, the construct of family and peer pressure is now modified, and it is stated that it will now influence the behavioural intention only in the case of users, who are not very tech savvy.

The fourth and novel construct which has not been part of the TPB before, is the voice interaction experience. In this model, the voice interaction experience is influenced by novelty and ease of use of the voice interaction and the entertainment value. The voice interaction experience then influences the behavioural intention, which in turn affects the behaviour to adopt an ISA device.

In addition to the changes described above, the research uncovered some additional RPs.

Additional components affecting behavioural intention

This research project supplements the literature on smart speakers' adoption by users with severe mobility impairments by presenting a theoretical model that extends TPB. The extension of TPB is twofold. The First addition to TPB is with regards to the addition of a factor, voice interaction experience, as an influence on the behavioural intention. The second addition is the inclusion of components constituting and affecting users' attitude, PBCs, SNs and voice interaction experience.

Additional factors constituting components affecting behavioural intention

In this study, the factors that had been proposed for the first time in the context of technology adoption (especially assistive technology adoption) of ISA devices were the following: lack of access to the open market, external engagement, residence type and trust in NTRECES advice.

In the modified model (see Figure 7) after the data analysis, three kinds of results were drawn regarding the influence of the factors proposed in the model. First of all, several factors like age, gender, etc., that have been known to have some influence on the behavioural intention in previous studies. Venkatesh et al [14] appeared to not have similar influence in this research project.

Second, some factors like perceived usefulness [15] showed similar influence on behavioural intention as in the previous studies.

Third, other factors like perceived security [18] were altered to account for the specific technology and the selected type of end users involved in the study.

Conclusion

This research project addresses a gap in the current literature by proposing a model that may help in understanding the factors that are specific in the adoption of assistive technology by users with severe mobility impairments.

The final model proposed in this research is supplemented by additional themes and RPs, such as considerations of the financial costs of assistive technologies to the users. A bespoke adoption model of assistive technology by severely disabled users may support a fairer and more equal academic debate about the dimensions that are particularly relevant to this user group.

This study provides guidance to manufacturers of existing EC devices, and NHS providers of assistive products and services. This research clearly highlights that the inclusion of voice interaction is a reasonable demand by service users as it affords more control and independence. Whilst voice interaction is not a method suitable for all service users with disability, the study certainly suggests that service-users, their family and carers should have agency in informing the device that is prescribed to them.

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Appendix 1: Interview questions

Name (Code):

Gender:

Age:

Diagnosis:

EC Issued plus Supplier/company supporting (example, Possum, Steeper, PCbyVoice, NTRECES)

Greetings followed by briefing of the proceedings.

Questions 1–4 answers may well be altered by COVID lockdown measures – may have to be ready to note this as a theme. Participants may answer for pre and during restrictions.

1. Can you name a few of the activities for which you have to leave your house? (1.7.2)
2. Are you in paid employment at the moment? (1.3.1) (1.7.1)

   a. If yes, what is your occupation
   b. How long you have been working in this occupation.
   c. How many hours
   d. Do you always work from home?
   e. If no, how long has it been since you have undertaken paid work.
   f. Can I ask you the reason you were unable to continue working?

Next 4 questions are about Purchasing process – topic is returned to Q 40–44 and will not be repeated if satisfactory answers has been obtained here.

3. If you want to purchase something what is your preferred way of purchase? (2.5.1)
4. Can you please walk me through a recent process of purchase, preferably a technology or an appliance? (For example, what was it, why you needed it, how did you chose that model.) (2.5.2)
5. How would you describe this process? What is effective and what is frustrating? (2.5.3)
6. Do you feel that you would have made a different purchase decision if you were able to browse all the variety of products available, and physically interact with it? (2.5.4)
7. Do you feel that if you can browse through the items of your interest, you are more inclined to purchase? (2.5.5)
8. What does independence mean to you? (1.4.1)
9. Can you list the activities that you are able to do and represent independence for you? (with or without EC) (1.4.2)
10. Can you list activities that you are unable to do? (with or without EC) (1.4.3)
11. Does it make you feel less independent? (1.4.4)
12. Do you ask help from your caregivers in those tasks? (1.4.5)

13. What are the tasks that you are currently unable to perform and that would enhance your sense of independence? (1.4.8)
14. Can you please give an example of a decision or action that was influenced by the opinion of your caregivers? (3.3.2)
15. How did you learn about EC service (NTRECES)? Was it recommended by someone? Can you tell me how the EC service was prescribed for you? (1.5.1)
16. During the demonstration visit (first visit of NTRECES staff) did you and the NTRECES staff agree about the devices most suitable for you? (2.4.2) (3.2.2)
17. On a scale of 1 to 5 (where 1 is very little to 5 is a lot), how much do you trust the advice of NTRECES staff. (2.4.1) (3.2.1)

    a. Can you give a reason for your trust or lack thereof?

18. Do you think that trusting the advice of NTRECES has been a factor in your adoption and use of your EC device? (2.4.3) (3.2.3)
19. How did you feel about the EC device before it was installed in your home? (1.5.3)
20. How do you feel about it now? (1.5.4)
21. What EC device was given to you initially? (2.2.5)
22. Are you still using the same device, or has it been replaced or updated? Why? (2.2.6)
23. How long you have had this equipment for? (2.2.7)
24. How did you go about learning to use it? (if they discovered and learnt by themselves there was more voluntariness). (1.5.5)
25. How often do you use it? (2.2.8)
26. What do you use it mainly for? (2.2.9)
27. In your opinion, how have the EC devices helped you in your work tasks and your social life? (1.7.5)
28. Is there anything you would change in the setup to make it easier for you or improve your connectivity to other people and the outside world? (1.7.6)
29. Which feature makes your EC device unreliable or reliable (from i to iv) (2.7.3)

    i. It performs seamlessly without interruptions.
    ii. It does not shut down abruptly.
    iii. It has backup in case of emergency.
    iv. Alerts you that it is down.

30. Has there been an instance when your EC device failed to perform? If Yes can you, please tell me about the incident. This question will be repeated in Question 51, in case of repetition it will not be asked again at Question 51 (2.7.4)
31. How do you feel about trying new technology? (1.6.1)

Return of topic from before in next 4 questions.

32. Do your family and friends/carers suggest what technology to buy? (3.1.1)
33. Do you welcome their suggestion? (3.1.2)
34. Do you ask for help? If so why. If not, why not? (3.1.3)
35. Can you give me an example of a device that you bought because it was suggested to you? (3.1.4)
36. What was the most recent device you have purchased? (2.3.1)

    a. Did you make the decision alone or sought someone's help and assistance?
    b. Did you require some training before starting to use the device? If yes, who provided the training?
    c. Have you ever abandoned a device on the basis of technical issues, for example, unable to customise font size, cursor speed, change input method from conventional keyboard and mouse to eye gaze or voice?

37. Do you have internet availability at your home? If no, why? (2.2.3) (2.11.1)
38. How did you choose your internet service provider? (This will allow us to understand whose advice they trust). (2.11.2)
39. What were the qualities you looked for when deciding about the internet service provider? (2.11.3)
40. Do you have a PC or a Laptop at home that you use? (2.2.4)

    a. How often do you use it? Once twice thrice a week daily
    b. What do you use it for? Email browsing entertainment (music/video) shopping account banking social media work skype hobbies others.
    c. Do you have any difficulties in operating your PC? Can you tell me the most important one?
    d. Do you have specialised hardware for using your PC? For example, eye tracking mouse or mouth operated IntegraMouse.
    e. If answer is yes, what, and why?

41. Can you tell me about any technical issues you had with any of the other technical devices you have? (2.2.2)
42. In case of a technical difficulty either with your EC device or any of your other equipment, who do you contact? (2.3.2)
43. If you are asked to rate different devices in your house on the basis of reliability, on a scale of 1 to 5, which device would you rate the highest? (2.7.1)
44. Can I ask why? Which features of the device makes it most reliable? (2.7.2)

i. It performs seamlessly without interruptions.
ii. It does not shut down abruptly.
iii. It has backup in case of emergency.
iv. Alerts you that it is down.

45. Can you tell me of a technology that you use, and you find easy to use? (2.6.1)
46. Have you ever replaced it? (2.6.2)
47. If so, how much on the scale of 1 to 5 (where 1 is very little to 5 is a lot), ease of use counted in your decision to replace it? (2.6.3)
48. Can you describe in your own words what it means for a technological device to be easy to use? (2.6.3)
49. When using different technologies for example your smart phone or internet how concerned are you on a scale of 1 to 5 (where 1 is low and 5 is high), about breach in confidentiality, for instance, your personal data being known by others? (2.9.1)
50. If the user was ever concerned then ask, can you give me an example? (2.9.2)
51. If the user was not concerned then ask, why? (2.9.3)
52. If the user is worried about confidentiality then we can ask, what precautions do they take against the breach in confidentiality? (2.9.4)

Brief about smart speakers, inquire if they own one or not. If they do not have a smart speaker show the demo video and allow some online interaction.

53. On a scale of 1–5 how much do you trust the technical giants like Google, Amazon, Facebook, etc., with your information? Why? (2.9.7)
54. If you have to install a smart speaker in your house, which room would you choose for its installation and why? (2.9.6)
55. On the basis of these qualities that you have discovered in the interaction (demo video and interaction with Alexa online with us) how likely is it that you would use this device from 1 to 5? (4.1.1)

If they have and use an ISA.

56. How much from 1 to 5 did the qualities we have just reviewed (listed in the table) influence towards your purchase and use of the device? (4.1.2)
57. On a scale of 1–5 how would you rate the ISA device as a conversational partner? Why? (4.2.1)
58. When addressing the ISA device would you rather use the pronoun it, her, or him? Why? (4.2.2)
59. Would you prefer a male or a female voice for the ISA device? Why? (4.2.3)
60. If I ask you to describe this technology how would you describe it? (4.2.4)
61. Do you think you would like to personalise this device if it was yours? (4.2.5)
62. How? (If they do not come forward with suggestions you can suggest a nick name, or something else) (4.2.6)
63. Why? (By asking why they may say for a stronger link). (4.2.7)
64. Do you think you would develop a strong link with this technology if you used it? (4.2.8)
65. Is there anything you would compare this technology to? (4.2.9)
66. If given a choice, would you like your device to have customised personal touches just for you? For example, in case of ISA device addressing the user by their name. (4.2.10)
67. In your opinion, addition of this emotional aspect of your user experience is a plus in an assistive device, agree or disagree. Why? (4.2.11)
68. Given the choice what method of interaction you would choose for what? voice or conventional? (2.6.5)

If they do not have an ISA:

Characteristics	Rate (EC) 1–5	Rate (ISA) 1–5	Reason, Why
Looks/sounds like humans			
Presence of consciousness			
Presence of emotionality			
Behaves like humans			
Extraversion e.g., talkative, enthusiastic			
Agreeableness e.g., polite, helpful			
Conscientiousness e.g., reliable, organised			
Neuroticism e.g., moody, tense			

Appendix 2: Questionnaire

Please fill in the questionnaire after the online interview.

1. How often do you connect with people from outside of your household (friends, peers) through phone, email, video call for reasons such as catchup, hobbies, support group, leisure activities)?

Every day or more than once a day	One to three times a week	Twice a month	Less than once a month	Never
5	4	3	2	1

(1.7.3)

2. You feel very connected to the outside world?

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
5	4	3	2	1

(1.7.4)

3. Generally, you feel comfortable with change (in daily routine or life in general)?

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
5	4	3	2	1

(1.6.2)

4. How often do you try new things, For example new technologies like robo-vacuums, doorbell cameras, etc.?

At least one every month	One in to 3 months	One in 6 months	One in a year	Never
5	4	3	2	1

(1.6.3)

5. You are the first one to try new technology before your friends and family:

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
5	4	3	2	1

(1.6.4)

6. You feel very independent in your daily life.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
5	4	3	2	1

(1.4.7)

7. Does the opinion of your caregivers' (family and others?) matter to you a lot?

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
5	4	3	2	1

(3.3.1)

Question 8 and 9 are in the context of the initial assessment and provision of the environmental control (EC) device to you, which may have been some time ago now.

8. You feel completely free in the decision of using the EC device?

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
5	4	3	2	1

(1.5.2)

9. You completely trust the advice of NTRECES staff.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
5	4	3	2	1

(2.4.1) (3.2.1)

10. In the list below please order the tasks that you consider more important for your independence and tick the box if you are able or unable to undertake them:

Task	Importance for independence 1 (very important) to 5 (not important at all)	Able to do. (with EC)	Unable to do
Walking			
Bed/chair transfers			
Eating			
Personal hygiene			
Shopping			
Make and receive calls			
Community travel			
Medication management			
Financial management			
Switch lights on and off			
Use of PC			
Bed controls			

(1.4.6)

11. How often do you use the following technologies listed below? including if you use your EC device to undertake the task.

Technology	Once or more than once daily (5)	Once or twice a week (4)	Twice a month (3)	Less than once a month (2)	Never (1)
1. TV					
2. Mobile phone					
3. Laptop/desktop					
4. Tablet					
5. Smart speaker					

Technology	Once or more than once daily (5)	Once or twice a week (4)	Twice a month (3)	Less than once a month (2)	Never (1)
6. CCTV					
7. DvD Player					
8. Smart watch					
9. Games console					
10. Satellite/digital radio					

(2.2.1)

12. You think your Internet Service Provider (ISP) is trustworthy

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
5	4	3	2	1

(2.11.4)

13. You think that the technical giants like Google, Amazon, Facebook, etc., can be trusted with your information?

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
5	4	3	2	1

(2.9.7)

14. Do you think ISA devices (such as Alexa, Google home, etc.) are reliable?

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
5	4	3	2	1

(2.7.5)

15. Do you think your existing EC device is reliable?

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
5	4	3	2	1

(2.7.5)

16. Do you think your most used technical device, for example TV or mobile phone is reliable?

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
5	4	3	2	1

(2.7.5)

17. You think you feel secure whilst using the different technologies listed below (if they use them)?

Name of technology	Strongly agree (5)	Agree (4)	Neither agree or disagree (3)	Disagree (2)	Strongly disagree (1)
1. Online banking					
2. Email					
3. Texting Apps like WhatsApp					
4. Search engines like Google					
5. EC device					
6. ISA device					

(2.8.1)

18. You think voice interaction is much easier as compared to conventional input methods?

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
5	4	3	2	1

(2.6.4)

Appendix 3: RP summary tables

Findings for user characteristics research propositions

RP No	RP	Accepted or rejected	Altered
RP02a	Age has a negative effect on the attitude to adopt an ISA device.	Rejected	
RP02b	Age has a negative effect on PBCs.	Rejected	
RP03a	Being female has a negative attitude towards intention to adopt an ISA device.	Rejected	
RP03b	Being female has a negative effect on PBCs.	Rejected	

(*Continued*)

RP No	RP	Accepted or rejected	Altered
RP04a	Desire for independence will positively influence attitude towards intention to adopt the ISA device.	Rejected	
RP04b	Desire for independence will have a positive effect on the PBCs.	Rejected	
RP05a	Voluntariness of the participant to try a new technology will positively influence their attitude towards intention to adopt an ISA device.	Accepted	
RP05b	Voluntariness of the participant to try a new technology will positively affect their PBCs.	Rejected	
RP06a	Openness to innovation leads to a positive attitude towards intention to adopt ISA device.	Accepted	
RP06b	Openness to innovation has a positive effect on PBCs.	Rejected	
RP07a	Participants with higher external engagement have positive attitude towards intention to adopt ISA device.	Accepted	
RP07b	Participants with higher external engagement have a positive effect on the PBCs.	Rejected	
RP08a	Participants with higher income will have a positive attitude towards intention to adopt an ISA device.	Altered	Participants with higher disposable income will have a positive attitude towards intention to adopt an ISA device
RP08b	Participants with higher income will have a positive effect on the PBCs.	Altered	Participants with higher income (disposable income) will have positive effect on the PBCs as participants can delegate the complex task of technology set up to the professionals.

Findings for subjective norms research propositions

RP No	RP	Accepted or rejected	Altered
RP09a	Family and peer pressure positively affect the intention to adopt an ISA device	Altered	For the participants, who lacked technical expertise, family, and peer pressure (advice) did play a positive part in the intention to adopt an ISA device
RP09b	Trust in the advice of the NTRECES staff is positively affect the intention to adopt ISA device.	Accepted	
RP09c	There is a positive relationship between the opinions of those who provide care and support and the intention to adopt ISA devices.	Altered	Depending on the strength of the relationship of the participant with the caregiver, opinion of the care support system will positively affect the adoption of an ISA device.

Findings for perceived behavioural control research propositions

RP No	RP	Accepted or rejected	Altered
RP11	There is a positive relationship between familiarity with technology and intention to adopt ISA device.	Accepted	
RP12	Users with a good technical support network will have a positive effect on the attitude towards intention to adopt ISA device.	Accepted	
RP13	Users' residence owned by a housing association negatively effects the attitude towards the intention to adopt ISA devices.	Altered	Residing in private residences positively effects the users' attitude towards intention to adopt an ISA device.
RP14	Trust in the advice of the NTRECES staff is positively affect the intention to adopt ISA device.	Accepted	
RP15	The lack of access to the open market has a negative effect on attitude toward intention to adopt ISA devices.	Rejected	
RP16	Perceived ease of interaction leads to positive attitude towards intention to adopt ISA device.	Accepted	
RP17	Higher perceived reliability of a device leads to positive attitude towards intention to adopt ISA device.	Altered	Perceived reliability does affect the attitude towards intention to adopt ISA device, but other factors such as lack of choice and availability of backup device should also be considered.

RP No	RP	Accepted or rejected	Altered
RP18	Higher perceived confidentiality results in a positive attitude towards intention to adopt ISA device.	Altered	Perceived confidentiality does not affect intention to adopt an ISA device negatively unless other factors are considered.
RP19	Higher perceived security has a positive impact on the attitude to adopt.	Altered	Perceived security will negatively affect the attitude towards intention to adopt an ISA device, if the user does not have a secure alternative device or if the device is being used for security critical functions.
RP20	Higher perceived usefulness leads to a positive attitude towards intention to adopt an ISA device.	Accepted	
RP21	Perceived trust in service provider leads to a positive attitude towards intention to adopt ISA device.	Rejected	

Findings for voice interaction experience research propositions

RP No	RP	Accepted or rejected	Altered
RP22	Identification and assignment of agency to ISA devices will positively affect the attitude towards intention to adopt the ISA device.	Rejected	
RP23	The greater the emotional attachment to the ISA devices, the stronger the attitude towards intention to adopt the ISA device.	Altered	The novelty and ease of the voice interaction, and the entertainment value positively affects the attitude towards adoption of an ISA device (RP23).