UNIVERSITY of LIMERICK

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Development of a design tool to optimise acceptance of exoskeletons by older adults

By

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Declaration

I hereby declare that this thesis is entirely my own work, and not been submitted for any other awards at this or any other academic establishment. Where use has been made to the work of other people, it has been fully acknowledged and referenced.

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Linda Shore

PhD by Publication Declaration

This body of work has been prepared and submitted as a PhD by publication. I hereby declare the publications that have been submitted/published and my contribution to each one listed below:

Publication 1: Older Adult Insights for Age Friendly Environments, Products and Service Systems.

Personal Contribution: I am the lead author. I conducted and was responsible for the strategy and plan of fieldwork with 22 older adult participants. In turn I prepared and presented the analysed findings as a major feature during a Co-Design symposium in Limerick, June 2016. I relied on the co-authors and my supervisors for minor review or recommendations.

Publication 2: Technology acceptance and user-centred design of assistive exoskeletons for older adults: A commentary.

Personal Contribution: I am the lead author. My main contributions were to establish findings from a literature review of technology acceptance models and other associated models and design approaches to exoskeleton development. These findings and knowledge were published as a narrative review. I relied on the co-authors and my supervisors for minor review or recommendations.

Publication 3: Technology Acceptance and perceptions of exoskeletons by older adults – A qualitative study using a grounded theory approach.

Personal Contribution: I am the lead author. This paper documents the second episode of fieldwork with 24 older adult participants. It documents and highlights novel application, research outputs, user narrative and expression collected and analysed by the lead author. This fieldwork was a major influence on the research outputs. I relied on the co-authors and my supervisors for minor review or recommendations.

Publication 4: Exoscore: A Design Tool to Evaluate Factors Associated with Technology Acceptance of Soft Lower Limb Exosuits By Older Adults.

Personal Contribution: I am the lead author. This paper documents the pilot study of Exoscore, including application of new constructs and items (major research outputs) during live concept testing of XoSoft. I relied on the co-authors and my supervisors for minor review or recommendations.

Abstract

Older adults may have some prior use and knowledge of technology, but may also express or experience the digital divide, whereby the pace of emerging technology can present challenges to older adults and their ability to 'keep up'. This can be a factor to device abandonment or loss in confidence to adopt the technology. The experience of ageing can be a positive one, with many older adults expressing the freedoms of mind and body when possible.

Exoskeletons and exosuits offer capacity to augment the ability and mobility of older adults who experience functional limitations. However, these emerging technologies also present challenges of acceptance and adoption by older adult users. It is critical that understanding and insights are incorporated throughout concept development phases as a means to optimise acceptance and adoption.

Study 1 explored and engaged with 22 older adult participants in order to observe and understand challenges to mobility and quality of life as we age. In addition, it implemented a number of design methods and collaborative approaches in order to share the findings from the fieldwork, culminating in a Co-Design Symposium.

Study 2 completed a narrative review regarding the Technology Acceptance Models and user centred design guidance in relation to older adults' acceptance of exoskeletons.

Study 3 was an opportunity to conduct a second phase of fieldwork with 24 new older adult participants. The purpose of this fieldwork was to investigate the perceptions older adults have to emerging technologies, including exoskeletons.

Study 4 Upon completion and analysis of the fieldwork, novel outputs emerged that created the basis for a Pilot study with older adult participants and XoSoft exoskeleton in a lab setting.

Globally, as the ageing population currently continues to grow, the intervention of social robots and robotic assistive devices offers potential additional supports to independence and quality of life.

Gerontechnology ensures we, as designers or developers of emerging technologies include understanding of the older adults' experience and acceptance as part of a user-centred design approach. Older adults have specific acceptance criteria regarding exoskeletons and exosuits, and to date, this is currently not widely understood or documented.

This research documents a ground theory approach, gaining knowledge, understanding and insights from older adults. It offers interpretations and analyses that have emerged as crucial factors to the development of an original approach to exoskeleton and exosuit development.

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I wish to extend my most sincere appreciation to my supervisors, Professor Adam de Eyto and Professor Leonard O'Sullivan; words cannot express how much I appreciate their encouragement, wisdom and support - guiding my landing as I learned how to fly.

The participants and groups that engaged with me during and throughout my fieldwork, sharing many laughter filled moments and at times, poignant share of what it is to be human and ageing at a time of technology and robotic advancements which can instil excitement, apprehension and opportunity. Their rich insights, time and thought have been immeasurably helpful and appreciated, thank you.

Warm gratitude and appreciation are extended to my Design Factors colleagues, particularly to Dr Eoin White & Dr Valerie Power for their knowledge and encouragement with project development, writing and chat. The School of Design, at University of Limerick has remarkable, knowledgeable and creative colleagues that were at all times available, encouraging, and supportive to me, thanks to all.

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The opportunity to work on XoSoft has broadened my learning, and the warmest gratitude and thanks are extended to the various partners who advised or supported my learning, as well as the funding provided through this Horizon 2020 project and the University of Limerick.

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Technology acceptance and user-centred design of assistive exoskeletons for older adults: A commentary.

Shore, L., Power, V., de Eyto, A. and O'Sullivan, L., 2018. Technology acceptance and user-centred design of assistive exoskeletons for older adults: A commentary. Robotics, 7(1), p.3. (https://www.mdpi.com/2218-6581/7/1/3)

Exoscore: A Design Tool to Evaluate Factors Associated with Technology Acceptance of Soft Lower Limb Exosuits By Older Adults. Human Factors.

Shore, L., Power, V., Hartigan, B., Schülein, S., Graf, E., de Eyto, A., & O'Sullivan, L. (2019) Exoscore: A Design Tool to Evaluate Factors Associated with Technology Acceptance of Soft Lower Limb Exosuits By Older Adults. Human Factors. https://doi.org/10.1177/0018720819868122

Manuscripts under review / accepted awaiting publication:

'Technology Acceptance and perceptions of exoskeletons by older adults – A qualitative study using a grounded theory approach'

Shore, L., de Eyto, A., & O'Sullivan, L.

Submitted to International Journal of Social Robotics

List of Conference presentations and papers

Co-Design Symposium, 2016

Age Friendly Environments

Shore, L, deEyto, A, Kiernan, L, Nic a Bhaird, D, Connolly, A, White, PJ, Fahey, T, Moane, S. (2016) Co-Design Symposium, ISAX, Limerick.

Engineering & Product Design Education Conference, 2017

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Shore, L, deEyto, A, Kiernan, L, Nic a Bhaird, D, Connolly, A, White, PJ, Fahey, T, Moane, S. (2017) Older adults' insights for age friendly environments, products and service systems. ISBN 978-1-904670-85-8

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Out in the field: perceptions of robotic assistive devices by Irish older adults

Shore, L, deEyto, A, O'Sullivan, L (2018) Out in the field: perceptions of robotic assistive devices by Irish older adults. http://ichn.ie/registration-open-irish-ergonomics-society-ies-annual-conference-in-trinity-college-dublin-on-thursday-31-may/

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Investigating perceptions related to technology acceptance & stigma of wearable robotic assistive devices by older adults – preliminary findings.

Shore, L, deEyto, A, O'Sullivan, L. (2018) Investigating perceptions related to technology acceptance & stigma of wearable robotic assistive devices by older adults – preliminary findings. DOI: 10.21606/drs.2018.477

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Exoscore – A design tool to evaluate factors associated with technology acceptance of soft lower limb exosuits by older adults.

Shore, L, deEyto, A, O'Sullivan, L (2019).

Open University Health & Wellbeing Research, 2019

Understanding perceptions & technology acceptance of exoskeletons by older adults.

Linda Shore / https://www.youtube.com/watch?v=Y_oVGBY4Whw&feature=youtu.be

List of Abbreviations

AAL – Active Assisted Living Programme

ADL – Activities of Daily Living

ANX – Anxiety

AT – Assistive Technology

ATT – Attitude Towards Technology

ATUT – Attitude Towards Using The Technology

BI – Behavioural Intention

CAQDAS – Computer Assisted Qualitative Data AnalysiS

EP – Experiential Perception

EU – European Union

EE – Effort Expectancy

FAC – Functional Ambulation Category

FC – Facilitating Conditions

HAAT – Human Activity Assistive Technology Model

HC – Health Condition

HCD – Human Centred Design

HRI – Human Robot Interaction

IADL – Instrumental Activities of Daily Living

ICF – International Classification of Functioning, Disability & Health

IDAM – Iterative Design Assessment Model

ISAX – Ireland Smart Ageing Exchange

ISO - International Organization for Standardization

MPT – Matching Person & Technology Model

PAD – Perceived Adaptiveness

PC – Personal Computer

PE – Perceived Enjoyment

PEG - Percutaneous Endoscopic Gastrostomy

PEOU – Perceived Ease of Use

PU – Primary User

PU – Perceived Usefulness

QOL – Quality of Life

QoLE – Quality of Life Enhancement

R&D – Research & Development
RADs – Robotic Assistive Devices
RESNA – Rehabilitation Engineering and Assistive Technology Society of North America
SE – Self-Efficacy
SI – Social Influence
SL – Self Liberty
SMS – Short Message Service
STAM – Senior Technology Acceptance Model
SUS – System Usability Scale
TAM – Technology Acceptance Model
TPB – Theory of Planned Behaviour
TRA – Theory of Reasoned Action
UCD – User Centred Design
UN – United Nations
UTAUT – Unified Theory of Acceptance and Use of Technology
UX – User eXperience
WHO – World Health Organisation

Glossary of Terms

Assistive Technology – a device or support system that assists a person experiencing a disability.
Co-Design – facilitates designers and users collaborating and working towards design solutions.
Design for All – see Universal Design
Digital Divide – a negative experience when the pace of technology development out matches ability of user groups – e.g. older adults.
Exoskeleton – a robotic device with a rigid chassis that can augment body movement.
Exosuit – a soft robotic wearable garment, without any rigid features.
Fieldwork – engaging with people in their settings and on their terms as part of a design research approach.
Gerontechnology – a design approach intended to deliver design solutions that impact and assist older adult users, as they engage with technologies that maintain or enhance independence.

Inclusive Design – a design approach that considers the diversity of users and how to meet these needs through design.

Interaction Design – considers how the person will interact or engage with a product or service system.

Lifespan Approach – A design approach that can be applied and considered across the lifespan.

Quality of Life – the level of satisfaction with life (health, wellbeing, fulfilled needs) as experienced by a person.

Self-fulfilling prophecy – a person’s expectation of an event of occurrence happening or about to happen.

Technology Abandonment – the unsuccessful adoption and use of a technology by a person.

Technology Acceptance – the successful adoption and use of a technology by a person.

Technology Acceptance Model – A model composed of a likert scale questionnaire that is used to describe factors that explain and affect user acceptance of a technology.

Universal Design – a design approach that considers and applies design solutions for users of all abilities.

User Centred Design – a process whereby users are involved and considered at each stage of design and iteration.

1. Introduction

This thesis will document a body of research that was undertaken as a means to identify knowledge gaps and older adult needs requirements to optimise exoskeleton and exosuit acceptance. Each chapter will discuss the specific aims, objectives and methods used as a means to discover and document the key findings that emerged from this enquiry.

1.1 Motivation & context of the research

In recent years the researcher has spent time out in the field on various studies and fieldwork with older adult participants as a means to understand the ageing experience and products and service systems that are used daily. Previous work has been discussed and shared at conferences with passion. The curiosity and integrity to deliver and define design solutions that benefit people is of paramount concern and deserves time and effort in order to produce and delivers outputs that benefit quality of life as we age.

The Horizon 2020 project XoSoft (www.xosoft.eu) project presented a new challenge to explore and learn how or what is required to optimise acceptance of exoskeletons by older adults. This research would expand and use various design research approaches and methods that include semi-structured interviews, cultural probes, observation, conversations, assistive device experience, memo writing, audio and video recording, visits and experience episodes with older adult participants, and journaling.

At all times the participants were treated with respect and consideration. The ethics applications for both fieldwork studies, ensured the participants understood and were aware of their value and expertise as contributors. The time spent out in the field is now documented in this thesis and intended to justify and validate the rich insights and time shared by the participants with the researcher.

Figure 1 offers a visual summary of the work and rigour applied to developing outputs and innovations of this research. Beginning in 2016 with a research statement and working through the various studies that were published along the way. In addition, and as per a grounded theory approach, memo writing, and constant comparison ensured a sense of action and amending as knowledge developed.

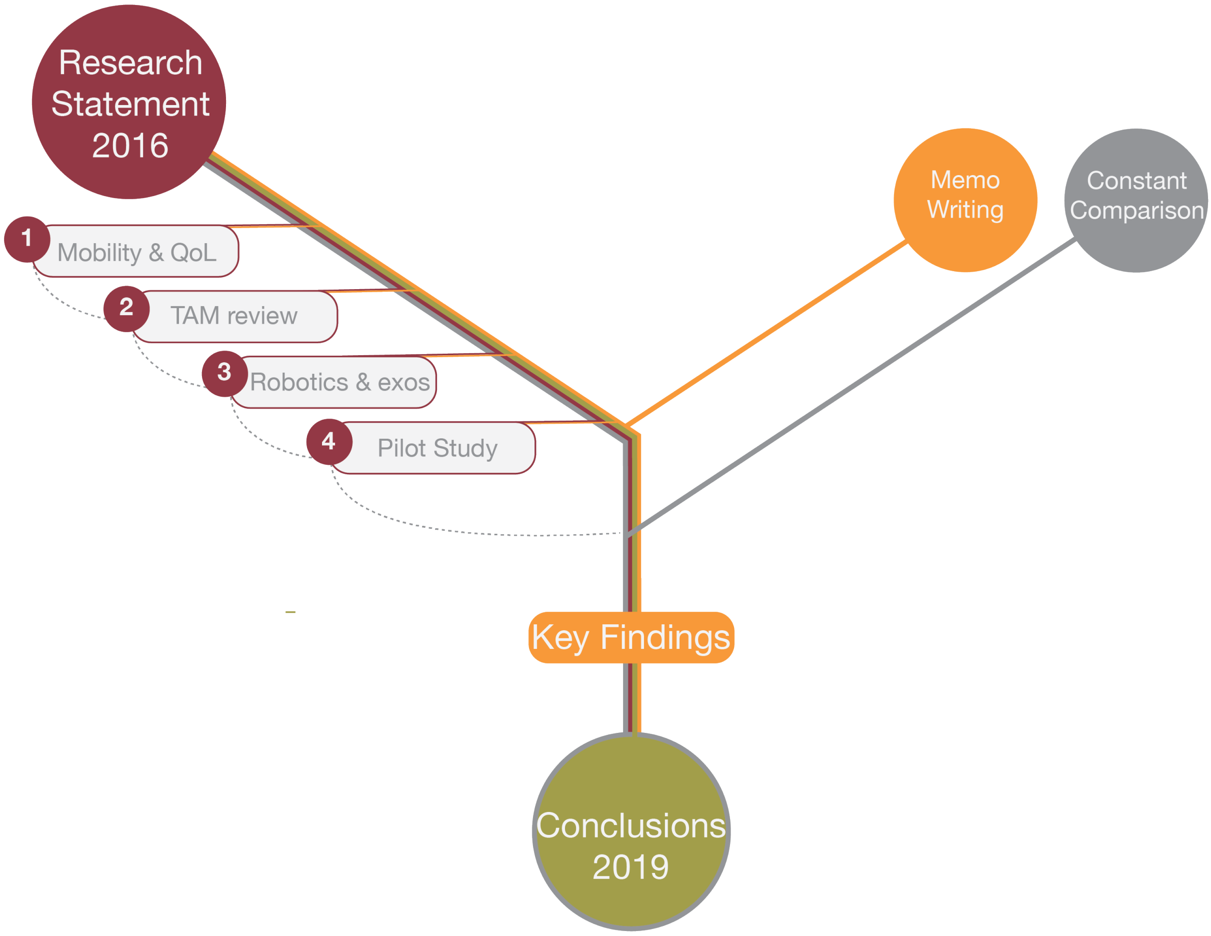

Figure 1 Research strategy and approach that documents the studies undertaken as a means to develop outputs and innovations of the research.

1.2 Research Scope

Previous post graduate work to this research was undertaken by the author during 2013-2015 (Shore, 2015) which highlighted how the ageing experience and independence can be challenged by limited mobility. This can impact on ability to socialise and engage with personal, social and community interactions, which in turn can impact on quality of life. Exoskeletons and exosuits can offer assistance to older adults who experience mobility decline. It is imperative to understand the acceptance criteria and perceptions older adults have towards these emerging technologies.

This research had four primary research questions:

1) What are older adult insights regarding mobility and age-friendly environments – and what design methods can support identifying and defining needs requirements and solutions?
2) What are the useful elements of existing TAMs and user centred design in relation to older adults' acceptance of exoskeletons?
3) What perceptions do older adults have of robotic assistive devices and how do they relate to technology acceptance and exoskeleton development?
4) Can an integrated assessment method and design approach be developed for exoskeleton design to help improve technology acceptance by older adults?

It was considered that qualitative methods with a grounded theory approach was appropriate as an enquiry approach about emerging technologies with older adult participants. Four studies were undertaken to develop knowledge and deliver outputs of the research that would benefit and optimise acceptance of exoskeletons by older adults. These studies are presented as four published papers (Chapters 3, 4, 5, 6).

1) Study 1 – Time spent 'out in the wild' with 22 older adult participants over a period of five weeks to understand and gain insight about Quality of Life and mobility of older adults (2016).
2) Study 2 – A literature review as a means to reveal knowledge gaps about TAMs and user centred design guidance in relation to older adults and acceptance of exoskeletons.
3) Study 3 – A further episode of fieldwork spent out in the wild, this time with 24 new older adult participants and a scope of enquiry that investigated perceptions older adults have to emerging technologies, including exoskeletons (2017).
4) Study 4 – The episodes of fieldwork and literature review were analysed and interpreted to reveal original and novel outputs of the research, of which a pilot study was undertaken with descriptive statistics and outputs discussed.

1.3 Overview of the research

This section will offer a brief overview of each chapter, the work undertaken, and outputs that were shared along the way through conference and/or publication.

Chapter 2 – Review of the Literature

The literature review was undertaken to critique and detail the current knowledge regarding technology acceptance models. More specifically, enquiry delved further to discover if there were any TAMs relating to older adult acceptance of emerging technologies or exoskeletons. This chapter discusses aspects of learning (e.g. ageing population, current assessment methods for assistive technologies and technology acceptance) that were necessary to gain knowledge as a means of developing the design research strategy, and an approach that was beneficial to the development of exoskeleton acceptance by older adults.

Chapter 3 – Preliminary fieldwork to understand older adult perceptions to environments, products and service systems.

The aim of this chapter is to document a Co-Design approach to understanding the challenges of ageing as experienced by older adults and how this can impact on Quality of Life and mobility. A design coalition between a number of academic institutions and an 'ageing' think tank in Ireland mobilised as a collaboration to organize a Co-Design symposium to report on and present findings from a field study facilitated by the current researcher.

This chapter highlights the research opportunity to 'deep dive' and explore the experiences of ageing with older adult participants. This activity included distribution of cultural probe packs (Gaver *et al.* 1999), as well as social activities spent with the older adult participants, e.g. going on a bus trip.

The fieldwork findings were presented and were crucial to the Co-Design symposium that was attended by in excess of 100 people, including some of the design research participants. The objective of the Co-Design symposium was that the attendees, by working together, could deliver concept solutions to the needs statements of the five identified themes - Mobility, Public Spaces, Safety, Social Engagement and Services and Facilities.

Various artefacts of research evidence were on display as well as sketching and modelling tools to support the visualisation and design activity. The collaborative approach of this design coalition working together with the participants and attendees, highlights the success that can be achieved in understanding mobility and age friendly environments.

Chapter 4 – Review of gerontechnology acceptance and user centred design of exoskeletons.

Exoskeletons and assistive robotic interventions can offer support to older adults as they engage in ADLs (Katz, 1983). These technologies can be a critical factor to the maintaining of independence and autonomy by older adults (Charness and Jastrzembski, 2009). TAMs have evolved from theoretical approaches to models of measuring attitudinal insight by users towards a technology (Venkatesh and Davis, 2000). These models do not currently cater for older adults and exoskeleton acceptance.

In addition, older adults have not typically been involved in the process of the design of exoskeletons. Their involvement could assist with de-stigmatising these technologies and removing a sense of being labelled dependent or seen as declining in ability by the older adult, thereby resulting in a greater probability of acceptance (Cook and Polgar, 2015). Finally, the lack of user-centred design guidance, and particularly for the unique needs of older adult users, highlights a need to develop an attitudinal measure and design approach that facilitates and caters for the unique needs requirements of older adults.

There is a gap in the literature whereby TAMs appear not to have evolved to cater for exoskeleton and exosuit development. In addition, very little is known about older adults' opinions of using exoskeletons or assistive robots on a day to day basis in the home (Wu *et al.* 2015). This chapter offers a narrative review about existing TAMs, including ones that have been introduced as a means to consider the physical, psychological and contextual characteristics of older adults needs in relation to everyday technology or social robots.

Chapter 5 – Investigating perceptions related to technology acceptance of wearable robotic assistive devices for older adults.

This chapter presents findings and data from fieldwork undertaken by the researcher with 24 older adult participants that investigated experiences of ageing and older adult perceptions of robots and exoskeleton devices. This chapter presents details of a grounded theory approach and the practice of constant comparison as a means to support the emerging theory (Charmaz, 2014).

The findings from the fieldwork were interpreted and analysed using a mixed methods approach of affinity diagramming, memo writing and mapping, as well as the use of Nvivo software (QSR International). This activity is documented further in the chapter, and in addition, a code book which displays the progression of line by line coding to categories and themes can be viewed in appendix 4.

The emerging theory as well as literature knowledge highlighted gaps and defined necessary inputs that could support exoskeleton and exosuit acceptance by older adults. The five themes provided broad understanding of perceptions older adults have towards exoskeletons. These findings motivated and developed a new design approach to evaluate attitudinal measure to exoskeletons by older adults.

Chapter 6 – Pilot study of Exoscore.

The aim of this chapter is to introduce Exoscore and test the findings from the fieldwork. The three new constructs introduced in Chapter 5 were applied and embedded into a new design evaluation tool - Exoscore.

This new tool is an original approach to wearable robotic design and testing that offers phases of perception, experience and reflection by older adults, engaged with design teams testing a concept exoskeleton in a lab setting. Exoscore is a hybrid of traditional TAM approaches and usability testing.

This chapter documents and presents the results of an initial pilot study of Exoscore with older adult participants during testing sessions of XoSoft exosuit.

In addition, Exoscore is embedded as part of a new Iterative Design Assessment Model (IDAM) that captures reflective practice, interactions and engagement between designers and participants throughout each evaluation phase.

Chapter 7 – Discussion

This chapter summarises the salient points of the research and highlights the novel findings. In addition and by way of conclusion, the limitations of this research are discussed as well as the future research opportunities and recommendations.

2. Review of the Literature

The aim of this chapter is to review literature in relation to a) Ageing, b) Assistive devices & technology, c) Exoskeletons & Exosuits, d) Technology Acceptance, and e) User centred design. As we age, challenges to our mobility can impede our independence and autonomy. This challenge can prevent or limit abilities by older adults to engage in day to day tasks and activities. Assistive technologies such as walking aids can offer enhanced support to reduced mobility. Exoskeletons and exosuits are emerging technology devices that can improve physical functioning and rehabilitation outcomes. Design approaches can support enquiry of acceptance of these devices in order to optimise their acceptance by older adults. Figure 2 displays the topics discussed in this literature review.

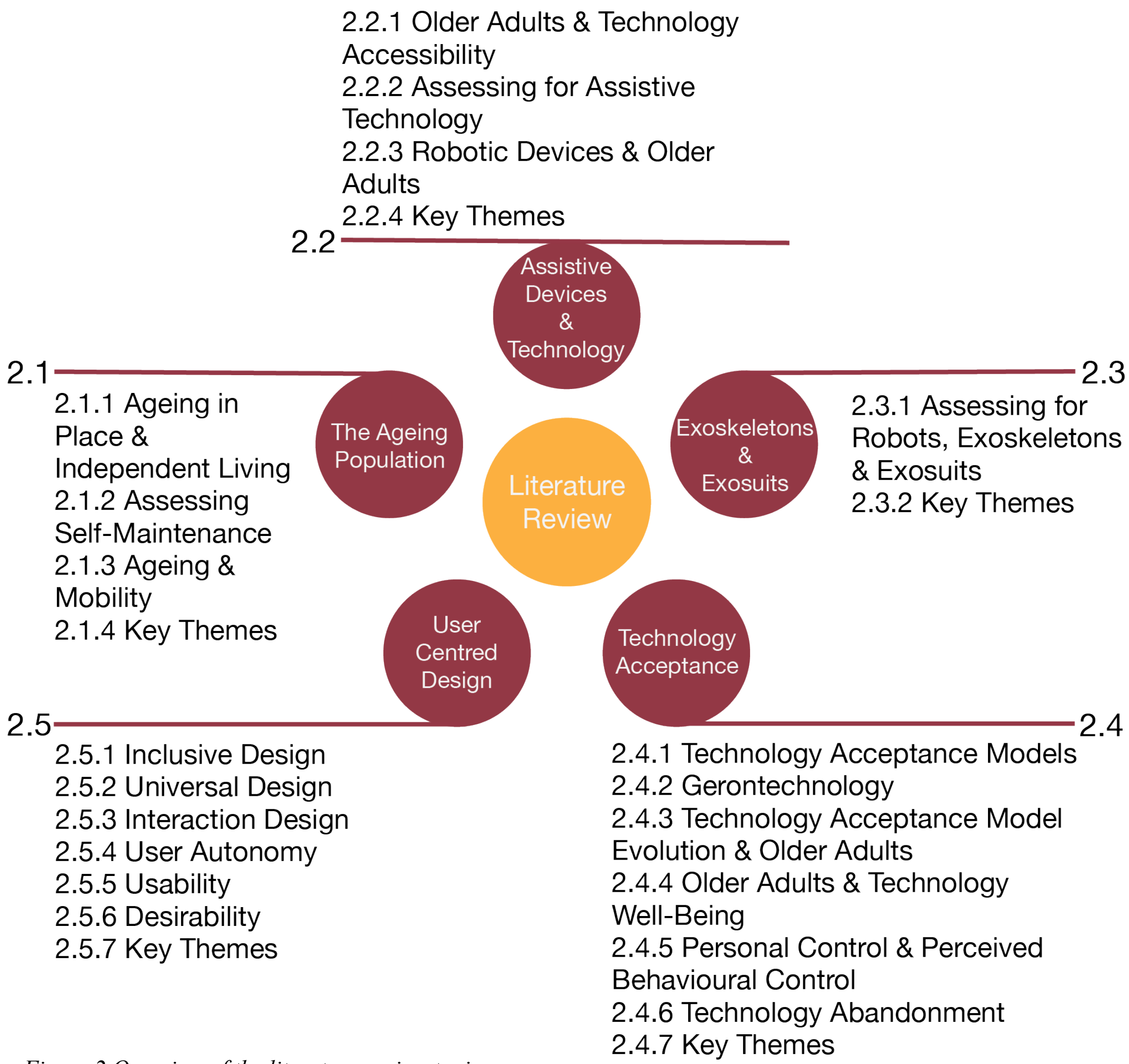

Figure 2 Overview of the literature review topics.

2.1 The Ageing Population

At least a quarter of the European population will be aged over 65 by 2020. This cohort will increase, growing by two million per year after 2012 (AAL-EU, 2016). There is also an expectation that children born after 2011 may live to 100 years of age (European Commission 2014). Policy makers and governments are being advised to take action and ensure that older adults maintain access to services and supports as they experience ageing and often age related deterioration of abilities in vision, hearing and mobility (UN, 2015).

The World Bank highlights various challenges now presented with an aging population e.g. fiscal inequality in retirement, reduced fertility. However, it also has identified areas of opportunity during this time: e.g. reducing health inequalities, improving health habits and health care reforms (Bussolo, et. al., 2015). This opportunity could be optimised particularly due to the shrinkage in the working age population (18-64) (European Commission 2014; AAL-EU, 2016). Increased longevity may impact on health care costs, not because of ageing, but more so due to advances in medical technology which in turn may add strain on health care budgets and expenditure (Bussolo *et al.* 2015). The following points offer an insight to future expected growth, decline and changes expected in European populations over the coming years:

- By 2020 around 25% of the European population will be over 65.
- People aged from 65 to 80 will rise by nearly 40% between 2010 and 2030.
- Since 2012, the European working-age population has started to decrease, while the over-60 populations will continue to increase by about two million people a year.
- The strongest pressure is expected during the period 2015-35 as the so-called baby-boom generation enter retirement.
- The ratio between people at work and the remaining population is expected to become 2 to 1, from the current 4 to 1.
- 65-74 years old Europeans, together with people on low incomes, the less educated and the unemployed, are largely represented within the 30% of Europeans that have never used the Internet.

(AAL-EU, 2016)

In countries where health systems are already well-equipped to diagnose and treat conditions associated with old age, public policies are needed to mitigate the upward pressure on national health care budgets exerted by the rising costs of health care services, and the longer lifespans and increasing numbers of older persons (UN, 2015).

The World Bank refers to the factors related to health care costs and the 'last years of life,' stating that death related costs are manageable; but during life there should be an approach of prevention of typical age-related diseases and life changes e.g. cardiovascular disease, obesity, workload application & performance.

Concern is expressed by other global agencies for action by policy makers and governments to deliver more innovative solutions to provide a positive ageing experience for older adults. The areas of consideration are:

- Accessibility options of older adults with reduced mobility, visual hearing or other age-related impairments.
- Access to public services in rural/urban areas.
- Improvement of proficiencies with technologies, mobile devices etc.
- Bridging the digital divide by providing access and education to learning.
- Connected health and similar service system applications that can offer updates via SMS etc.

  (UN, 2015)

The narrow focus that directs spending on long term care to health care resources is increasing overall costs. This impacts on the experiences and quality of life for older adults and the sandwich generation i.e. women looking after children and ageing parents and perhaps, also working themselves. There is a need to direct care and funding to more community-based settings (Bussolo *et al.* 2015).

2.1.1 Ageing in Place & Independent Living

The environments we age in also present the challenge that we remain independent and autonomous to how we socially engage with communities and activities daily (Cooper, 2014). 'Ageing in place' is a term that describes the living experience for an older adult to maintain choice and access to housing and living arrangements that ensure they:

"*remain independent for as long as possible*"

(UNFPA and HelpAge International, 2012).

By remaining independent, older adults can enhance or maintain their quality of life and maintain integration in community and social settings.

Every second, two people celebrate their 60th birthday across the world. This milestone reflects advancements in longevity, medical/health care, nutrition, education and economic well-being (UNFPA and HelpAge International, 2012). This highlights also, the challenges that present to ensure that:

> *"People everywhere must age with dignity and security, enjoying life through the full realisation of all human rights and fundamental freedoms. Looking at both challenges and opportunities is the best recipe for success in an ageing world."*
>
> (UNFPA and HelpAge International, 2012, P12)

Rowe & Kahn (1987) discussed and evolved 'usual ageing and successful ageing' detailing how 'extrinsic factors' (physiologic, psychologic or sociologic) and personal habits can determine or influence the usual ageing process. The loss of a spouse (bereavement) and of friends and neighbours (relocation) are common events for older adults and can present challenges to an older adult maintaining their sense of independence and autonomy (Rowe and Kahn, 1987). Age-related physical decline and reduced economic autonomy as a result of retirement can impact our autonomy and control. This consequence can occur whether we remain independently living in our own home or set up a new home in our later years, including institutional or 'care' home supports.

It is therefore considered important that for ageing to be deemed 'successful' support mechanisms that are in place for the older adult need to consider the needs, requirements, and effects of those supports. Another key observation by Rowe & Kahn is the importance of avoiding 'infantilising' or 'learned helplessness'. This may happen as a result of supports that don't offer encouragement to the older adult as they complete a task, or supports that removes autonomy or the ability to do a task (Rowe and Kahn 1987).

Successful ageing is a relevant term to the description of ageing in gerontology studies. Rowe & Kahn's definition (1997), Figure 3 contains the three elements deemed necessary when describing successful ageing:

> *"low probability of disease and disease related disability, high cognitive and physical functional capacity, and active engagement with life."*
>
> (Rowe & Kahn, 1997)

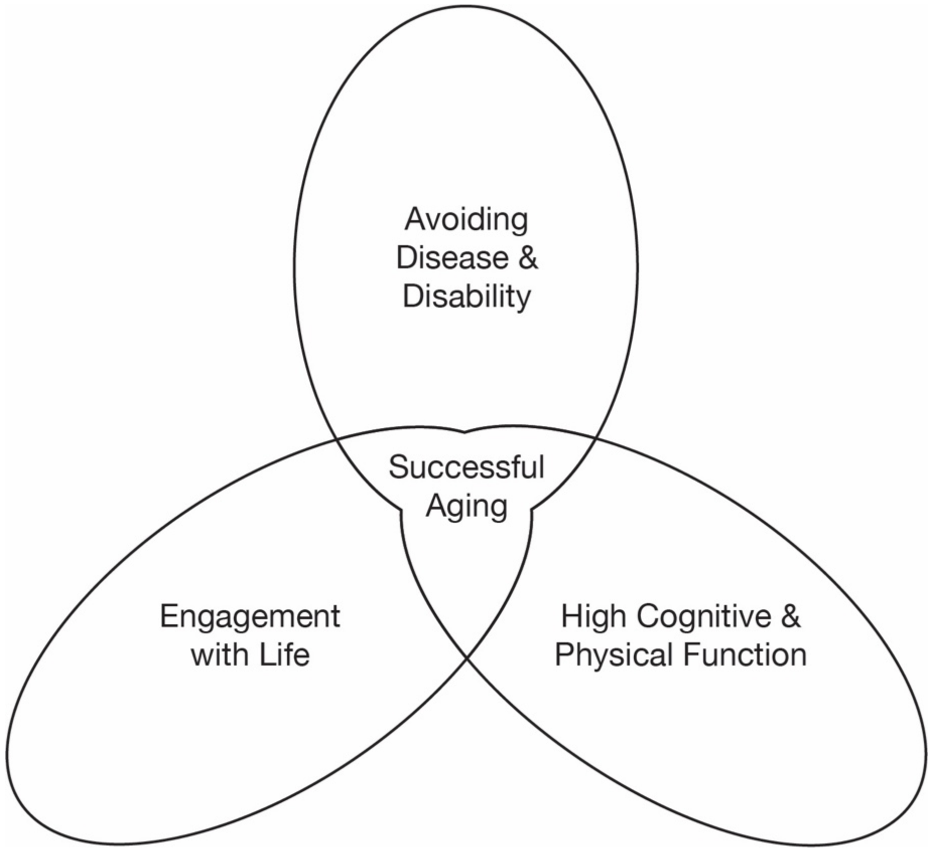

Figure 3 Model of successful ageing (Rowe & Kahn, 1997)

There are various reasons why we may wish to age in place. Our home holds memories and connections to the past as well as holding the possessions we have acquired, and importantly the connection to the neighbourhood or community we live in. Moving to an institution is not desirable for some older adults, and they may opt to adapt or retrofit their home as a means to support ageing in place (Van Hook, et. al., 2003). Ageing in place supports the continuity of the living environment, maintenance of independence in the community and social inclusion (Barrett, et. al., 2012).

Independence and social inclusion by older adults ageing in place can be resolved by appropriate design, application and education to using and interacting with assistive devices and technologies specific to supporting age related decline management between the older adult and care-givers (Mahmood, et. al., 2008).

2.1.2 Assessing self-maintenance

Long term care of an ageing population both in institution and non-institution settings has been raised as a point of concern for a number of years, particularly in relation to typical chronic age-related conditions (cardiovascular disease, arthritis, fractures etc.) and the older adult as they conduct activities of daily living e.g. bathing, dressing, walking (Katz, et. al., 1963).

A reduction in functional ability and health by an older adult requires formal supports (e.g. community and health services) and informal care givers (spouse, family, friends etc.) (Morris, et. al., 1996). The increased support need can be a source of isolation and desolation if there are no informal caregivers available to the older adult (Katz, 1983). A snapshot 24-hour study of IADLs, noted gender difference may also indicate preferences when conducting IADLs, e.g. men appear to value driving, handling money, whereas women appear to value reading, medication management (Fricke and Unsworth 2001)

Two index models were reviewed in relation to assessing activities of daily living. The ADL index introduced by Katz (1963), has six functions that can be measured to inform professional observers about the range of capacities and independence of an older adult. The six functions are described in Table 1.

Table 1 Activities of Daily Living (ADL) index functions, Katz, 1963

Bathing	Assistance in bathing washing or showering
Dressing	Ability to dress
Going to the toilet	Ability to get to the toilet and use if any of aids to toilet (bedpan, commode etc.)
Transfer	Moving in and out of bed or to a chair, further functions associated with same with or without supports.
Continence	Control over bowel and bladder ability.
Feeding	Ability to prepare and get food from plate to mouth.

The ADL scale is important to consider when planning design research, because of the value of the six functions, and their relationship to the day to day experiences of ability and function by older adults. ADL offers insight to the daily functional requirements and abilities of older adults (Katz, et. al., 1963).

Lawton & Brody introduced their model ‘Instrumental Activities of Daily Living (1970) (IADL) (Figure 4). This scale introduced an expansion to ADL and in addition assessed activities that generate functional ability, e.g. using telephone, shopping, food preparation, housekeeping, laundering, use of transportation, use of medicine and financial behaviour (Lawton & Brody, 1970). The ADL and IADL index ratings offer perspective to evaluate the independence and ability of a person.

INSTRUMENTAL ACTIVITIES OF DAILY LIVING SCALE (IADL)
M.P. Lawton & E.M. Brody

A. Ability to use the telephone **SCORE**

1. Operates telephone on own initiative; looks up and dials numbers, etc.
2. Dials a few well known numbers.
3. Answers telephone but does not dial.
4. Does not use telephone at all.

B. Shopping

1. Takes care of all shopping needs independently.
2. Shops independnetly for small purchases.
3. Needs to be accompanied on any shopping trip.
4. Completely unable to shop.

C. Food Preparation

1. Plans, prepares and serves adequate meals independently.
2. Prepares adequate meals if supplied with ingredients.
3. Heats, serves and prepares meals, or prepares meals but does not maintain adequate diet.
4. Needs to have meal prepared and served.

D. Housekeeping

1. Maintains house alone, or with occasional assistance (e.g. 'heavy work domestic help').
2. Performs light daily tasks such as dishwashing, bedmaking.
3. Performs light daily tasks but cannot maintain acceptable level of cleanliness.
4. Needs help with all home maintenance tasks.
5. Does not participate in any housekeeping tasks.

E Laundry **SCORE**

1. Does personal laundry completely.
2. Launders small items; rinses stockings, etc.
3. All laundry must be done by others.

F. Mode of transportation

1. Travels independently on public transportation or drives own car.
2. Arranges own travel via taxi, but does not otherwise use public transport.
3. Travels on public transportation when accompanied by another.
4. Travel limited to taxi or automobile with assistance of another.
5. Does not travel at all.

G. Responsibility for own medications

1. Is responsible for taking medication in correct dosages at correct time.
2. Takes responsibility if medication is prepared in advance in separate dosage.
3. Is not capable of dispensing own medication.

H. Ability to handle finances

1. Manages financial matters independently (budgets, writes checks, pays rent, bills, goes to bank), collects and keeps track of income.
2. Manages day-to-day purchases, but needs help with banking, major purchases, etc.
3. Incapable of handling money.

Figure 4 IADL index - Lawton & Brody 1969.

Graf (2008) discusses the differing benefits of using an ADL or IADL scale, she states that IADL function may be lost before ADL function. Therefore, IADL is a good indicator to the independence and ability of the person being assessed, e.g. the ability to shop independently may go before the ability to get dressed. The Instrumental Activities of Daily Living Scale is considered a useful tool to gather data and insight to the challenges of reducing independence and mobility that is being experienced. An example of data gathering using the IADL is displayed in Table 2 (Graf 2008).

Table 2 Graf (2008) IADL function scoring and information.

Questions	Response	Score and Rationale
"Do you have a telephone at home?" "If you need to make a doctor's appointment, do you use the telephone to do that?" "Do you call friends or your family, or receive calls from them?"	Georgia Koppel is evasive about discussing the telephone, doesn't remember the last time she used it, and can't tell Rose Applebaum her telephone number.	**Ability to Use the Telephone: 0** Ms. Koppel's answers suggest that she is at the low end of possible responses to telephone use.
"Tell me about shopping for groceries?" "How do you get to the store?" "How do you shop for large items like clothes or sheets and towels?"	Ms. Koppel walks down her street to a small store, alone or with a neighbor. She says she has plenty of clothes and can get everything she needs at her local store. She seems confused at the prospect of buying sheets and towels and doesn't answer.	**Shopping: 0** Ms. Koppel is able to shop independently for small purchases only and cannot identify how she would shop for larger or more complex purchases. She is often accompanied by a neighbor for small food purchases.
What type of food do you like to cook and eat?" "Do you ever cook using your stove?"	She says she doesn't cook much and usually microwaves frozen meals. She doesn't remember using the stove, but sometimes eats at the church or makes or buys sandwiches.	**Food Preparation: 0** Ms. Koppel gives no indication that she is able to cook a more complex meal using the stove.
"Do you have anyone who helps you with household chores, such as cleaning the bathroom or vacuuming?"	Ms. Koppel laughs and says she doesn't need help with cleaning or vacuuming and that she can sweep the floors with a broom.	**Housekeeping: 1** Ms. Koppel's response troubles Ms. Applebaum because of its lack of detail about how she accomplishes these tasks. Ms. Applebaum makes note of this but scores this item in keeping with Ms. Koppel's responses.
"What about laundry: do you do it by yourself?" "Do you have your own washer and dryer?"	Ms. Koppel seems puzzled by these questions and says she uses the sink to wash clothes. She reiterates that "everything is fine" and she doesn't need help.	**Laundry: 1** Ms. Koppel receives a score of 1 even though she seems again unable to provide complete information about how she is performing the task.
"Do you drive your own car? How do you get to your doctor's office?"	Ms. Koppel says that she doesn't drive but that friends from her church pick her up every Sunday for services. She has not	**Mode of Transportation: 0**

"Do you take a bus or a taxi, or do you drive?"	been to the doctor for a long time because she never gets sick.	Ms. Koppel's ability to travel independently or to arrange travel appears extremely limited.
"When you take medicines, do you take them by yourself or do you have help with it?"	Ms. Koppel replies that she doesn't take medicines (except "maybe aspirin for a headache" which she takes on her own).	**Responsibility for Own Medications: 1** As with the housekeeping and laundry items, this category is scored according to responses, although Ms. Applebaum is left with questions about Ms. Koppel's abilities.
"Ms. Koppel, do you pay your own bills, write checks yourself, go to the bank – or does anyone help you with that?"	Ms. Koppel says, "I can't believe how expensive everything is. I don't pay if it is too much."	**Ability to Handle Finances: 1** As Pearson observes, for some items "a score of 1… does not… mean that the highest performance criteria in that item has been met." **Total: 4 (of a possible 8)**

2.1.3 Ageing & Mobility

Age related decline can result in mobility impairment resulting in pain, poor balance, posture or limb weaknesses. Assistive devices, typically walking aids, help older adults to maintain independence and increase overall well-being (Stowe, et. al., 2010). Remaining active and productive as ageing progresses can remove perceptions of being 'old' by family, friends, and even the older adult themselves (Dychtwald 1999).

The effects of mobility decline on the older adult impacts on their independence and quality of life (Mollenkopf, et. al., 2004). Mobility that is required for social, cultural, economic and political processes, is referred to as **'motility'** (Kaufmann, et. al., 2004). Motility has three elements that support an ability to choose (or not) a capacity to be mobile:

- Access
- Competence
- Appropriation

Access refers to the various mobility options one has within a context of time, place, or other limitations as a result of the available services or equipment.

Competence is interdependent to access and appropriation and is reliant on the skills and abilities of providers to assist the mobility challenged person. Disabilities experienced by people can be greatly improved by the intervention of assistive devices, particularly those that are recommended by a professional. This will ultimately offer enablement and independence to the user with a disability

Appropriation refers to the interpretation and action undertaken by agents to access and skills requirement. It also states how skills and decisions are evaluated.

Mobility and motility are linked to the social, cultural, economic and political processes and structures that are interlaced within the three elements and experienced by people (Kaufmann *et al.* 2004).

2.1.4 Key themes emerging from this section:

- Public policies are required to mitigate the upward pressure on healthcare budgets by the increasing costs of healthcare and longer lifespans.
- The importance of supports and networks that encourage older adult autonomy when completing or engaging in day to day tasks and activities.
- Ageing in place offers positive prospects of ageing.
- ADL and IADL scales offer insight and consideration when conducting design research with older adults.
- Age related decline can result in pain, poor balance, posture and/or limb weakness.

2.2 Assistive Devices & Technology

People who experience age-related physical limitations may rely on devices or products, such as crutches, orthoses, wheelchairs, hearing aids, talking books. These devices are all commonly referred to as Assistive Technologies/Devices. These supports, when assessed appropriately for the person in the context of their world, have been shown to be powerful resources that support quality of life and experiences (World Health Organisation, 2011).

The evaluation and prescribing of a mobility device is recommended to be conducted by a professional (Van Hook *et al.* 2003; Pigliautile, et. al., 2012) to determine whether the priority for a person with limited mobility is to bear weight or maintain and assist balance (Van Hook *et al.* 2003). The risk of falls has also been shown to increase significantly in situations where mobility device are not professionally prescribed (Chen *et al.* 2011). Users of assistive devices are more inclined to report falls, however they may also be less inclined to walk outdoors due to increased fear of falls and likewise are unable to walk for more than ten minutes without resting (West, et. al., 2015). Critical requirements when prescribing the right assistive device are highlighted below:

- Characteristics of the tool (comfort, availability, functionality, durability)
- The patient (age, physical and cognitive impairment and goals)
- Both factors time between injury and tool fitting ability to perform social activities. (Pazzaglia & Mollinari, 2016)

Four types of evaluation that can be used to assess suitability of a device for a person are: 1) effectiveness, 2) efficacy, 3) availability, 4) efficiency. These can be used with various questions or assessment instruments as a means to assess suitability for the patient (Cook and Polgar 2015).

2.2.1 Older Adults & Technology Accessibility

Other emerging technologies such as autonomous vehicles can enable freedoms of choice and actions by older adults to their mobility and accessibility options. Driving of manual vehicles can become more challenging as we get older, and age related limitations or conditions may result in loss of driving licence, leading to a reduction in out of home activities (Gish *et al.* 2017). These out of home activities may lead to less access to health care, reduced independence, social isolation and depression (Edwards *et al.* 2009). Alertness while driving has been studied and suggestions for interactive alertness maintaining tasks such as music trivia e.g. name that tune as a method to avoid driving fatigue or boredom particularly for older drivers (Song *et al.* 2017). Technology advancements in driving can potentially offer solutions that equip and support older drivers. Modes of transportation, and access to these is a listed IADL and an important element to maintaining independence.

Technology has the potential to enable older adults engage in social and personal activities (Mitzner *et al.* 2018). Advancements in technology are intended to empower users from all socio economic areas, however older adults may in fact experience inequality through the digital divide due to challenges with use and acceptance of these types of technologies (Marston *et al.* 2019).

The introduction of smart phones has increased access to, and the importance of the internet. Information and communication-based technologies offer potential for improved quality of life and rehabilitation supports, however there are still segments of the older adult population that do not or cannot access the internet nor do they own a computer or smart phone (Marston *et al.* 2015).

Health and fitness apps offer successful interactions between users and technology, however it has been noted that some of these apps are not accommodating to older adults' needs (Silva *et al.* 2014). Remaining physically active and exercising has been shown to reduce depression amongst older adults (Singh *et al.* 2005). A Co-Design approach may well enhance the acceptability and use of health & fitness apps by older adults (Harrington *et al.* 2018), with calls for health technology products and services to be an integral component of health and ageing policy (Garçon *et al.* 2016).

2.2.2 Assistive Technology Assessment Tools

Older adults highlight the importance of maintaining independence to their quality of life as they age. The intervention of technology based products can enhance autonomy, if faced with a disability (Charness and Jastrzembski 2009). Accessibility and use of assistive technologies such as walkers by older adults can be impacted by feelings of a 'devalued identity' by accessing and relying on such devices. Everyday walking aids such as ski poles are viewed as more acceptable than medically issued walking sticks/aids (McNeill & Coventry, 2015).

Assistive technology assessment tools are used for referencing or application when people with disabilities engage with usually healthcare professionals to assess and determine a most suitable device or service for their particular needs.

For the purpose of this research three models were reviewed:

1. International Classification of Functioning, Disability & Health (World Health Organisation, 2001)
2. Human Activity Assistive Technology model (HAAT) (Cook and Hussey 2002)
3. Matching Person & Technology Model (Scherer 1986

International Classification of Functioning Disability & Health (World Health Organisation, 2001) offers classification to gauge individual's health or disability in the context of their environment or ability. The classification highlights five areas that help determine needs requirements a person may have:

- Activity: the execution of a task by the person.
- Participation: the involvement in a life situation.
- Activity limitations: difficulties a person may experience when carrying out activities.
- Participation restrictions: the challenges experienced in life by the person.
- Environmental and personal factors: make up the physical, social and attitudinal aspects of the person.

It offers support and guidance, by stating qualifiers to activities and experiences a person may have throughout their life. Figure 5 details the framework, the left to right headings refer to the three levels of human functioning: body or body part functioning; the whole person and finally the person in a social context.

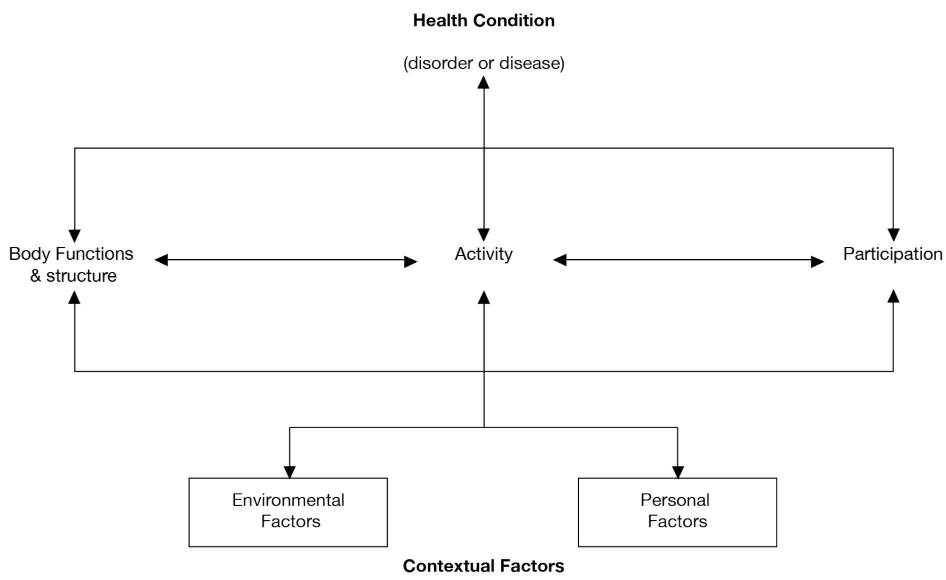

Figure 5 Representing the model of disability – Person, and the factors that affect the experience of disability, ICF, 2001

The ICF is a classification that allows for data collection and knowledge on functioning and disability. It references the effects that a disability may have on the individual, and the means to consider in order to improve or guide the day to day quality of life for the person.

Human Activity Assistive Technology Model: As an iteration to Bailey's Human Performance model, Cook & Hussey introduced the Human Activity Assistive Technology Model (HAAT) (B) (Cook and Hussey 2002). The Human Activity Assistive Technology Model (HAAT) (Figure 6) (A) displays the interactions that occur between the 1) human, 2) the task, within 3) the context of use.

HAAT was developed to analyze the complexities of someone (a person with a disability) doing something (an activity) somewhere (within a context), especially when the use of assistive technology is part of that context. It is considered to be invaluable as a tool to assist with the requirement considerations for technology devices. HAAT suggests two major adaptations of Baileys model, that being:

- A broadening of context to include social and cultural aspects, environments and physical conditions.
- Assistive technologies are included in order to display the relationship to the other three components of the Human Performance Model Figure 6 (B).

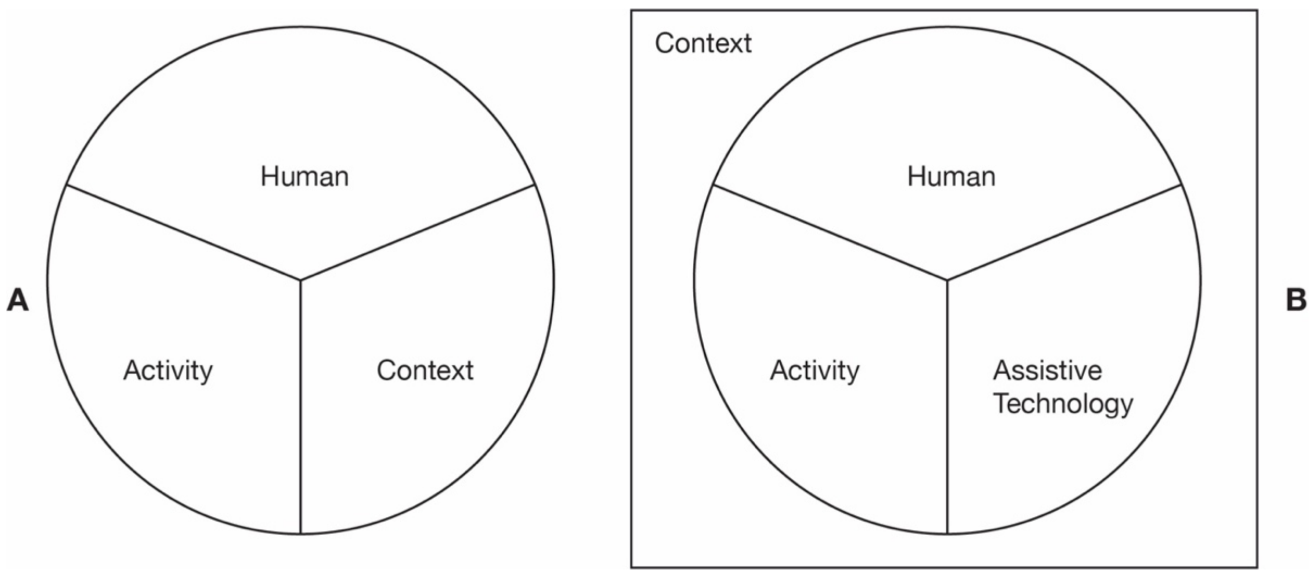

Figure 6 Adaptation of the model of human behaviour / Bailey. Cook & Hussey (2002)

As a means to explain the HAAT model, Cook & Hussey present an example narrative:

> *"Tony needs to write reports. Thus 'writing' is his activity. He is required to accomplish this as part of his work, and this specifies part of the context.*
> *Because of a spinal cord injury, Tony is unable to use his hands, but he is able to speak clearly. A speech recognition system (the assistive technology) is obtained for him. This system allows Tony to use his skills (speaking) to accomplish the activity (writing) by translating what Tony says into computer recognisable characters. As Tony speaks, the assistive technology recognises what he says and sends it to the computer as if it has been typed. Because there are other workers in the office, Tony uses a noise cancelling microphone to avoid errors in speech recognition, and he works in a cubicle to avoid bothering other workers. These further define the context of the system. Tony's assistive technology system consists of the* ***activity*** *(writing) the* ***context*** *(at work in a noisy office) the* ***human skills*** *(speaking) and the* ***assistive technology*** *(speech recognition system)"*

(Cook & Hussey, 2002: P38)

The components that could be considered helpful to the design of assistive technologies within HAAT are displayed in Figure 7:

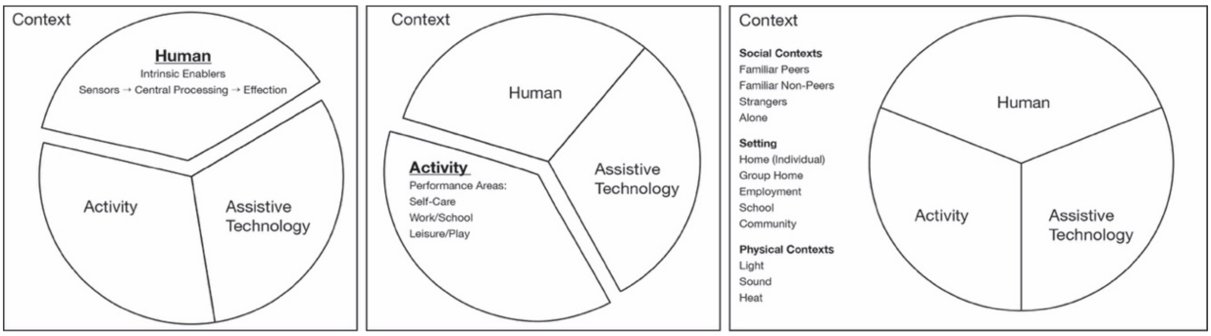

Figure 7 The Activity component of the HAAT model displaying the components that can assist design of technology devices (Cook & Hussey, 2002)

Matching Person & Technology (MPT): This model consists of validated instruments for persons with a limitation or disability aged 15+. It was developed as a result of a grounded theory study that identified three assessment areas (Scherer & Craddock, 2002). It is considered the most published model specific to assistive technology device selection (Bernd, et. al., 2009). However, it is not designed to predict use or non-use of an AT device (Lenker and Paquet 2003).

Long term use and acceptance of assistive technology devices depends on the interaction of milieu/environment, person, and the technology (see Figure 8) (Lenker and Paquet 2003; Federici, et. al., 2014). It is acknowledged that there is no standard for AT provision, and often this can lead to service gaps for the person as a result of lack or collaboration between disciplines (Federici *et al.* 2014).

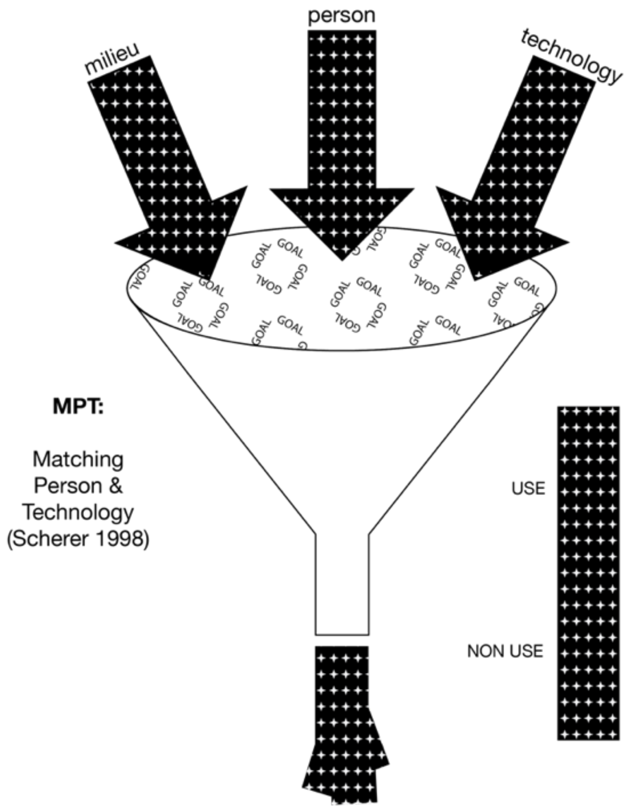

Figure 8 The Matching Person & Technology model displaying milieu, person and technology and the positive or negative outcomes that can be influenced as a result of the various interacting influences.

2.2.3 Robotic Devices & Older Adults

Robots and robotic devices are introduced as supports to rehabilitation or social assistance. Robotic devices can assist independence of older adults as they engage with tasks and activities of daily living (Pigliautile *et al.* 2012; Smarr *et al.* 2014; Wu *et al.* 2014). As the ageing population increases, ageing conditions and factors such as arthritis, or stroke, may reduce mobility, and impact on quality of life (Cook and Hussey 2002). It is acknowledged that little is known about older adults' opinions of assistance by robots in the home (Smarr *et al.* 2014). Preferences of assistance by older adults to robots, was the basis of a study of 21 older adults. The older adult participants expressed they had preferences of assistance from humans and robots in the following ways –

- Preferring robot assistance for tasks related to chores, manipulating objects and information management.
- Preferring Human assistance for tasks related to personal care and leisure activities.

(Smarr et al. 2014)

Extending and supporting independence to older adults can be supported by the intervention of social robots and assistive devices (Johnson *et al.* 2014). Wu et al (2014) discusses the place of rehabilitation robots and social robots in supporting independence and enhancing the well-being of an older adult, and the importance of understanding why older adults accept or reject robots. This understanding will be important for:

> *"improving robot design and elaborating diffusion strategies in order to maximise their uptake."*
>
> (Wu, et. al., 2014)

In order to test acceptance and predict use, Wu recruited 11 participants for a one-month study. It had been suggested that robot/user acceptance is more successfully measured over a longer period of time because of the need to familiarise with the robot. Positive attitudes and direct interaction can predict successful acceptance of robots. The methods used by Wu were questionnaire and semi structured interview with the eleven participants in a 'living lab' setting. The semi structured interviews had three themes:

- Interaction experience
- Intention to use an assistive robot
- Barriers to acceptance of an assistive robot

Guide of questions used in semi structured interview (2014):

- What do you think about this experiment?
- What do think about the appearance of the robot?
- What do you think about interaction with the robot?
- What do you think about having this type of robot one day?
- Would you use this kind of robot one day?

Typical sample tasks asked of each participant in addition to questionnaire were:

- To look up a calendar
- To program an appointment in the calendar
- To check emails
- To send an email
- To prepare a shopping list
- To check weather forecast
- To play a cognitive game
- To check medication reminder
- To make a skype conference call
- To activate a music broadcast program

Table 3 displays the robot acceptance questionnaire as administered by Wu et. al. It is based on The Almere Model (Heerink, et. al., 2010), an adaptation of the 'Unified Theory of Acceptance and Use of Technology'(UTAUT) (Venkatesh, et. al., 2003).

Table 3 Robot Acceptance Questionnaire (Wu, et. al., 2014: P804)

Dimension	Items
Anxiety	If I should use the robot, I would be afraid I would make mistakes with it. I find the robot scary. I find the robot intimidating.
Attitude Towards Robots	It is a good idea to use the robot to help me with everyday tasks in the future. The robot would make life more interesting and stimulating in the future. It is good to make use of the robot to help me with everyday tasks today. The robot would make life more interesting and stimulating today.
Intention to Use	If the robot was available, I would use it.
Social Influence	I think society will encourage older people to use the robot to assist people in everyday tasks. In the coming years, my family (children, friends) and health professionals would appreciate that I use the robot to help me with everyday tasks. I think in the future; it will be a trend for the elderly to use a robot to keep them company and to help them manage daily tasks.
Perceived Usefulness	I think the robot is useful for me today. I think the robot would be useful for me in the future.
Perceived Ease of Use	I think I will know quickly how to use the robot. I find the robot easy to use. I think I can use the robot without any help. I think I can use the robot when there is someone around to help me. I think I can use the robot when I have a good manual.
Perceived Enjoyment	I find the robot enjoyable. I find the robot fascinating. I find the robot boring.
Perceived Sociability	I find the robot pleasant to interact with. I feel the robot understands me. I think the robot is nice.
Images of an Assistive Robot	I think only people who are no longer independent would use an assistive robot.

The findings of this study include the following:

- Some older adults have a preference to learn how to use technologies in order not to feel alienated.
- Some participants displayed a lack of interest in the technology.
- The stigma of being embodied by an assistive robot was seen as a barrier to acceptance.
- The only condition to justify the reliance of an assistive robot was when one becomes dependent.

Robots potentially can be a source of assistance and comfort to support older adults remain independent in their home (Smarr *et al.* 2014). Exoskeletons designed for older adults should address aspects of acceptance and usability, in addition to assistance (Di Natali *et al.* 2019).

2.2.4 Key themes emerging from this section:

- The risk of falls has been shown to increase significantly in a situation where a mobility device was not professionally prescribed.
- Accessibility and use of assistive technologies such as walkers by older adults may result in feelings of a 'devalued identity' by relying on or being supported by these devices.
- Assistive technology assessment tools are used for referencing or application when people with a disability engage with a healthcare professional to determine suitability of a device.
- Little is known about older adults' acceptance of assistive robots in the home.
- Exoskeletons designed for older adults should address aspects of acceptance, usability and assistance.

2.3 Exoskeletons & Exosuits

The benefits of wheelchair use as enablers to promoting activities of daily living and social inclusion are acknowledged (Borisoff, *et. al.* 2017). However, there remains a strong desire for users to aspire to engage in daily activities and tasks whilst standing or walking (Wolff, *et. al.* 2014; Pazzaglia and Molinari, 2016) e.g. older adults with age related mobility conditions, users with spinal cord injuries and post-stroke patients.

Powered exoskeletons and exosuits are part of an emerging Assistive Technology sector (Borisoff, *et al.* 2017; Czaja, *et al.* 2019). Exoskeletons are described as

> *"powered robotic orthosis for people with disabilities."* (Borisoff *et al.* 2017)

The quality of tool and body connective awareness, termed 'embodiment' is considered a critical factor to 'functional recovery'. Likewise, if embodiment is not accepted it can lead to device rejection (Pazzaglia and Molinari 2016). Furthermore, the ability for the immobile user to stand upright can improve physical functioning and maximise rehabilitation outcomes. When users can respond and make eye contact as a result of being upright, it can result in autonomy and independence as they participate in social and leisure activities, and reduce the likelihood of depression or social isolation (Pazzaglia and Molinari 2016). Nathan (2014) discusses two typical applications (medical, industrial) but comments on the potential exoskeletons have assisting people recover after spinal injury as rehabilitation devices. Wheelchair users can often experience secondary or complicating conditions that can impact on health (Young and Ferris 2017). A study conducted by Wolff et al., (2014) using quantitative and qualitative methods was conducted with healthcare professionals and wheelchair users to explore reasons why they would recommend the use of exoskeletons.
The main response to this enquiry was the health benefits that could be experienced. Additionally, the main design features that were rated as highly important were:

- Minimal falls risk
- Comfort
- Putting on and taking off device
- Cost

Wolff, et. al., (2014) discusses four areas to assist the development of exoskeletons as:

- Robust control
- Safety and dependability
- Ease of wear ability/portability
- Usability/acceptance

Exoskeletons normally have a rigid structure that facilitates movement control (Walsh 2018). Exosuits are wearable textile based devices that do not contain any rigid elements (Wyss Institute, 2019) and can apply forces across the joints collaboratively with the muscles of the body (Ding, *et al.* 2018). Exosuits have the potential to facilitate a positive interaction due to the lightweight and less restrictive nature of these soft wearable robotic devices (Awad *et al.*

2017). XoSoft is an example of a soft robotic exosuit (XoSoft 2016) and could assist mobility of older adults (Di Natali *et al.* 2019). Exoskeletons for older adults not only need to facilitate task assistance, but also require other factors such as trust, acceptance and usability factored into their development. Therefore some authors believe exosuits are a preferable approach to pursue than exoskeletons (Di Natali *et al.* 2019).

2.3.1 Assessing for Robots, Exoskeletons and Exosuits

Recently soft wearable exosuits have come to the fore as a means to avoid heavy, rigid and often bulky exoskeletons (Di Natali *et al.* 2019). In addition to the various quantitative and ergonomic assessments, it is critical that users are involved throughout design and development of these devices (O'Sullivan, *et al.* 2017). Some challenge has been expressed to implementing metric specific design requirements for personal service robots, and adaptability being a stated required feature (McGinn, *et al.* 2018). There are Standards that offer specific requirements about safety, interpretation of robot category and risk assessment or reduction, but no criteria that considers user acceptance of these emerging technologies.

ISO 13482 Robots and robotic devices – Safety requirements for personal care robots (ISO 2014).

This standard was introduced as a means to offer safety requirements regarding three specific groups of personal care robots (mobile servant robot, physical assistant robot, person carrier robot), wearable suits and exoskeletons are considered physical assistance robots.

It advises on the appropriate operation, charging, and information on using the robot. It also offers guidance regarding physical stress or strain as well as mental strain or usage hazards. It states that information for use should offer a list of instructions. The interaction of the user and the provider's communications will support and ensure appropriate and comfortable experience. There are four suggested operational modes (autonomous, manual, semi-autonomous and maintenance) see Table 4, which are all defined as per risk assessments.

Table 4 Characteristics of operational modes of personal care robots (ISO, 2014)

Characteristic	Operational mode			
	Autonomous mode	Semi-Autonomous mode	Manual mode	Maintenance mode
Initiation of action	By the robot or the user	By the user	By the user	By an authorized person
Frequency of human intervention	Once/rare	Frequently	Constantly	Constantly
Degree of supervision by the human	None/very low	Low to high	High	High
Task example	Fetch and carry task for mobile servant robot	Person carrier robot with autonomous navigation capability. Human can override speed and direction.	Teaching, tele-operation, programming and program verification	Maintenance
User restriction	None	None	None	Key lock or password protection required.

ISO/PRF TR 23482-2-2019

Robotics - Application of ISO 13482 - Part 2: Application guidelines (ISO 2019).

Personal care robots are a subset of service robots. Overlaps of scope from ISO 13482 and other standards have resulted in more than one interpretation of robot category applicable to one type of robot. As a means to reduce this overlap issue, a robot category can be determined based on the intended use. Further guidance is offered on risk assessment and risk reduction of personal care robots. This technical report provides examples of risk assessments for the various groups of personal care robots. It facilitates design of personal care robots as per ISO 13482 and offers further guidance to users with limited experience of risk assessment or risk reduction. It also attempts to avoid duplication of interpretation to ‘types’ of robots e.g. detailed risk scenarios and evaluations of risks are documented to support knowledge; an example is displayed in table 5.

Table 5 ISO23482 (ISO, 2019) part of Table 10 - Risk evaluation before applying risk reduction measures.

#	Type of hazard	Hazard and hazardous event	Potential consequence	Risk Estimation S: Severity of harm F: Frequency of exposure O: Probability of occurrence R: Risk index	Risk Evaluation	Clause of ISO 13482:2014
7	Thermal	Maintenance person touching a high temperature part inside the robot during maintenance	Burn	**S1:** High temperature parts of this robot can cause only minor burn. **F2:** The maintenance person is exposed to this hazard whenever a recently used exoskeleton is opened. **O3:** Normal use leads to high temperature of certain parts inside the exoskeleton. **A1:** Trained maintenance person will avoid touching high temperature parts. **R2**	**Acceptable**, as severity is low and the maintenance person can avoid the hazard.	5.7.4
8	Electrical	Touching of electrical connectors with wet hands	Electric shock	**S1:** Contacting an electrically live part causes only minor injury due to low battery voltage. **F2:** The user is exposed to this hazard whenever the user wears the robot. **O2:** Reaching live parts when touching the connector can occur in rare cases. **A2:** Electric shock develops fast and cannot be avoided. **R1**	**Acceptable in principle, but marked for further risk reduction**, as state-of-the-art solutions for this problem exist.	5.2

2.3.2 Testing of exoskeletons and exosuits

Soft exosuits have the potential to assist and correct gait and walking pattern, and developed to act in synchronicity with the wearer (Awad *et al.* 2017). Testing of the exosuit involved post-stroke participants wearing a tethered, unilateral (worn on one side of the body) exosuit. The participants conducted ambulatory tasks in a lab setting. This study demonstrates the potential and feasibility of gait restorative exosuits and state the need for further studies both in clinical and community settings (Awad *et al.* 2017).

Bryce, et. al., (2015) presents a framework to assess the usability of exoskeletal orthosis. The Framework of Usability for Robotic Exoskeletal Orthoses (FUREO) consists of six modules that are designed to inform all stakeholders. The six modules are: Functional Applications, Personal Factors (e.g. fit within the device), Device Factors (e.g. device components), External Factors (e.g. financial resource, access, rehabilitation facilities), Activities (e.g. training, learnability of the device), & Health Outcomes (e.g. physical effects). The authors posit that FUREO modules are suited to assisting guidance on the clinical prescription of robotic HKAFOs (hip-knee-ankle-foot exoskeletal Orthoses) (Bryce *et al.* 2015).

Investigating and understanding the complete human-robot system, whereby, the new technology (e.g. exosuit) is understood from biological and pathological function as well as the adaptations applied by the human is critical. Development of these complex technologies requires iterative and continuous development throughout, with data captured both quantitatively and qualitatively (Walsh 2018).

2.3.3 Key themes emerging from this section:

- There is a strong desire for people who experience disability to engage in daily activities and tasks while standing or walking.
- The ability of an immobile person to stand upright can improve physical functioning and maximise rehabilitation outcomes.
- Exoskeletons normally have a rigid structure that facilitates movement control.
- Exosuits are wearable textile-based devices that do not contain any rigid elements.
- Challenges have been expressed to implementing metric specific design requirements.
- Development of exoskeletons and exosuits require iterative and continuous development throughout with data captured both quantitatively and qualitatively.

2.4 Technology Acceptance

This section will explore and discuss the use, and sometimes the non-use, or abandonment, of technologies. In addition, it will explore the evolution of TAMs to gauge older adult acceptance of technology. TAMs and how theories have influenced their development is helpful to building knowledge of needs requirements towards facilitating and optimising technology use by older adults.

2.4.1 Technology Acceptance Models

TAMs are used typically as a means to predict user acceptance of a technological application (Venkatesh and Davis 2000) and as a tool to map influence between a user's intention to use a device and their actual use of that device (Heerink *et al.* 2010).

The usefulness and perceived ease of use by the user and their behavioural intention of system usage has been historically rated as being able to predict the actual usage (Heerink *et al.* 2010). With regard to the interaction and acceptance of social robots and older adults, Heerink, et. al. applied additional attributes of 'perceived enjoyment', 'perceived sociability,' 'social presence' and 'perceived adaptability' as constructs that could assist with enquiry to measure acceptance of social robots and technologies. There is a need for a narrative review of TAMs relating to older adults and exoskeletons.

The application of TAMs as a means to predict acceptance or use of technology involves the participants rating statements via a scale (i.e. Likert) (Salovaara and Tamminen 2009). Furthermore, Salovaara & Tamminen (2009) suggest the ability of the user to 'invent' new or alternative uses for products cannot be measured using traditional models, with further understanding required of user mindsets and activity contexts.

2.4.2 Gerontechnology

The term 'Gerontechnology' is used in this literature review as per composite definition between the words gerontology – the study of ageing, and technology - iterative development to evolve new and improved products and service systems in five areas: Longevity & Health, Housing, Working, Mobility & Transportation, Information Systems & Communication (Harrington and Harrington, 2000).

There are three central areas of consideration in order to understand how society and technological advancements can offer and continue to give older adults a sense of integration and place and they are not excluded from society. Ambitions (and motivations) are also discussed and the differing requirements of men and women as they age, whilst still meeting their needs through the introduction of assistive technologies. The intervention of these technologies should not hinder autonomy or independence to the older adult. Gerontechnology's focus is to live "primarily in the future, remaining aware of existing and upcoming technologies that support ageing and technology acceptance (Harrington and Harrington, 2000).

Age related conditions can impact on quality of life, and mobility is a major concern to maintain quality of life and independence. Gerontechnology is intended to deliver solutions that impact and assist older adults as they engage with technology devices that maintain or improve good health and independent living (Harrington & Harrington, 2000; Fisk, et. al., 2004). Wu, et. al., (2015) conducted research with older adults that identified four themes.

- **Project participation** – participants expressed positive insights and shared how participation would offer opportunity to maintain engagement in life and society, as well as keeping themselves up to date with technology.
- **Digital divide** – The participants expressed an opinion overall that people who master technologies are 'empowered' and there are differences between the older and younger generations in ICT adoption.
- **ICT adoption** – needs to use technology were often expressed as a reason to accept and adopt the technology. However, participants when asked about ICT adoption, also reported social pressure as a means to 'fit in' with society, and otherwise may not adopt it.
- **Opinions of assistive ICTs** – The participants in this research considered themselves active and healthy and viewed devices as shared during research as not being applicable to them now, but in the future may become so due to reducing ability and frailty. They also expressed users of these devices were

  "very old people with major cognitive impairment or those who are lonely or isolated." (Wu, et. al., 2015)

A qualitative study conducted with Older Adults in Hong Kong (Chen & Chan, 2013) noted how positive attitudes to technology were associated with advanced features and convenience of use. Whereas, negative attitudes to using technology were related to health risks and associated problems when using the technology.

Gerontechnology is an integration between technology, the person and their environments (Chen & Chan, 2013). By enhancing this synthesis, and to encourage non-users to accept technology, it is important to remove barriers at personal, technological and environmental areas. Overall it appears the participants preferred a slow-paced approach to teaching new technologies, preferring also to learn from others (though not their children) to learn new technologies. Positive perceptions and acceptance were mainly related to convenience and perceived ease of use (Chen & Chan, 2013).

Newell (2011) discusses the lack of empirical evidence to support the development of mainstream technology products and the study of older adults using technology. In particular, the areas of cognitive processing, visual search working memory and selective attention, which, he points also to concerns regarding older adult of confidence with technology and how it can lead to negative stereotyping. Heerink (2010) adds commentary positioning how stigmatisation is a factor to technology devices not being used by older adults. Some users may perceive the risk of stigma associated with the use of an assistive device. Concealment of the product may be one strategy to consider as a means to reduce stigma (Vaes, 2014).

2.4.3 Technology Acceptance Model evolution & Older Adults

Cook & Hussey (Cook and Hussey 2002) share the insight from Kielhofner who suggests that older adults in the age group of 65/70 have some prior use and knowledge of technology. They may express some fear to the learning of new technology, e.g. fear of breaking it or the cost of repairs if they are responsible for damaging it. This is exacerbated sometimes further by a decline in sensory, motor or cognitive skills as ageing progresses, and ability or skill can be reduced.

A number of factors are listed as a means to improve acceptance of a technology and ensure that older adults will be more willing to accept and use the device regularly (Pigliautile *et al.* 2012).

- Training the user to use the device and understanding of how the support system works.
- Successful matching or prescribing of technology and user.
- Ensuring that trust is established, and the device will work properly, safely and reliably.
- The perception of the user that the advantages to using far outweigh the disadvantages to using.

Pigliautile et. al., (2012) further discuss various commentaries from authors that relate to older adults acceptance of technology:

- Coping strategies employed by older adults to offset the awareness of their reducing abilities.
- The adaptation of the older adult's home environment as a device is required for assistance.
- The features of daily living and the environmental barriers, that the device is introduced to support that may prevent acceptability e.g. stairs.

These commentaries add knowledge to consideration of exoskeleton development and acceptance by older adults.

2.4.4 Older Adults and Technology Well-Being

Ageing can also be perceived as a source of stigma, with age discrimination and the experience often shown to be a time of increasing vulnerability and lack of protection. In turn this can lead to a sense of insecurity or exclusion. Age discrimination is part of one of the priority actions recommended by the UN to ensure a sense of wellbeing and autonomy is experienced by older adults (UNFPA and HelpAge International, 2012). Ageism has been highlighted as a factor that facilitates or hinders successful ageing and acceptance of assistive devices (Heerink *et al.* 2010; Calasanti 2015).

Calasanti (2015) also notes the experience of ageing from participants in his research with regard to ageing and ageism it can be an experience of reduced autonomy, and one can feel invisible or powerless. The perception to age as being 'successful ageing' (Rowe and Kahn 1987) can give an indication of 'winners and losers' (Foster and Walker 2015). The perception of 'winners and losers' if your longevity and life experience is a positive one, appears to have been considered by Rowe & Khan (1987) when they state:

> *"Support, so defined, in our view, can either increase or decrease the autonomy and control of the recipient. Teaching, encouraging, enabling, are autonomy-increasing modes of support."* (Rowe and Kahn, 1987).

Design and development of exoskeletons, with regard to an ageing population requires a cognisant effort to ensure these devices do not add to discrimination or a sense of stigma when wearing an exosuit or exoskeleton.

The internet and users of the internet by their anonymity can become 'ageless' and are not classified or stigmatised by their age or appearance. Older adults aged 65+ are reportedly the fastest growing group of internet users where they can maintain social networks from their homes (Amichai-Hamburger and Barak 2009). Older Adults believe it can be important to learn how to use new technologies in order not to feel alienated from society. However, the stigma of being perceived dependent or declining in abilities is perceived as an unacceptable dependence and presents as a barrier to using technology (Chen and Chan 2013; Wu *et al.* 2014).

Wu (2014) discusses how current older adults may be less accepting of technologies such as assistive robots, and the importance of destigmatizing acceptance of assistive robots as a means to facilitate their acceptance. Wu concludes with a suggestion that a universal design approach is important to produce devices that assist, but in a non-stigmatising way, and introduce some capabilities that offer alternative use other than the functional health care or assistance.

Chen and Chan (2014) state that unlike UTAUT and with respect to personal attributes, age and gerontechnology, self-efficacy appeared to be the most powerful predictors of technology acceptance. Factors such as age, gender, education, health and ability characteristics affect technology acceptance behaviour. High levels of self-efficacy and low levels of anxiety increase use of gerontechnology (Chen and Chan, 2014).

2.4.5 Personal Control and Perceived Behavioural Control

Some older adults experience a 'self-fulfilling prophecy' internalised as a belief that they are unable to cope with or use computers and technology (Amichai-Hamburger and Barak 2009).

Locus of control refers to control we perceive to have in a given situation or operation of a task. Awareness to the degree of control a person feels they have can be an important factor to the prediction and understanding of how they may cope with:

- New technological requirements
- Changes of technology
- Difficulties encountered when using technology

(O'Driscoll *et al.* 2009)

Psychosocial factors or influences of use and ability by the user is a critical element in addition to the physical and cognitive challenges faced by a user of assistive technology. In addition these factors relate to the user throughout their lifespan and developmental needs (Cook and Hussey 2002).

Ajzen (2002) describes the value of correlating self-efficacy and perceived controllability as components of a hierarchical model of perceived behavioural control. This model, Ajzen believes best describes how perceived self-efficacy, perceived controllability, and perceived behavioural control, are interconnected as factors relating to the variances between intentions and actions of a behaviour.

It is acknowledged that humans are motivated and energised by a curiosity and to apply their talents by mastering new skills etc. However, on the reverse of that, there is also an acknowledgement that this motivation may sometimes be lacking and may affect people's social development and well-being (Ryan and Deci 2000).

Three interrelated needs that can promote self-motivation and personality integration according to Ryan and Deci (2000) are: competence, relatedness and autonomy. These needs are factors that can influence the motivation of people to be intrinsically or extrinsically aware. They can also influence a positive embrace to pursue new challenges and can be influenced by the attempts of others (e.g. teacher, parent, coach, therapist etc) to foster behaviour in the user and the 'taking in' or internalising the value or regulation to pursue, as displayed on Figure 9:

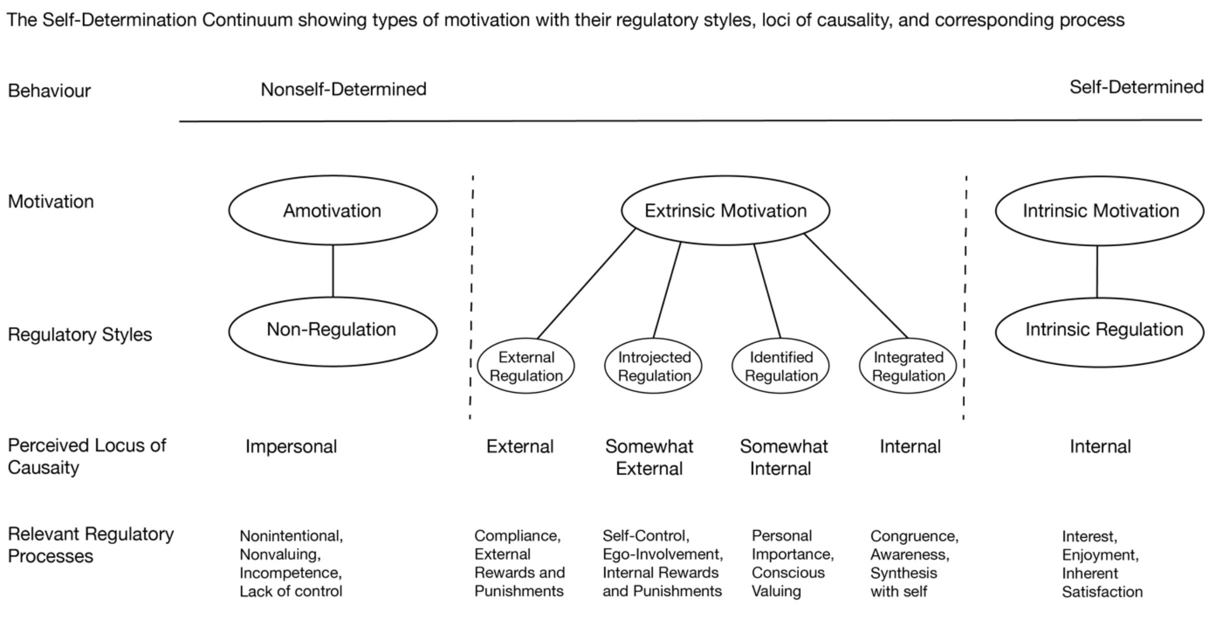

Figure 9 The Self-Determination continuum (Ryan and Deci 2000)

There is a requirement to understand older adults' motivators to take in or accept the interaction with technology assistive devices. Important factors to consider are elements of self-determination, and how best to endorse self-efficacy and the ability to remain confident and competent to use and enjoy assistive devices.

2.4.6 Technology Abandonment

Technology abandonment describes reasons why a user may no longer engage with or use an assistive device. Cook and Hussey (2002) state that this may be as a result of shortcomings regarding consumer satisfaction, and refer to four factors identified by (Phillips and Zhao 1993) as the main reasons someone may abandon using an assistive device as:

- **Failures of providers to take consumers opinions into account** - can be whereby the consumer has a sense that their opinion or experience does not matter, and the structure of the system and delivery system does not support and continually leaves the user with unmet expectations and delivery.
- **Easy device procurement** - references the ability to purchase devices such as crutches or canes with no evaluation or prescribed process, in turn placing responsibility for learnability and usability with the user and no supports to enhance or build confidence and positive experience.
- **Poor device performance** - as a result of inaccurate or inappropriate expectations that result in the user abandoning devices because of them expecting more from the device than it is programmed to deliver – 'misuse'.
- **Changes in consumers' needs or priorities** – can be addressed by providing a "flexible allocation of functions" that address the changing or ongoing needs of the user.

A positive reason for abandonment of a technology, is that the person's condition improves and no longer requires an assistive device (Cook and Hussey 2002). Furthermore, a person's low self-confidence may adversely influence non-adoption of medical technologies (Pazzaglia and Molinari 2016). If the user cannot easily use, or the technology is novel and not easily learned, this can lead to abandonment or under-use of the device (Wolff *et al.* 2014).

Wolff et al, (2014) highlights the lack of research on exoskeletons and user acceptance and perceptions of use involving both the user and the healthcare professional. The term ‘abandonment’ is discussed with a view to replacing it with the word ‘discontinuance’ as a means to acquire some explanation for the use or not of assistive technologies. In the past, factors such as – irresponsibility on the part of the consumer, industry and service providers as a result of consumer abandonment, in addition to industry over prescribing, and service providers inappropriately selling, led to discontinuance of use (Lauer, et. al., 2006).

It also discusses methods used to enquire about abandonment and assistive technology application, by literature review and pilot survey used to gauge user experience. Various terms are shown to be associated with technology abandonment and the authors state how this is usually connoted with negative experience and outcomes of the intervention of the technology:

- Disuse (Kittel, et. al., 2002)
- Non-use (Geiger 1990; Forbes, et. al., 1993; Bentur, et. al., 1996)
- Rejection (Gitlin 1995)
- Avoidance (Scherer, 1994)
- Non-compliance (Wielandt and Strong 2000)
- Abandonment (Phillips and Zhao 1993; Scherer, 1994; Mann, et. al., 1995; Hocking 1999; Kittel *et al.* 2002)
- Discontinuance (Riemer-Reiss and Wacker 2000)

The relevance of using ‘discontinuance’ is the belief that it reduces confusion and offers a more positive factor (healing, or no longer requiring its use due to pathology improvement) and the ‘Discontinuance’ is how a device is no longer used after a period of time (Lauer *et al.* 2006).

Figure 10 displays the various elements of a model of positive and negative discontinuance. The ‘Modifiers’ box to the top right recognises the demographic features that can influence continuance or discontinuance of assistive devices.

Three elements can vary and fall under the label titled ‘Other.’ The interesting range and factors are highlighted in the box to the left that displays negative factors of influence to discontinuance, the box to the right highlights the beneficial and positive factors to the discontinuance of the assistive device.

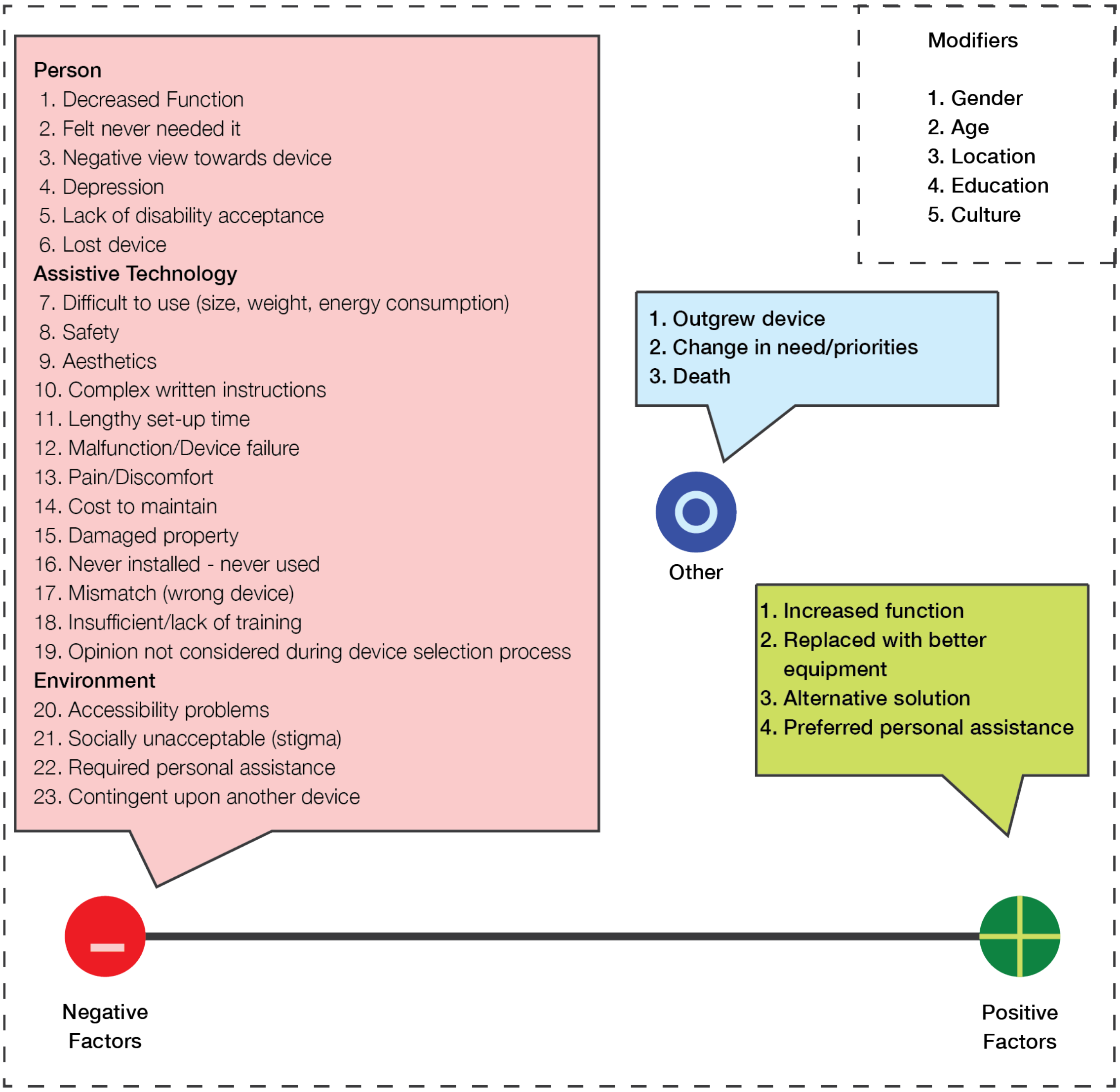

Figure 10 Conceptual model of Positive and Negative Discontinuance (2006: P4).

2.4.7 Key themes emerging from this section:

- TAMs are applied typically as a means to predict user acceptance of a technological application.
- Constructs such as perceived enjoyment, perceived sociability, social presence, perceived adaptability, and self-efficacy can assist with enquiry to measure acceptance of social robots and technologies by older adults.
- Gerontechnology's focus is to live 'primarily in the future', remaining aware of existing and upcoming technologies that support ageing well-being.
- There is a lack of empirical evidence to support the development of technology products and the study of older adults using these products.
- Today's population of older adults (65-70) have some prior use and knowledge of technology.
- Fear may be expressed by older adults when they are learning new technology (fear of breaking it, or the cost of repair if they are responsible for damaging it).
- Stigma and anxiety may be factors or barriers to acceptance and use of technology.
- A universal design approach may be helpful with development and design of robotic healthcare devices.
- Competence, relatedness and autonomy can influence motivation and intent to pursue new challenges, which in turn can also be influenced by the attempts of peers.
- A lack of satisfaction may be a factor to technology abandonment.
- There is a lack of research on exoskeletons, user acceptance and perceptions of use involving both users and healthcare professionals.
- Design and development of exoskeletons, with regard to older adults, requires a cognisant effort to ensure these devices do not add to discrimination or a sense of stigma when wearing an exosuit or exoskeleton.

2.5 User Centred Design

This section will discuss where design has input and responsibility to assistive devices design and older adults' acceptance. It will consider further from TAMs, the place of usability as a factor of predictive use and experience. Usability will be referenced as a means to display rigour of understanding when evaluating user acceptance and perceived ease of use experience for the Older Adult user. Approaches of inclusive design and universal design will be shared and discussed to consider not just one, or a type of user, but the addition of associated stakeholders as supporters to enhance usability and experience.

2.5.1 Inclusive Design

Inclusive Design is an approach whereby designers ensure that the products and services that are designed are accessible and usable by people irrespective of age or ability (Clarkson & Coleman, 2015; Torkildsby 2018). Design can be viewed as a source for improving life, and awareness of everything that is designed; is made and used by people (EIDD 2004).
Stockton describes stigma as "*the Achilles heel of Inclusive design*" (2009) explaining how the artefact, can carry negative perceptions by people, and therefore apply stigma before a user engages with it. As a means to de-stigmatise products, Stockton describes how some designers have approached stigma through education, as an example Philippe Starck's 1998 'TeddyBear band' (Figure 11) which could be interpreted two ways:

- The bear has brought some friends along to play.
- The bear can teach children through play that people may come in different formats

Figure 11 Philippe Starck, Teddybear Band

Starcks approach to design is commended by Pullin (2009) who relates the designer's capacity to bring warmth and wit to everyday products. The teddybear band, it would appear is a commentary on the differences, but the qualities people can bring to society.

2.5.2 Universal Design

When designing for older adults and as a means to integrate the input of older adults into the process of design, a Universal Design approach is recommended (Farage, et. al., 2012; Czaja *et al.* 2019). In addition Co-Design, through which various stakeholders (both expert and non-expert) collectively agree what to do, and decide how they will do it together (Manzini, 2015) can be an action based approach to resolving and defining solutions that benefit all.

Cook & Hussey (2002) discuss the value of consumer as co-developer. The consumer is involved in all aspects of assistive technology design and development. Endorsing this approach further the Administration For Community Living (Department of Health and Human Services, USA, 2019) critically value participatory research as a means to ensure that people with disabilities, their families and the professionals involved in care, are also involved in the provision and design of assistive technology. RESNA (Rehabilitation & Engineering Society of North America) offer standards of practice and code of ethics in relation to assistive technology devices

- Hold paramount the welfare of persons served professionally.
- Practice only in their area(s) of competence and maintain high standards.
- Maintain the confidentiality of priveleged information.
- Engage in no conduct that constitutes a conflict of interest or that adversely reflects on the association and, more broadly, on professional practice.
- Seek deserved and reasonable remuneration for services.
- Inform and educate the public on rehabilitation/assistive technology and its applications.
- Issue public statements in an objective and truthful manner.
- Comply with the laws and policies that guide professional practice.

(RESNA 2019).

2.5.3 Interaction Design

Dunne (2008) discusses the interaction between man and machine and the 'humanising' of technology and points to the importance of user friendliness as a means to success when the user engages with the interface or the device. He discusses the potential 'enslavement' as shared by Virillio 1995, by producing transparent interfaces intended to close the gap between man and machine. Dunne points out that the enslavement is not necessarily to the machine but more to the embodied systems within the machine (Dunne, 2008).

Dunne also discusses Rick Robinson's (1994) critique of Don Normans 'Things that make us smart' (1993) who states:

> *"User-centeredness is not just figuring out how people map things, it absolutely requires recognising that the artefacts people interact with have enormous impact on how we think. Affordances to use Norman's term, are individually, socially and culturally dynamic. But the artefacts do not merely occupy a slot in that process, they fundamentally shape the dynamic itself."* (Dunne, 2008).

Dunne describes the designer as the 'packager of technology' we design the 'skin of an object that houses technology' referencing Daniel Weil's radio in a bag – 1983 that displays the application of technology being packaged in the product – radio (Figure 12).

Figure 12 Daniel Weil - Radio in a bag, 1983 (Dunne, 2008)

Cooper (2004) separates program design and interaction design, referring to interaction design as design that affects the end user of that product (or system). Furthermore, he states the benefits of Interaction design as a freedom to create products that do new things based on the interactions between users, programmers, designers etc.

The term UX or user experience design has three elements of focus: Form, Content and Behaviour (Figure 13). Interaction design relates to the design of the experience and behaviour, expanding this focus to include how that behaviour relates to form and content (Cooper *et al.* 2014).

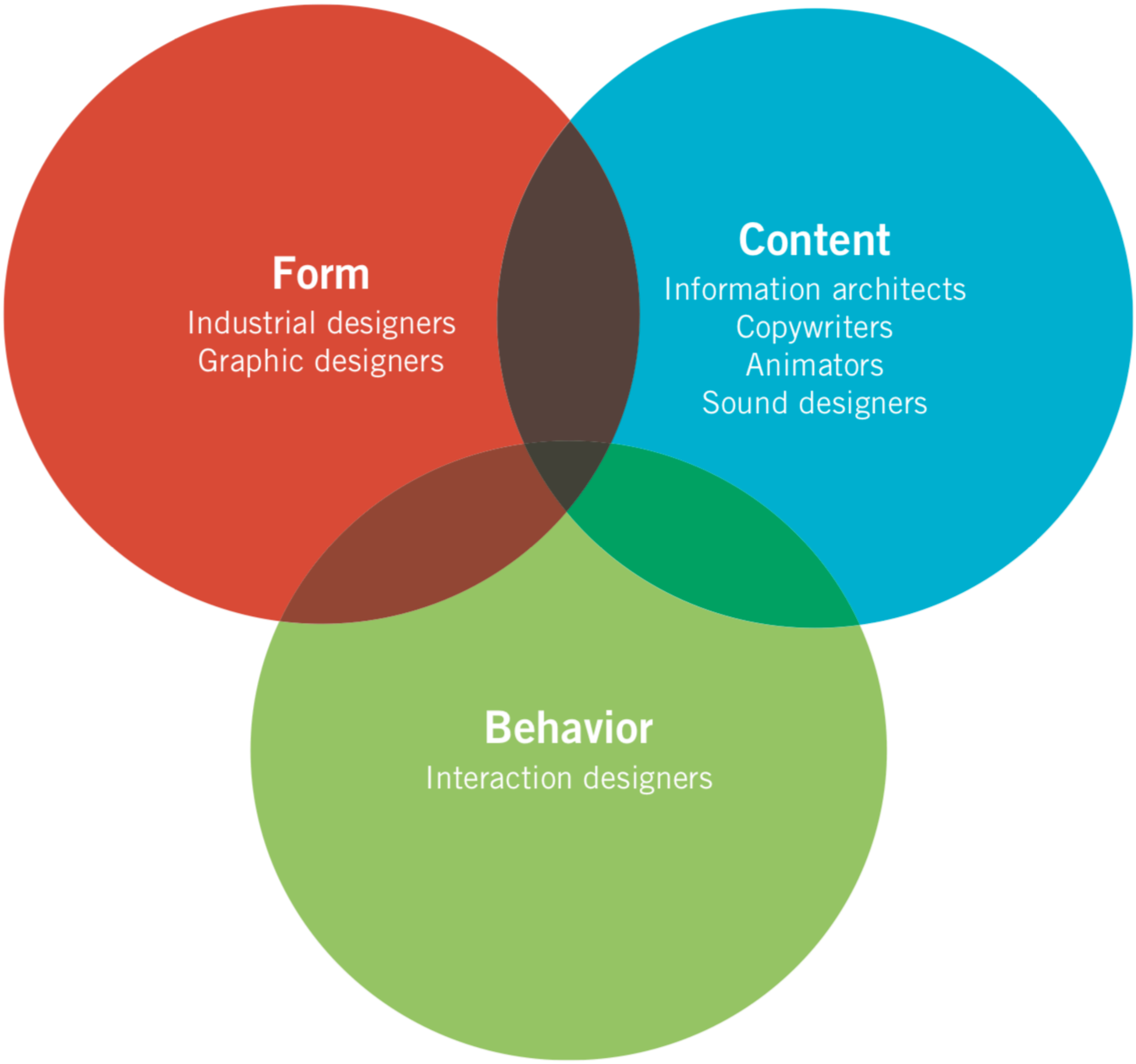

Figure 13 The three overlapping elements of user experience (UX) design.

Cooper describes the engagements between interaction designers, industrial designers and graphic designers, expanding to further disciplinary members on the teams such as engineering, marketing and business leads. This collaborative approach ultimately is orchestrated by designers as a means to create a successful and satisfying product or system for people (Cooper *et al.* 2014).

Cañas (2009) refers to the theoretical and practical sides of Interaction research :

- Theoretical: goals set to explain the interaction behaviour.
- Practical: goals set to improve system design, user's performance etc.

A frustrating aspect shared by Cañas is the lack of one size fits all type interaction research method. He discusses further a possible alternative methodological approach whereby the human and the system can be studied simultaneously (Cañas, 2009).

During development of products/systems; by applying a top-down, bottom-up approach, new design characteristics can be established (Nielsen 1993). Human Robot Interaction (HRI) establishes the human factors needs requirements in research and design of robots. Emerging and current technologies e.g. autonomous vehicles, drones, wearable robotic devices requires further participation from the Human Factors community to enquire the following:

- Lifestyle, fears and perceptions of robots by humans.
- What levels of automation are required to be completed by robots in relation to tasks, jobs etc.
- What assistance abilities can be provided by robots, particularly as supports to care for sick or frail individuals are required
- In the context of security, how much autonomy can robots operate, and to what level should they be authorised to making decisions regarding the killing of people? (Sheridan 2016).

2.5.4 User autonomy

Bandura defines perceived self-efficacy:

"Peoples beliefs about their capabilities to produce designated levels of performance that exercise influence over events that effect their lives."

(Bandura 1994)

Subjection to depression, stress reduction and the achievement of personal accomplishments are determined by our 'efficacious outlook'. The balance between belief and doubt in our capabilities can be determined by our outlook to either see challenges as opportunities to master a task or activity or be perceived as threats that are best avoided. Self-efficacy and resilience associate the balance between the easy successes, and the challenges, or difficulties to overcoming obstacles. This balance when achieved offers an individual the awareness and tenacity to pursue and believe they have the ability to rebound from setbacks and persevere (Bandura 1994).

Sources of self-efficacy: According to Bandura, there are four sources that develop self-efficacy:

- **Resilient sense of efficacy** that requires experiences that required perseverance and determination to overcome challenge.
- **Vicarious experiences** where the individual builds belief in their abilities through observing similar people to themselves succeed by sustained effort.
- **Social persuasion** to verbally encourage or persuade another that they have the ability to perform or succeed.
- **Reduce peoples stress reactions** by considering how the individual views or perceives the task.

The four major psychological processes (cognitive, motivational, affective & selection) influence our engagement with tasks or activities and determine our level of self-efficacy (Bandura 1994).

Rating self-efficacy: As per the concept of self-efficacy, empirical research is required as a means to rate self-efficacy whereby participants are presented with a challenge or problem to solve (Ajzen 2002). The participants are then asked to rate perhaps on a 100-point scale with 10-unit intervals, their confidence to solve the challenge or problem.

In addition, and as a means to enhance autonomy, a network of stakeholders (Krippendorff & Butter, 2008) can be effective to the design and experience outcome for users. Companies require profit generation and also will often have 'Associated stakeholders' (Goodman *et al.* 2012).

2.5.5 Usability

The usability of a product or service system should consider functionality efficiency and desirability as a means to illicit positive user experience. (Goodman et al., 2012)

> *"A good user experience doesn't guarantee success, but a bad one nearly always leads to failure."*
>
> (Goodman et al., 2012:22)

The usability testing of a product or service system (e.g. an app) involves participant users to engage and test experience and performance prior to release or launch of a product or service system.

Assessment of usability also considers the levels of challenge or difficulty experienced by the person interacting with the system (Thimbleby *et al.* 2001). Usability applies five basic principles as introduced by Nielsen (1993)

- **Learnability** – The system should be easy to learn so that the user can rapidly start getting some work done with the system.
- **Efficiency** – The system should be efficient to use so that once the user has learned the system, a high level of productivity is possible.
- **Memorability** – The system should be easy to remember, so that the casual user is able to return to the system after some period of not having used it, without having to learn everything all over again.
- **Errors** – The system should have a low error rate, so that users make few errors during the use of the system, and so that if they do make errors, they can easily recover from them. Further, catastrophic errors must not occur.
- **Satisfaction** – The system should be pleasant to use, so that users are subjectively satisfied when using it.

(Nielsen 1993)

Usability has been defined in ISO 9241-11:1998; ISO 9241-11:2018 part 11 as:

> *"[the] extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use."*
>
> (ISO 1998; ISO 2018a).

Usability may become a shared activity and hence the user may indicate and agree preferences of use with 'associated stakeholders' and 'Shared Usability' which is defined as:

> *"Mutual agreement between the user and Associated Stakeholder(s) on the levels of management or interaction required with a product or service as an objective to achieve positive usability."*
>
> (Shore, 2015)

The concept of 'Shared Usability' can be a tool of interaction to ensure autonomy of the end user with the network of associated stakeholders. Shared usability offers a broad user consideration and particularly is a tool that can be applied successfully to the implementing and testing of products and services that are intended for older adult use (Shore 2015).

2.5.6 Desirability

Desirability can be considered a less tangible aspect of understanding user experience due to the nature of emotions and connections that make sense to the user as they engage with products (Goodman *et al.* 2012). Dunne refers to users as 'protagonists' that enter a space between

> "*desire and determinism, a bizarre world of the 'infra ordinary', where strange stories show that truth is indeed stranger than fiction, and that our conventional experience of everyday life through electronic products is aesthetically impoverished.*"
>
> (Dunne, 2008)

The user is co-author of a narrative experience of use, as opposed to a passive consumer of a product's meaning. This implies the need for engagement between designer and user when developing products that address the desires and determinism of the user. Benedek & Miner (2003) argue how it is unlikely that desirability can be measured in a lab/usability test setting because the artificial nature of the 'lab setting' and the questions directed by the practitioner to the participant who may get different meaning from the intended questions. As a means to measure desirability, Benedek and Miner used tools:

- **Faces questionnaire** – Pictures of six different faces were used representing an array of emotions from joy to frustration to be rated using a likert scale. The participants were asked as they performed tasks to rate how they felt.
- **Product reaction cards** – a large set of word cards (75) that form the basis for a sorting exercise and discussion about the product.

During the 1980s product semantics influenced the design of electronic products by considering the form of devices and how it may influence or communicate implicit meaning (Dunne 2008). Dunne offers an example referring to Stelarc's interplay between self-control of the body and technological devices that can impart logic and control on the body through an embodied device. Assistive technologies are intended to assist people with disabilities but, despite well-intended efforts these technologies are not always a source of happiness. The cognitive, emotional and physical needs of stakeholders accommodates a 'call to action' whereby patients and occupational therapists in their environments with designers/design teams can steer the creative process and deliver new and optimistic outcomes (De Couvreur *et al.* 2013).

2.5.7 Key themes emerging from this section:

- Design can be viewed as a source for improving life, and awareness of everything that is designed, is made and used by people.
- Co-Design and universal design approaches are beneficial when designing with/for older adults.
- Interaction design relates experience and behavior, and how that behavior relates to form and content.
- The balance between belief and doubt in our capabilities can be determined by our outlook to either see challenges as opportunities to master a task or activity – or to be perceived as threats that are best avoided.
- The usability of a product or service system should consider functionality, efficiency, and desirability as a means to illicit positive user experience.

2.6 Research Questions

A grounded theory approach relies on research questions and literature review as a means to establish the boundaries of the research (Birks and Mills, 2015). In addition, the research questions pose as a means to react, and drive the research process toward an emergent and insightful conclusion (Charmaz 2014).

The ageing experience is new for the older adult to engage with. If there is no lack of cognitive function, but an apparent reduction in mobility, this can have a profound effect on quality of life, and wellbeing of the person (United Nations and HelpAge International, 2012).

Exoskeletons will become mainstream devices in the coming years (Young and Ferris 2017) and will offer opportunity in a number of areas as supports or ability enhancement devices (Borisoff *et al.* 2017).

At the outset of this research, the areas of research were agreed between the author and supervisors and was based on the following:

- Previous research experience and skillset of the author.
- Exploring design requirements and technology acceptance in relation to exoskeletons and older adults
- Project requirements related to XoSoft.

The agreed areas of research afforded the opportunity to establish the boundaries of enquiry and the opportunity to conjure entire new puzzles, while gathering data (Charmaz 2014).

Initial Research Statement: This research proposes to develop empirical evidence that will lessen negative product related stigma and improve technology acceptance for older adults with reduced mobility that wear a soft robotic biomimetic exoskeleton when conducting everyday tasks and activities.

This dissertation documents the journey of a qualitative body of research motivated by the initial overarching statement of research intent, about emerging technology experience and older adult perceptions to these. Each chapter develops a question and states solutions as new knowledge emerges; theory is developed as major outputs of this research. The literature review had presented some knowledge gaps and initiated a number of questions to pursue using qualitative methods – semi-structured interviews with a grounded theory approach.

Therefore, it was also necessary to get out into the wild and spend time with older adults. The purpose of this activity was to gain insight and knowledge at first hand from the participants and learn about the environments, products and services they interact with daily. The fieldwork sessions were documented and planned and approved by the ethics committee in University of Limerick.

Three main areas 1) older adults, 2) technology acceptance, 3) exoskeletons & robotic assistance, have been investigated as a means to present the findings and original outputs that emerged as a result of these investigations. New knowledge is presented and shared throughout this body of work. Table 6 documents each of the chapters and associated research questions that were explored and resolved.

Table 6 The research questions that are addressed in this thesis.

Chapter		Research Questions
3	Preliminary fieldwork to understand older adult perceptions to environments, products and service systems.	*1. What are older adult insights regarding mobility and age-friendly environments – and what design methods can support identifying and defining needs requirements and solutions?*
4	Review of Gerontechnology Acceptance & User Centred Design of Exoskeletons.	*2. What are the useful elements of existing TAMs and user centred design in relation to older adults' acceptance of exoskeletons?*
5	Investigating perceptions related to technology acceptance of wearable robotic assistive devices by older adults.	*3. What perceptions do older adults have of robotic assistive devices and how do they relate to technology acceptance and exoskeleton development?*
6	Pilot study of Exoscore.	*4. Can an integrated assessment method and design approach be developed for exoskeleton design to help improve technology acceptance by older adults?*

2.7 Research Approach

This research was undertaken with an 'applied' approach (Norman, 2007) as a means to study the culture and experiences of older adults in order to determine solutions that optimise acceptance of exoskeletons by them. An ethnographic approach (Hammersley, 2007) within grounded theory ensured that data and analysis was generated from the interactions and experiences with the older adult participants, in addition to other sources of knowledge (Charmaz 2014). Chapters 3-6 document in further detail, each of the research methods used as a means to establish learning, identify needs gaps and determine outputs from the research.

Chapter 3 - Preliminary fieldwork to understand older adult perceptions to environments, products and service systems.
This chapter shares and discusses the method of design ethnography and time spent out in the field with older adult participants. The findings of this fieldwork were interpreted as a means to develop Co-Design solutions for the environments, products and service systems experienced by older adults. It also discusses the benefits of these approaches to a practical symposium that was attended by a number of stakeholders from various backgrounds.

Chapter 4 – Review on Gerontechnology Acceptance & User Centred Design of Exoskeletons
The aim of this chapter is to present a narrative review of Technology Acceptance Models, gerontechnology and design regarding exoskeletons. By literature reviewing and drafting this commentary it offered highlights from initial learning to pursue further advances about technology acceptance of exoskeletons (Paré and Kitsiou 2017).

Chapter 5 - Investigating perceptions related to technology acceptance of wearable robotic assistive devices by older adults.
The aim of this chapter is to discuss the interpretations of fieldwork that was undertaken with grounded theory and ethnographic strategies. This chapter also documented a mixed methods approach of affinity diagramming and applying qualitative documentation to Nvivo as a means to deliver codes, categories and themes that emerged from fieldwork with 24 older adult participants.
This chapter displays the rigour and approach of a qualitative body of work that applied a 'constructivist' grounded theory approach (Charmaz, 2014) and the interpretation of the findings as a means to build outputs of the research to benefit older adult users of exoskeletons.

Chapter 6 - Pilot study of Exoscore.
The aim of this chapter was to document the methods that were applied to this body of research as a means to generate the findings. It highlights a pilot study that was conducted and also the resulting descriptive statistics from testing Exoscore in a lab setting with older adult participants and members of the XoSoft team.

2.9 XoSoft Project

XoSoft (2016-2019) was an EU Horizon 2020 project comprising of 9 European academic and industry partners. As one of the partners, the Design Factors Research Group in the School of Design, University of Limerick was responsible for the identification of users' needs requirements, a UCD approach and the iterative development of the exoskeleton.
The aim of XoSoft was to develop a soft robotic exoskeleton to provide mobility assistance to older adults, and people recovering from stroke, or with partial spinal cord injury.
This research specifically focussed on older adult experiences of ageing and their perceptions towards current technology, robotics, and exoskeletons during the project. The insights that were expressed, in addition to new knowledge from literature, contributed to the overall project and concept development.

3. Preliminary fieldwork to understand older adult perceptions to environments, products and service systems.

Study rationale: To this point a research statement had been established which identified a need to understand older adults and day to day experience of ageing. It was believed that by undertaking this initial fieldwork it would would assist the framing of what and how to approach a larger, more concise study regarding the specifics of robotics, exoskeletons, dressing and assistive technologies. Approval was sought from and given by the ethics committee in University of Limerick. The images that are displayed in this chapter were taken with the attendees knowledge and anonymised to protect privacy. The images that display identities are with permission, and of staff members involved in the Co-Design Symposium day.

Purpose: The aim of this chapter is to document fieldwork that was undertaken during the early stages of the research as a means to gain initial understanding to the ageing experience and Quality of Life and mobility of older adults.

Background: Globally the ageing population is increasing. We are also living longer, and sometimes with an underlying condition. These factors can impact on our health and wellbeing, particularly in the environments, products and service systems which we interact with daily. Literature review suggests that multi-disciplinary expertise and Co-Design approaches can lead to positive outcomes and experiences for older adults.

Novelty & contribution to knowledge: This study contributes to the knowledge by documenting the following: 1) Identifying challenging aspects experienced by older adults and their day to day activities and experiences. 2) Displaying and documenting a design coalition of students, industry, organisations and older adults that contributed to a Co-Design Symposium with successful design outputs and concepts (see Appendix 1 & 2).

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Study 1: Older Adult Insights for Age Friendly Environments, Products and Service Systems

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Abstract

The environments we grow old in present a challenge to be adaptive to our changing needs and limitations. Environments, in the context of this paper, are the spaces, products and product service systems that we engage with, alone or with others, within and outside the home. A design coalition (Manzini 2015) was generated between a number of academic Institutions and ISAX (Ireland Smart Ageing Exchange - (ISAX 2016) an 'ageing think tank' organisation in Ireland. The intention of this coalition was to generate awareness of needs requirements for age friendly environments and to provide an example of how participatory design research can inform innovation in business and policy development at a local and state level.

A five-week study was conducted using design and ethnographic methods with twenty-two older adult participants (age range 69 – 80). The themes of study were identified as: mobility, public spaces, safety, social engagement, services & facilities. Cultural probes, semi-structured interviews and user observation, by both researchers and older adult participants, were used as methods to identify the unmet needs of participants within the sample group.

A Co-Design Symposium (http://info.isax.ie/national-co-design-symposium - now expired link) was held during June 2016 as an opportunity to demonstrate to a wider stakeholder audience the needs identified from this study. This Symposium was attended by over 100 people of various backgrounds (town planners, architects, transport experts, retailers, builders, health and other

service providers). The older adult participants and designers (staff and researchers from the School of Design at the University of Limerick, IT Carlow, Limerick Institute of Technology and Limerick School of Art & Design) were placed within teams of ten. The research was presented using audio/visual presentation as well as artefacts from the fieldwork, completed diaries, scrapbooks, storyboards etc. (see Appendix 1). Solutions were worked on and delivered at the end of the day. This Symposium has impacted positively whereby policy makers in local government have invited ISAX to further discuss research outcomes and the needs of older adults as a means to develop access areas in and around Limerick City. This paper outlines in further detail the design research methods used, and the benefits through design education Student/ Researcher /Stakeholder collaboration by application 'in the 'field' and displays the effectiveness of design coalitions in influencing and affecting change and insight into policy. It highlights how co-design collaborations can impact and generate design solutions that improve day to day experiences.

3.1 Introduction

There are a number of age specific agencies focusing on the needs identification and mobilization of the older adults' voice as a means to influence and deliver product and service systems that benefit all. One such agency is ISAX (the Ireland Smart Ageing Exchange). As a result of a rapidly growing ageing population and an increase in longevity, everyone who lives long enough will experience a disability, or a gradual decline in physical, sensory or mental abilities (Morris *et al.* 2010). The ageing population is a design concern that requires ensuring that design in industry, and higher-level design education, generate awareness by engaging with older adults using participatory or co-design methods. As design becomes more embedded in society new practices are emerging (Broadbent and Cross, 2003).

Emerging design practices, centre around people's needs or societal needs, and require a different approach in that they need to take longer views and address larger scopes of inquiry (Sanders and Stappers, 2008). To elicit their user knowledge and to better understand the context of user experience, the active participation of potential users in the early stages of the design process has gained importance (Sleeswijk Visser *et al.* 2007; Turhan and Doğan, 2017). A collaborative coalition of academic institutions, (University of Limerick, Institute of Technology Carlow & Limerick School of Art and Design, Limerick Institute of Technology) came together with ISAX; with the intention to organize a co-design symposium to exemplify how this activity can affect change and influence policy. Research through design (Frayling, 1993) is an activity that diarises and documents the paths to understanding and defining needs requirements. There is a move from designing for people to designing with people (Sanders and Stappers, 2014). Designers as part of a team are responsible for carrying out research, analysis, and interpretation of data and creating solutions with the stakeholders involved in any given context (Bate and Robert, 2007). Designers can also use the ideas generated by others as sources of inspiration and innovation. Co-design as described by Manzini (2015) as a "*social conversation*" was deemed a suitable approach on which to build the collaborations required for the Symposium. Co-design in various forms, from participatory design to co-creation, is growing rapidly. Co-design is not just about being responsive to stakeholders and listening to their needs; stakeholders actively contribute to the design of solutions (Bate and Robert, 2007). Designers and design researchers are exploring the creation of tools that non-designers can use to create their own solutions. Therefore, a variety of stakeholders including older adults collaborated in a symposium to identify needs and develop solutions in a variety of areas. It was agreed that in order to build the structure of a symposium, themes would need to be identified that would offer insights to ageing, and day to day activities and tasks. A strategy to recruit participants, including an ethics approved plan for fieldwork, was devised. Older adult participants, students, researchers and staff from the School of Design, University of Limerick created a collaboration to work together and learn from each other and through each other. This activity would deliver identified needs statements as the brief for each theme and work for the symposium.

3.2 Design Education

In conducting design research there is also a growing emphasis on ethnographic and observational research. Observing people using products and services can lead to the discovery of unmet and unarticulated needs which can lead to a breakthrough in innovation (Cooper and Evans, 2006).

Despite industry advances there is a belief that education is not supporting these opportunities and that design students are not well prepared with the skills for professional practice when they graduate (Kiernan and Ledwith, 2014; Sanders and Stappers, 2014). There are however some moves to include design research methods including generative and participatory design methods and knowledge from the social sciences at undergraduate and postgraduate level (Sanders and Stappers 2014).

The objective however in introducing any new methods to a curriculum is to also promote a positive learning experience for students. It has been shown that active (McMahon, 2006) and collaborative learning (Entwistle, 2000) can lead to deep learning by encouraging critical reflection (Entwistle, 2000; McMahon, 2006). A peer to peer and group-based learning environment is additionally recognised within design education. Symposiums and workshops can also go beyond the traditional learning model, with limited surface learning, to a transformational learning experience of deep learning. Symposiums and workshops can enable students to relate to the content personally fostering deep learning through personalisation and critical thinking (Watkins, 2014).

3.3 Methods

In user-centred design, many approaches can be undertaken that involve user influence and activity to inform design, namely participatory design (Sanders and Stappers, 2008), Universal Design (Story *et al.* 1998), & Co-Design (Manzini, 2015). There is widespread recognition for the importance of designers to gain empathy with the users for whom they are designing (Kouprie and Visser, 2009). This involves designers becoming immersed in the lives, environments, attitudes, experiences and dreams of potential users and understanding their needs (Battarbee and Koskinen, 2005). This article describes two stages to a participatory design project, 1) fieldwork with older adult participants, 2) a co-design symposium with a wide variety of stakeholders. A five-week study was conducted using design and ethnographic methods (Blomberg *et al.* 1993; Salvador *et al.* 1999) with twenty-two Older Adult participants (age range 69 – 80).

3.4 Fieldwork

The themes identified by the coalition to pursue in the fieldwork were: mobility, public spaces, safety, social engagement, and services & facilities. The fieldwork began in April 2016 and continued over a period of five weeks. At this point the researcher was joined by an undergraduate student of Product Design & Technology in University of Limerick who was working on a Faculty scholarship. The role of the student was to learn through experience of fieldwork by accompanying the researcher and engaging with the older adult participants in their homes, and while on task observation studies. During this time, the following qualitative methods were used, informal interviews, task observations, and self-observed diarizing by a selection of older adult participants of their world and day to day activities over the course of one week using cultural probe packs.

Cultural probes are a design research tool that gives control of data collection to the participant (Burrows *et al.* 2015). The probes did not require analysis (Gaver *et al.* 1999) but offered further opportunity to gain knowledge and insight from the world of the participants (Jones and Marsden 2006).

This facilitated the opportunity by the researcher to become intimately familiar with the day to day tasks and activities undertaken and to observe and understand challenges and pleasures experienced by the participants in their worlds. The researcher pursued enquiry with a tacit knowledge that was enhanced further by the narrative shared by the participants during the fieldwork. A template was developed for the interview sessions, the format of which would be loosely structured. This template was used as a tool to memo and add notes or sketches during the interviews. The template details information regarding the participant and their 'ref' anonymity. It also consists of open spaces for memo taking and sketching. The headings are listed with some reflective keywords in brackets - the purpose of this is to allow the participant to lead the conversation, however the researcher can introduce keywords of association to prompt or seek expression and opinions.

As a means to display credibility, integrity and rigour, both to older adult potential participants and other stakeholders, ethics approval for the research was sought and approved through the normal ethics procedure of University of Limerick. This enabled an action plan to present to groups and individuals, and an invitation to participate in field studies. The criteria for participants were:

- participants aged over 65, living in the Limerick environs, who were deemed independent and living in the community.

One of the opening questions to each of the participants in addition to the typical age, home type etc., was "are you active?" Interestingly this was a good conversation opener; 100% of the participants in both groups answered yes and proceeded to list activities and interests they pursued. The pool of participants was twenty-two older Adults, as displayed in Figure 14.

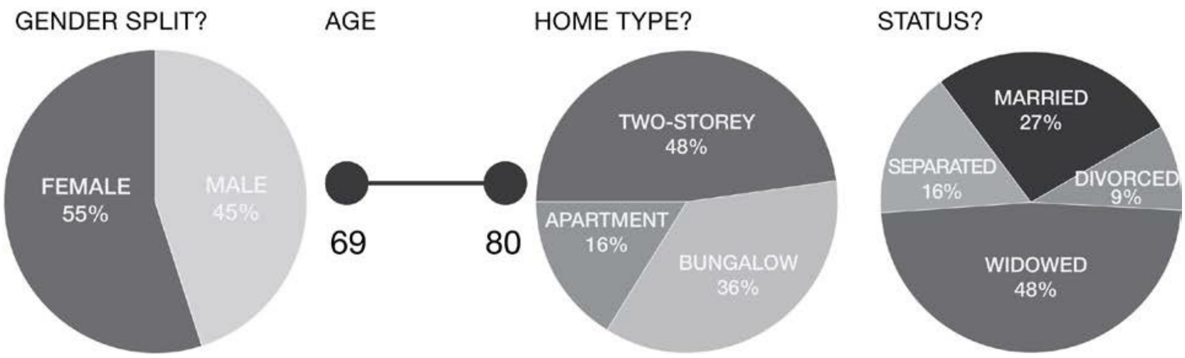

Figure 14 statistical breakdown of participants.

The participants were split into two groups of eleven, with Group One agreeing to be interviewed and observed undertaking various daily activities and tasks. Group Two were briefed and issued with cultural probe packs that would be left with the participants for the course of a week Figure 15. These participants would diarize and record items or experiences of interest. The packs were issued in a large wallet and consisted of the following:

- Mood board and stickers that the participant could very quickly indicate positive or negative experiences from each day and for each of the themes.
- Scrapbook and glue stick to place articles, or items read or noticed.
- Disposable camera to use as they wished for photographic capture and storytelling.
- A notebook to write, and express what went on each day.

Figure 15 Cultural probe pack (left) older adult participant with researcher (right).

During fieldwork, it was important to measure the effectiveness of the experience by the student accompanying the researcher, observations to note were:
Initially the student was quiet and somewhat unsure of the freedom and flexibility to be curious with the participant.
By session two, the student grew in confidence and began to enquire and express her curiosity to understand and empathise with the experiences and stories shared by the older adult participants.
The participants were curious about the student, sometimes they would talk in terms of generational difference, i.e. *in my day...*; *would it be like that now*? There was a warm rapport and interesting exchange between both.
On conclusion of the experience of being out in the field, the student reflected on the work and experience gained, stating:

> *"At first, I was quite nervous about how to interact with the participants, as I had not conducted any research in this way before. One of the key things I remember from the visits was learning that a conversation is much more valuable than an 'interview'. From watching and listening to Linda I learned a lot about gathering information through gently guided conversation. Without the formality of interview questions and the pressure that they can bring, the participants felt free to direct conversations to the things they felt most passionate or annoyed by.*
> *I was not lucky enough to know my grandparents very well as an adult. I have incredibly warm and fond memories of them from my childhood, but these are really the only interactions I have had with 'older adults'. Before I became involved with the project, this was not something that I had thought about. In the weeks, I spent speaking and listening to the participants in the study, I realised what a terrible absence that was. Older people, from my experience of the ISAX project, are full of life and a genuine desire to share their knowledge and stories with others.*
> *There are many misconceptions about old age out there but the mental strength of the participants I met made me reconsider my 'preconceptions.' There were also serious and more sombre conversations, highlighting areas where older adults were not being catered for. Without these conversations, the mix of fun and reality, I would never have considered some of these problems."*

This sharing of experiences highlights the impact and valuable learning that can be gained out in the field. When students are attentive to values, meanings and aspirations of those they are designing for, it can contribute to human flourishing (Lynch, 2015). An example of this approach is the Engineering for Humanity course in Olin College of Engineering in

Massachusetts. During their first year, students on this programme each work with one older adult participant, and throughout a semester, identify a problem, for which to develop and build a solution. The older adult participants are recruited from the community and surrounding areas of the campus, the module is described as a *“complete start to finish process of learning to design for a single user*” and this activity, it is believed helps students develop and build meaningful relationships with participants, and an awareness that the solutions can make real difference to people’s lives (Lynch, 2015).

3.5 Co-Design Symposium, Limerick, June 2016

Co-design can be considered ‘messy’, the collaborations of as many stakeholders as possible have input to the design process. This participation, in turn affords an iterative process that encourages autonomy and ownership between stakeholders, with outcomes and intent collectively developed (Donetto *et al.* 2015). The older adult participants offered expert perspectives of their lived experiences (Sanders and Stappers, 2008). The role of the researcher was to gather those insights and translate them to effective needs statements that each group could work with on the day of the symposium. Participants and partners of ISAX were invited to work together (Figure 16) (presentation slides Appendix 1) for one day on design solutions identified and stated as, ‘needs statements’ for each of the five themes observed during the fieldwork:

Mobility – Need: Improvement of accessibility experience outside the home – Bus access, parking, cyclist awareness & pedestrian experience.

Public Spaces – Need: Older adults with reduced mobility and their carers require access to busy areas safely, efficiently and conveniently, as a means to conduct everyday tasks and social engagements.

Safety – Need: Older adult safety and reassurance when outside the home.

Social Engagement – Need: Interaction, support and communication across communities and generations.

Services & Facilities – Need: Impartial trustworthy guidance to manage and plan finances and bills in the following areas: banking, general utilities, mobile phone options & estate planning.

Figure 16 Sample of attendees, including older adult, under-graduate & post graduate participants from University of Limerick.

To enhance empathic communication, raw data including photos and videos of users in their home and individual stories and quotes have been advocated as a way to let designers make personal connections to the users' experiences (Fulton Suri, 2003; Visser *et al.* 2005; Visser and Stappers, 2007) as how users are visually depicted can promote or hinder empathic understanding (Sleeswijk Visser *et al.* 2007).

There were various artefacts of research evidence (video displays, storyboards, photographs, diaries etc.) displayed and available for all attendees to view. The research evidence expressed in tangible ways the older adult experiences recorded during the research. Highlighted were various 'joy and pain points.'

The 'joy points' ranged from simple things such as well-placed park benches, opportunities for social engagement, volunteering, gardening, friendships and family life. The 'pain points' showed up problems as diverse as a lack of 'set down' areas for cars in Limerick City to 'drop off' a relative, unsafe street crossing areas, car park spaces with limited ambulatory accessibility, tablet blister medication packs that were a challenge to open, and personal security devices that didn't offer reassurance to users.

Participants then worked in teams of ten (Figure 17) to build new solutions for these problems, facilitated by design staff and students. Each team focused on one of the themes and comprised of stakeholder attendees, designers (students and staff from School of Design, University of Limerick., Institute of Technology, Carlow, Limerick School of Art & Design) as well as two to three older adults who had been involved in the research. Co-design implies a need for the designer to become the facilitator (Sanders and Stappers 2008) that encourages creativity by all.

Figure 17 'Pitch' role-play delivery by group facilitator.

Co-design encourages stakeholders to become part of the design team, and this experience can be enhanced by the provision of the right tools to assist creativity (Sanders and Stappers 2008) and freedom to express. The teams worked together and availed of tools and discussion to assist and generate ideas. These tools were: modelling tools, whiteboards to map and visualise thinking, artefacts from the fieldwork – diaries, scrapbooks, and large printed boards with summary to each theme. These summary boards encouraged group talk and interactions with other attendees for further discussion, see Figures, 18, 19, 20, 21 & 22.

Figure 18 Mapping interactions and relationships on whiteboards.

Figure 19 Modelling tools were accessed and used by all throughout the symposium.

Figure 20 Contextual tools from the self-observation groups were displayed: scrapbooks with images and diaries with narrative of day to day thoughts by each participant.

Figure 21 Further selection of modelling tools displayed and used to relay narrative and concept development.

Figure 22 Discussion locations were encouraged beyond the tables of each team to encourage interaction. Tools to support the conversations are the theme backdrops as displayed in the background of this image.

3.6 Findings

This section discusses the day's activity outcomes from the concepts produced, in addition, reflections from the experience are shared by a snapshot of attendee and organising students and lecturer. Towards the end of the Symposium, each team was invited to 'pitch' their idea and express the benefits of each design solution. There were ten design solutions offered:

Mobility

Solution 1: Volunteer Support Service Club

Create a new membership club, which is aimed at improving access by foot or transport links to commercial or public buildings. The club would engage early retirees, second level transition year students and others interested in volunteering their time, to 'map' good pathways or access links to bus schedules for onward/return journeys by public transport or for car parking spaces.

Solution 2 – Improved Car Parking Spaces

Getting in and out of cars more easily by alternating (L-shaped) car parking spaces, to ensure that car doors can be opened fully, and designing age friendly 'logo' for specific car parking spaces.

Public spaces

Solution 3 – Designated Drop Off Points

Create 'drop-off' points accessed by drivers, dropping off less-mobile persons. Each car would have a sticker ID on the windscreen provided by local policy makers. Signs and way finders would ensure the person dropped off and is aware of route back to pick-up point.

Solution 4 – City Ambassadors

Focus on passenger experience with reduced mobility. City ambassadors working within 1km of city centre, near banks, post offices and hotels, to provide support and information at drop-off points and main car parks.

Safety

Solution 5 – Safety in the Home Poster

Design an interactive poster for the home that is linked to a smart device. Buttons will have short cut icons to activate calls to family, emergency services, taxi, and house alarm.

Solution 6 – Sub-dermal implants

Automatic contact that is always on and is always worn. Sub-dermal implant worn by users for fall or other security alerts.

Social Engagement

Solution 7 – Hands of Friendship Network

This group would engage with new members of communities or areas with older adult population to make new friends and/or re-engage with an area. Building trust, a "Hand of Friendship" group would grow through word of mouth and social activities.

Solution 8 – Generation Allies

Inter-generational activities through a 'Generation Hub' – a community space, to facilitate trust, collaborative learning and laughter. Using 'Generation Allies' over the lifespan, so that security, respect, health, friendship, advocacy and wisdom can travel in both directions. Suggested tasting event, e.g. BBQ, communal garden. Inform and invite new members using radio, social media and 'Tell-a-friend' methods.

Services & Facilities

Solution 9 - Digital Training

Fear of technology is limiting access to online services. Access to a connected device and internet availability are two major issues. The suggestion was that the state offers retirees access to training that will enable people to become digitally literate. Once trained, an incentivised scheme would empower people by providing internet access with a suitable device with apps to access sites such as banking, flight booking and government agencies.

Solution 10 – Service Navigators

Service system to help people to manage their affairs and provide information that leads to informed decision making, e.g. appointing an executor for a will, putting 'power of attorney' in place for future, opening/closing accounts with utility companies. Part of the service would be to provide trusted 'navigators' who can facilitate when needed, e.g. set up a meeting with someone from a utility company, go to medical appointments, or to provide knowledge to assist decision making for major purchase (car). Put a loop system in place to ensure that every service item is managed to its conclusion.

On conclusion of the 'pitch' (figure 23), the attendees were issued with stickers and invited to vote by applying a sticker to their favourite solution. This democratising and validation of opinion led to a clear winning solution; however, the real objective of the day was achieved, a demonstration that cross collaborations between older adults, students, researchers, policy makers and industry stakeholders can deliver efficient and tangible solutions to identified unmet needs.

Figure 23 Older adult participant 'pitching' the benefits of their design solution to attendees.

3.7 Reflections

As a means to learn and understand experience from the perspectives of lecturers, students and stakeholders, involved in the organising and facilitating of the symposium, questions were devised and sent out to gather knowledge and insights.

The questions posed were:

Prior to attending the co-design symposium, what were your expectations or thoughts to the practice of co-design?

During the day, what observations or experiences did you find beneficial to the application of engaging with the various stakeholders and themes of the day?

Since the co-design symposium; are there any take-away thoughts or actions that have been inspired, and you have applied to your work – reflections?

To summarise the answers; it is clear that there was an element of anticipation and uncertainty to the day by the answers expressed for Question one. Regarding Question two, there is a certain amount of freedom and passion expressed by the activities undertaken on the day and the interactions with other attendees and participants from the fieldwork. The actions expressed in answers to Question three endorses the activity of co-design as a collaborative exercise with solutions created and stakeholders involved with designers and design researchers.

Sample responses:

Q1: Prior to attending the co-design symposium, what were your expectations or thoughts to the practice of co-design?

> *"Was nice and ideal in theory, but the practice wasn't always as easy, fluid or productive!"* (Lecturer)
>
> *"Before attending the co-design symposium, my expectations were based on my experiences in working with clinicians during my own research to inform design decisions. This involved a more solo approach to design in order to generate design milestones, for which the clinicians would then be present to offer guidance and feedback."* (Student)
>
> "*I was looking forward to taking part in the event, I was interested in seeing how designers interact with users and input from anyone really. I wondered if the designers would take control and dominate the tables."* (Student)

Q2: During the day, what observations or experiences did you find beneficial to the application of engaging with the various stakeholders and themes of the day?

"Having the themes and problems set out really helped to focus the projects at the start. Having the older adults present really brought the issues home and trashed my preconceived notions about the limitations (or lack of limitations as I found out) of older adults." (Lecturer)

"Interestingly, and perhaps obviously, dealing with clinicians is much different than working with the stakeholders during the co-design symposium. Clinicians tend to deal with cold hard facts, whereas it was quite refreshing to engage with stakeholders with a sense of empathy. There was also a more conversational approach to informed design too, which was also a stark contrast to the structured feedback sessions I've experienced in the past." (Student)

"Loved the whole day, I thought it was great brainstorming together and getting to know people while doing it. During the event, I noted that one of the moderators, while helping and building the tables as she walked around, was pushing certain solutions to us. I don't think it was intentional but the opinions and biases from organisers is very influential… On the day were we all her 'Users'? At the end of the day, the team I was a part of won the event with the most votes. Our team was the only one which had a user present the work instead of the designers (which every other team did)." (Student)

Q3: Since the co-design symposium; are there any take-away thoughts or actions that have been inspired, and that you have applied to your work - *reflections*?

"I would love to have real-world insights into the users and bring in a co-design process into all of the student projects since, but this isn't always possible!" (Lecturer)

"I believe that the key take-away experience that inspired me was the enthusiasm of everyone involved. While each group appointed a leader to keep each group on track, there was equal involvement from everyone. No idea was discounted, and there was a great sense of collaboration which culminated in an overwhelmingly positive experience. The symposium has helped me personally by giving me experience into working with people other than clinicians, and perhaps a more accurate reflection of co-design." (Student)

"Since then I question, is there a difference between HCD (Human Centred Design) done well and co-design? In practice, it's all about listening to each other and taking part in the co- design event has reinforced that to me. I also believe the role of the designer will still be important when working in these user lead/orientated sessions. A great metaphor I came across which explained this was: the designers and other stakeholders are like an orchestra; each play their part and the designer acts like the conductor which helps keep everyone in sync and flowing together." (Student)

3.8 Discussion

The value of collaborations between students, industry, organisations, and in this example, older adult participants, display the effectiveness and impact these kinds of coalitions can influence on product and service system design. Design is a social process and constructivist theories of learning recognize that learning is a social activity (Wenger, 2000; Bucciarelli, 2002). Collaborative and active learning through projects that integrate multidisciplinary specialists and end users is also an approach that better facilitates the solving of today's complex design problems (Seidel and Godfrey, 2005). Design education should be refocused on teaching designers to function in multidisciplinary teams emphasizing the complex process of enquiry, learning and decision-making through working collaboratively using several languages (Dynn *et al.* 2006). Links with industry and communities to create real-world design projects are crucial to the education of designers (Cardozo *et al.* 2002; Watkins, 2014).

The landscapes of design and design research will continue to change as design and research blur together and designers increasingly co-design with users and stakeholders. Furthermore, it offers students in higher level education insights to see beyond the studio and gain experiential awareness and empathy for the value of co-design. In a studio-based learning environment the student can be encouraged by the facilitative approach of lecturers. This can motivate the students to become critical thinkers and display an ability to influence and research through design. Kolb's et. al., (2001) experiential learning model, where knowledge is gained through experience, displays the responsibilities learners (students) have when undertaking this type of project. Design students are further encouraged to have the courage to create (May, 1975) and become self-starters, self-motivated and driven towards sustainable change (Designers Accord, 2011).

By encouraging learning beyond the studio and immersion with users as a co-design strategy; minds, curiosity and empathy can be embedded as a subconscious tool. This collaboration paradigm has previously been shown by DeVere et al., (2010) to encourage social responsibility and sustainability among students. It also influences an approach to develop a responsibility to design, delivering projects that can influence real world problems (De Vere *et al.* 2010). The co-design symposium is a clear example of what can be achieved when a cross disciplinary approach is undertaken. This is not always addressed through application in a design education context.

An additional benefit through the symposium was in the case of postgraduate students who tend to be most isolated in conducting their individual projects. The symposium afforded them the opportunity to collaborate with others, refresh their thinking and establish networks bringing additional benefit to their own projects. Suggestions to improve this approach would be to encourage workshops or small studio team-based projects. Students would work with a specific cohort through a user-based approach to enquire into and explore the unmet needs of daily problems people experience with product and service systems.

A further suggestion would be to undertake a cross disciplinary post graduate program with an industry partner to 'mesh' design through research and collaboration with specific user groups. The objectives of this collaboration would be to identify and define unmet needs in product and service systems. Addressing collaborative practice between Stakeholders encourages the use of co-design and collaborative coalitions to maintain user experience at the centre of the design method.

3.9 Research development & context

This study contributes to the overall research by developing purpose and understanding about what it is to age and engage daily in tasks or activities that are not always straightforward experiences. Regarding the participants, at times they shared contenment about their world regarding freedoms, options to holiday when they wished or to assist their (adult) children financially or by minding and enjoying time spent with grandchildren. Some of the daily experiences were beginning to detail challenge about assistive devices (e.g. hearing aids) mobility reduction and accessibility to computers, vehicles, buildings and packaging. The Co-Design symposium offered tangible application of action and response by coalitions to enhance and improve the ageing experience. This motivated enquiry about the following study to explore and understand current application and understanding of technology acceptance and older adults.

4. Commentary on Gerontechnology Acceptance & User Centred Design of Exoskeletons.

Study Rationale: The previous study had documented fieldwork evidence that offered insights to the ageing experience. However, this study needed to explore literary evidence of the tools or applications that are currently available to measure acceptance of technology by older adults. It would review acceptance models of existing technologies (TAMs), and explore if any models exist in relation to emerging technologies and robotics, more specifically – exoskeleton acceptance by older adults. Finally, it was important to assess and review what current guidance is published in relation to user centred design of exoskeletons.

Purpose: The aim of this chapter is to display and document current practice and knowledge regarding TAMs, older adults and exoskeleton acceptance. In addition, it discusses approaches to user centred design of exoskeletons.

Background: Exoskeletons can support older adults with reducing mobility as they engage in day to day activities and social interactions. To date, there is limited evidence of user involvement in the development or design of exoskeletons, particularly with respect to older adult users. Currently TAMs do not cater for evaluation, guidance or attitudinal measurement of older adult's acceptance criteria and expectations of exoskeletons. A lack of user involvement and insight to exoskeleton design could be a barrier to optimising their acceptance.

Novelty & contribution to knowledge: This chapter addresses and identifies knowledge gaps in relation to TAMs, older adults and exoskeleton acceptance. There was no TAM identified in the literature that offered attitudinal measure or insight in relation to older adults and exoskeletons. There is a distinct lack of user-centred design guidance for exoskeletons. This knowledge supports the need for a new design tool and model that measures and clarifies acceptance criteria by older adults towards exoskeletons.

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Study 2: Technology Acceptance and User Centred Design of Assistive Exoskeletons for Older Adults: A Commentary.

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Abstract

Assistive robots are emerging as technologies that enable older adults to perform activities of daily living with autonomy. Exoskeletons are a subset of assistive robots that can support mobility. Perceptions and acceptance of these technologies require understanding in a user-centred design context to ensure optimum experience and adoption by as broad a spectrum of older adults as possible. The adoption and use of assistive robots for activities of daily living (ADL) by older adults is poorly understood. Older adult acceptance of technology is affected by numerous factors, such as perceptions and stigma associated with dependency and ageing. Assistive technology (AT) models provide theoretical frameworks that inform decision-making in relation to assistive devices for people with disabilities. However, technology acceptance models (TAMs) are theoretical explanations of factors that influence why users adopt some technologies and not others. Recent models have emerged specifically describing technology acceptance by older adults. In the context of exoskeleton design, these models could influence design approaches. This article will discuss a selection of TAMs, displaying a chronology that highlights their evolution, and two prioritised TAMs—Almere and the senior technology acceptance model (STAM)—that merit consideration when attempting to understand acceptance and use of assistive robots by older adults.

Keywords: assistive robots; technology acceptance; mobility assistance; user-centred design.

4.1 Introduction

Older adults (aged 65+) are expected to account for at least 25% of the European population by 2020, increasing to 40% between the years of 2010–2030 (AAL-EU, 2016). Globally, disability rates in adults aged 60+ have been recorded as 43.4% in lower income countries and 29.5% in higher income countries (WHO, 2011). Assistive technology (AT) devices can offer improved quality of life to older adults, with robotics offering new directions within the field of AT (Bedaf *et al.* 2017). In 2013, approximately 13% of the population in the United States of America were living with a mobility impairment, which is considered the most prevalent disability (Borisoff *et al.* 2017). In 2015, there were over 20 million people living in the USA with an ambulatory disability (Lauer and Houtenville, 2017); globally, this figure exceeds a billion people (WHO, 2011). In Europe, approximately 80 million people live with some form of disability (European Commission, 2010). Disability in older adults commonly manifests itself as mobility impairment experienced in daily life. Disabled older adults experience higher rates of illness, reduced quality of life and social isolation (Manini, 2013).

Exoskeletons are rapidly gaining in prominence as an assistive technology; the wearable robots and exoskeleton market is forecast to be worth US $2.1Bn by the year 2021 (Researcj and Markets, 2016-2021). However, as an emerging technology, there is still a lack of robust quantitative evaluations of their performance (Young and Ferris, 2017). In addition, relatively little is known about older adults' opinions on using exoskeletons, or assistive robots in general, for daily tasks in the home (Bemelmans *et al.* 2012; Smarr *et al.* 2014). Issues with adoption and acceptance may be expected, since some older adults are slower to adopt and use new technologies compared to younger people (Wu *et al.* 2015). Therefore, research providing user insights may be useful to help understand and optimise the acceptance and adoption of such devices by older adults.

Nathan (2014) discussed the emerging opportunities for exoskeletons in medical and consumer applications. Assistive robots (Van der Loos and Reinkensmeyer, 2008) have been introduced as aids in manipulation, mobility and cognition contexts. Exoskeletons can offer support for older adults to remain independent as they engage in activities of daily living (ADLs) (Katz 1983; Smarr *et al.* 2014; Wu *et al.* 2014). At a physical level, assistive robot interventions can maintain body movement and provide motivation for older adults to remain active. At a social level, when users are able to respond and make eye contact as a result of being upright, it may result in greater autonomy and independence as they participate in social and leisure activities, thus reducing the likelihood of depression or social isolation (Cook and Polgar, 2015;

Pazzaglia and Molinari, 2016). There is a significant market, and strong social and design opportunities for assistive consumer exoskeletons that can support older adults and enhance quality of life (Smarr *et al.* 2014). For exoskeletons to penetrate the consumer market segments, they must meet essential user expectations in order for older adults to accept and adopt them in their daily lives. However, exoskeleton technologies remain primarily focused on rehabilitation, and military and industry applications (Van der Loos and Reinkensmeyer, 2008; Young and Ferris, 2017). There are many challenges with exoskeleton design to be solved before they become a part of mainstream daily living (Borisoff *et al.* 2017; Young and Ferris, 2017) (e.g., outside the home, with a companion, and in training to use the device (Borisoff *et al.* 2017). As complex wearable systems, there are several potential barriers to the adoption of exoskeletons in daily life such as stigma, technology anxiety and fear of dehumanizing society (Broadbent *et al.* 2009; Wu *et al.* 2014).

Hill et al. (2017) state that enquiry to gauge user perspectives of exoskeleton technology is minimal, with no literary evidence of user involvement in the development or design of exoskeletons. Wolff et al. (2014) surveyed wheelchair users and healthcare professionals about their opinions of exoskeleton use. The primary reasons cited for adopting an exoskeleton were around health benefits. As part of the study, they also reported on important design-related aspects that should be considered, in particular, minimising the risk of falls (when wearing an exoskeleton), comfort in use, ease of putting on and taking off, and cost. They projected a need for exoskeleton design to specifically focus on the following:

- Robust control
- Safety and dependability
- Ease of wear ability/portability
- Usability/acceptance

Older adults highlight the importance of maintaining independence with regard to their quality of life as they age; technology products can be critical to enhancing and maintaining autonomy if faced with a disability (Charness and Jastrzembski, 2009). Gerontechnology is intended to deliver solutions that impact and assist older adults as they engage with technologies to maintain or improve health and independent living (Pazzaglia and Molinari, 2016). From a design perspective, gerontechnology relates to understanding older adults' experiences and barriers to using technologies. When applied successfully, technology acceptance by the target group of older adult users can be achieved. It is important that older adults do not feel overwhelmed or intimidated by the complexity of an assistive robot, or find it frustrating to use, thereby demotivating them (Harrington *et al.* 2000; Wu *et al.* 2014). These negative experiences may ultimately result in abandonment.

Randolph and Hubona (2006) discuss the perspectives and varying needs that people with disabilities have when adopting and using new technologies. They state how ability is measured and easily assessed, but that the skill to use technology can be more ambiguous, and not so easy to predict. This presents a challenge to the design of exoskeletons, which are still an emerging technology, but in the coming years may be worn by people in social and community settings (Young and Ferris, 2017).

Exoskeletons have potential applications in a wide variety of environments aside from healthcare, and where they are not necessarily classified as medical devices (ISO, 2014) or for use by people with disabilities. Technology acceptance in relation to exoskeletons must be considered in broader terms than typical frameworks by which assistive technology is prescribed for patients, such as the International Classification of Functioning Disability & Health (World Health Organisation, 2001), the Human Activity Assistive Technology (HAAT) model (Cook and Polgar, 2015) or Matching Person and Technology model (MPT) (Federici and Scherer, 2012). These models are acknowledged as user-focused and are for assessment by collaboration between the user and their health professional to determine suitability for assistive technologies. The concept of assessing person–environment–technology interaction developed as a result of concern about AT abandonment rates, and commentary expressing how a multi-disciplinary approach to assessing and understanding user needs can reduce AT abandonment (Federici and Scherer, 2012). There is a need to explore other frameworks and tools that assist with understanding users' perceptions of assistive exoskeletons and implementing acceptance criteria in the design of such devices.

Technology acceptance models (TAMs) have evolved to describe users' acceptance of technological applications (Venkatesh and Davis, 2000) and are tools to relate users' intended use with their actual use of devices (Heerink *et al.* 2010). The purpose of this article is to comment on a literature review of TAMs applicable to exoskeleton technologies, in particular for older adults. The commentary highlights the importance of user-centred design in technology acceptance, and how the exoskeleton design life cycle should take into account and apply recommended design guidance in this regard.

4.2 Technology Acceptance Models

TAMs are theoretical approaches to describe factors that affect user acceptance of technologies (Venkatesh and Davis, 2000). They can also be used to describe factors that explain users' intentions to use a device (Heerink *et al.* 2010). More recent developments of technology acceptance models specifically gauge acceptance by older adults of technology devices, e.g., computers, mobile phones, assistive social robots 1) Almere Model (Heerink *et al.* 2010) & 2) Senior Technology Acceptance Model - STAM (Chen and Chan, 2014).

We performed an analysis of the literature for technology acceptance models and provide a narrative review of the key models identified, including a chronological positioning of the main developments (Figure 23). This section will discuss these models and their evolution, culminating in models of technology acceptance by older adults.

The review identified six models, which are summarised in Figure 24 and listed below.

These models are described in the subsequent sections.

- Theory of Reasoned Action (Ajzen and Fishbein, 1980)
- Theory of Planned Behaviour (Ajzen, 1985)
- Technology Acceptance Model (Davis, 1985)
- Unified Theory of Acceptance and Use of Technology (Venkatesh *et al.* 2003)
- The Almere Model (Heerink *et al.* 2010)
- Senior Technology Acceptance Model (Chen and Chan, 2014)

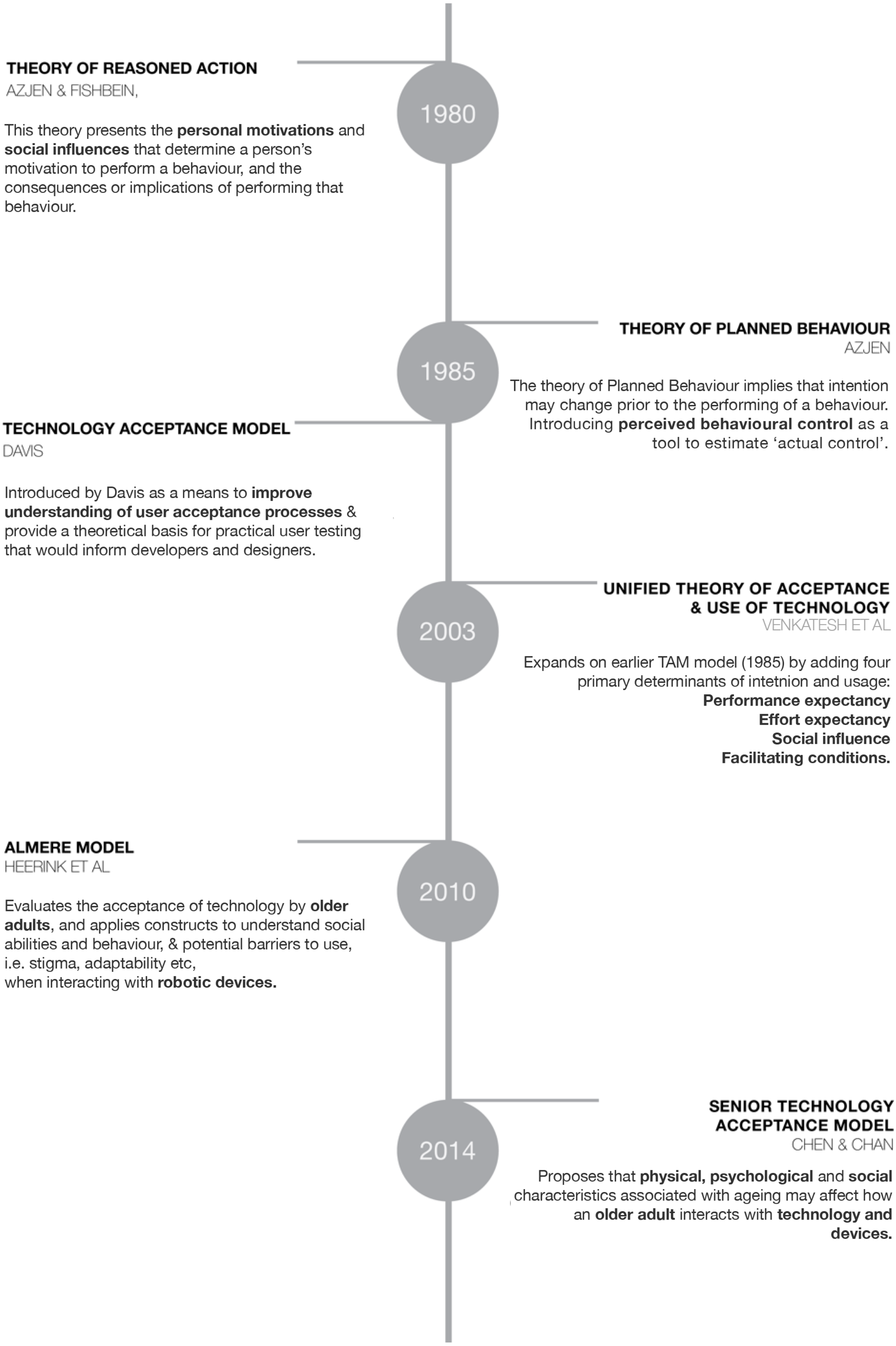

Figure 24 Chronology of selected technology acceptance models, highlighting their development and evolution to include older adults and technology devices.

4.2.1 Theory of Reasoned Action (TRA)

Azjen and Fishbein (1980) presented the theory in which people consider consequences or implications of decisions they make before engaging in a behaviour (Figure 25). The theory of reasoned action presents the idea that two factors influence the intention of the person: personal motivation (attitude toward the behaviour) and social influences that determine motivation to perform the behaviour (subjective norm). The model distinguishes between beliefs, attitudes, intentions and behaviours as a means to assess a person's attitude.

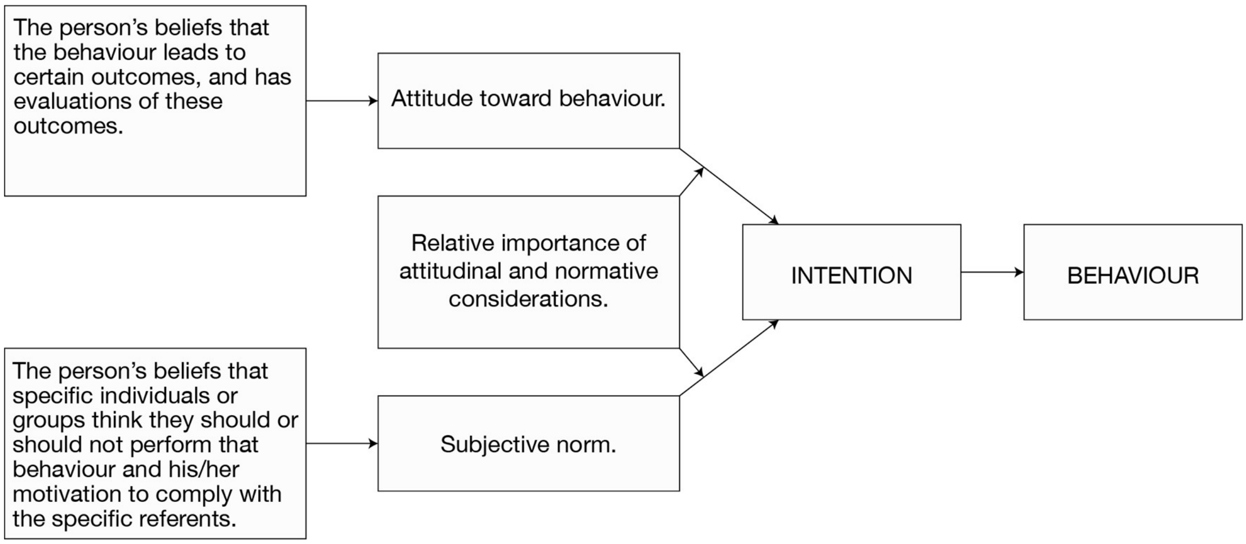

Figure 25 Ajzen and Fishbein present the idea that people consider consequences or implications of decisions they make before engaging in a 'behaviour'. The above figure displays the factors that determine a person's behaviour, as per the theory of reasoned action.

4.2.2 Theory of Planned Behaviour (TPB)

The theory of planned behaviour, by Ajzen (1985), extended previous work to include the construct of 'attempt' to perform the behaviour, and that 'intention' should be noted with the awareness that factors outside the control of a person may impact or change the person's intention to successfully perform the behaviour. This presents a need to incorporate the beliefs and attitudes towards trying, as well as a behaviour's success or failure. Perceived behavioural control is discussed in the theory as offering insight into understanding a person's motivation and self-efficacy/awareness of consequences of success and failure of a particular behaviour.

4.2.3 Technology Acceptance Model (TAM)

Davis (1985) proposed the first model labelled a technology acceptance model (Figure 26) and is regarded as authoring the seminal work on this topic. Davis introduced the concepts of perceived usefulness (PU) and perceived ease of use (PEOU). Figure 26 displays the various responses to the example design features that are generically displayed as X1, X2 and X3 and their causal relationships to the potential user's overall attitude towards using a system. A few years later, Davis (1989) acknowledged the influence of self-efficacy on both of these factors. The model indicates how design features relate to cognitive responses (PU and PEOU), which result in an affective and behaviour response. As such, it specifically highlights the role of design features in this regard.

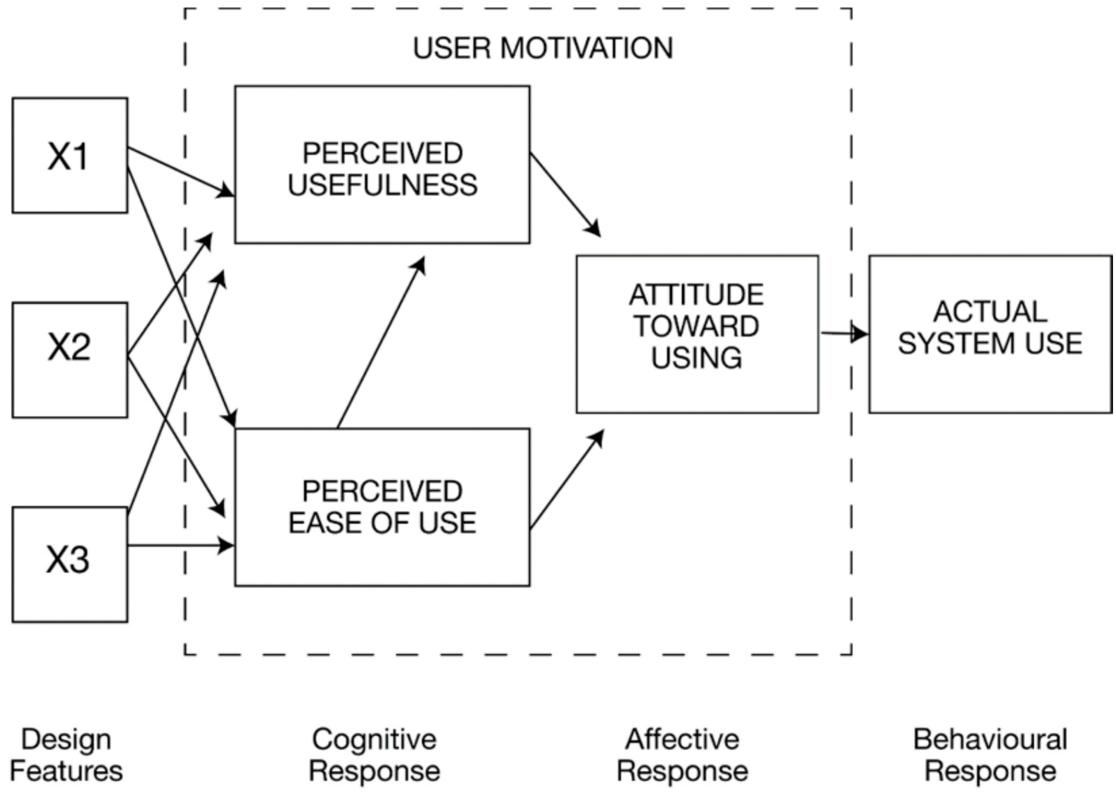

Figure 26 Technology acceptance model (TAM) displaying the various responses and the constructs of TAM affected by the design features that are displayed as examples, and stated as X1, X2 and X3.

Davis also proposed a generic user acceptance testing process, which is not routinely detailed in TAM models. The acceptance testing method (Figure 27) uses four sub-procedures: opportunity scanning, functional screening, interface screening, and prototype testing (Davis 1985). These four sub-procedures offer direct insights for exploring acceptance of technology by highlighting the importance of awareness of new and emerging technologies. Davis (1985) suggests how the TAM might be applied in design settings in relation to the overall design approach. Furthermore, the type of testing, by way of hands-off (verbal descriptions, slide presentations, video) versus hands-on testing (user interaction with test systems) is considered. The model specifically stresses the role of prototype testing and refinement regarding user requirements. It is notable how TAM, at this time, was directed towards systems and technology applications in a workplace setting, and not in a social or domestic environment. This, in turn, presents a question to understand how TAM can be applied with consideration to technology acceptance of people in a domestic setting using assistive devices to support ADLs (Katz 1983).

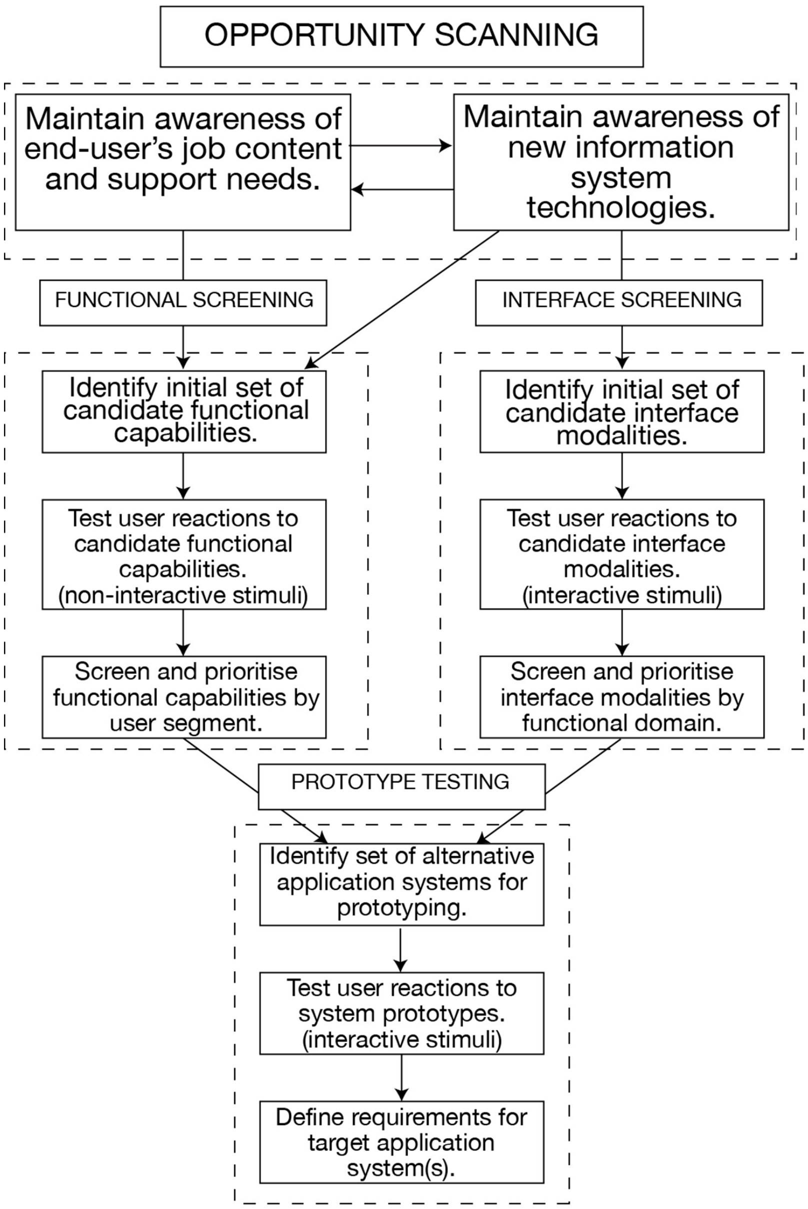

Figure 27 Generic user acceptance testing procedure as created by Davis. It highlights the selection of new support systems that have the highest probability of acceptance by users.

4.2.4 Unified Theory of Acceptance and Use of Technology (UTAUT)

Venkatesh et al. (2003) developed this model as an extension of Davis' (1985) TAM. The UTAUT model (Figure 28) illustrates the relationship between the four primary determinants of intention and usage (on the left) and behaviour intention and use behaviour. The model also details key mediating factors in this relationship (on the bottom). Performance expectancy can be impacted by gender and age and is considered in UTAUT as a determinant of intention to use.

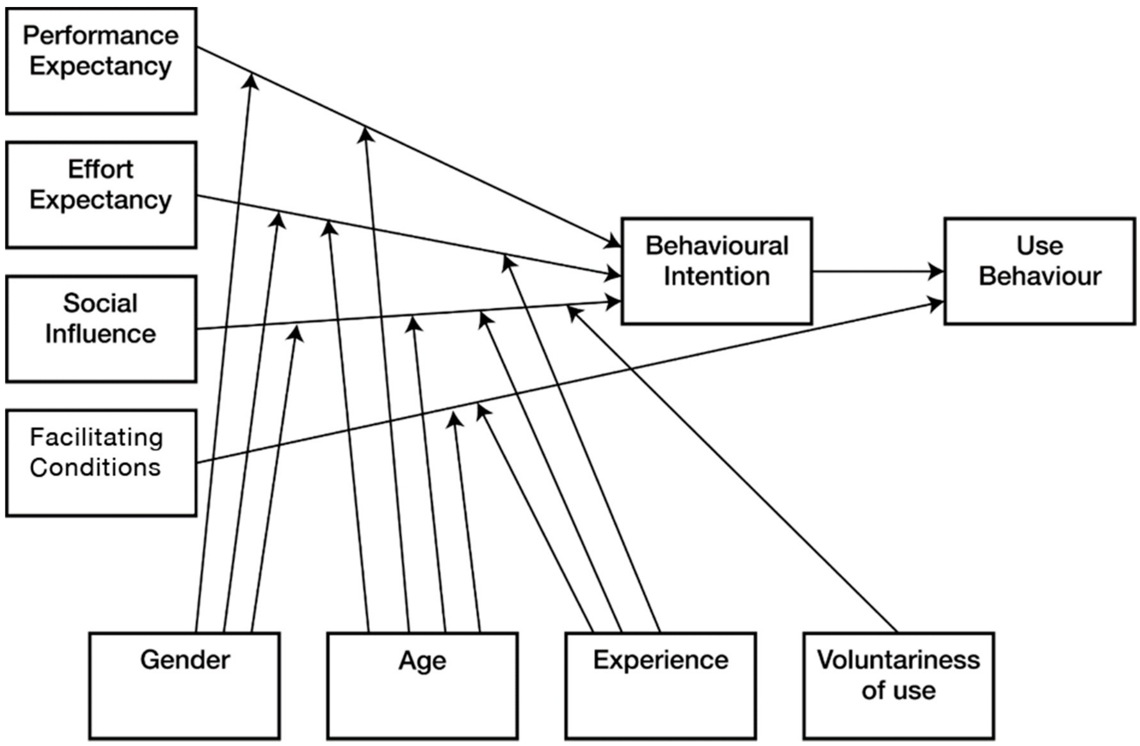

Figure 28 Unified Theory of Acceptance and Use of Technology (UTAUT) model as introduced by Venkatesh et al. expands further on technology acceptance models by including four primary determinants of intention and usage (performance expectancy, effort expectancy, social influence & facilitating conditions).

The constructs in UTAUT are detailed as follows with examples:

- Performance expectancy—e.g., I would find the system useful in my job.
- Effort expectancy—e.g., It would be easy for me to become skilful at using the system.
- Attitude toward using technology—i.e., using the system is a bad/good idea.
- Social influence—e.g., People who influence my behaviour think that I should use the system.
- Facilitating conditions—e.g., I have the resources necessary to use the system.
- Self-efficacy—e.g., I could complete a job or task using the system . . . if I could call someone if I got stuck.

- Anxiety—e.g., It scares me to think that I could lose a lot of information using the system by hitting a wrong key.
- Behavioural intention to use the system—e.g., I intend to use the system in the next number of months.

4.2.5 Almere TAM

Heerink et al. (2010) proposed the Almere TAM specifically for robot use by older adults. It builds on the UTAUT model (Venkatesh *et al.* 2003) and includes the variables of perceived usefulness and perceived ease of use from Davis (1985). Heerink worked off the UTAUT, suggesting it was a better platform than traditional TAMs for exploring technology acceptance of robots by older adults, particularly in social environments. Heerink amended previous TAM constructs to a list of thirteen and proposed relationships between them, as detailed in Figure 29.

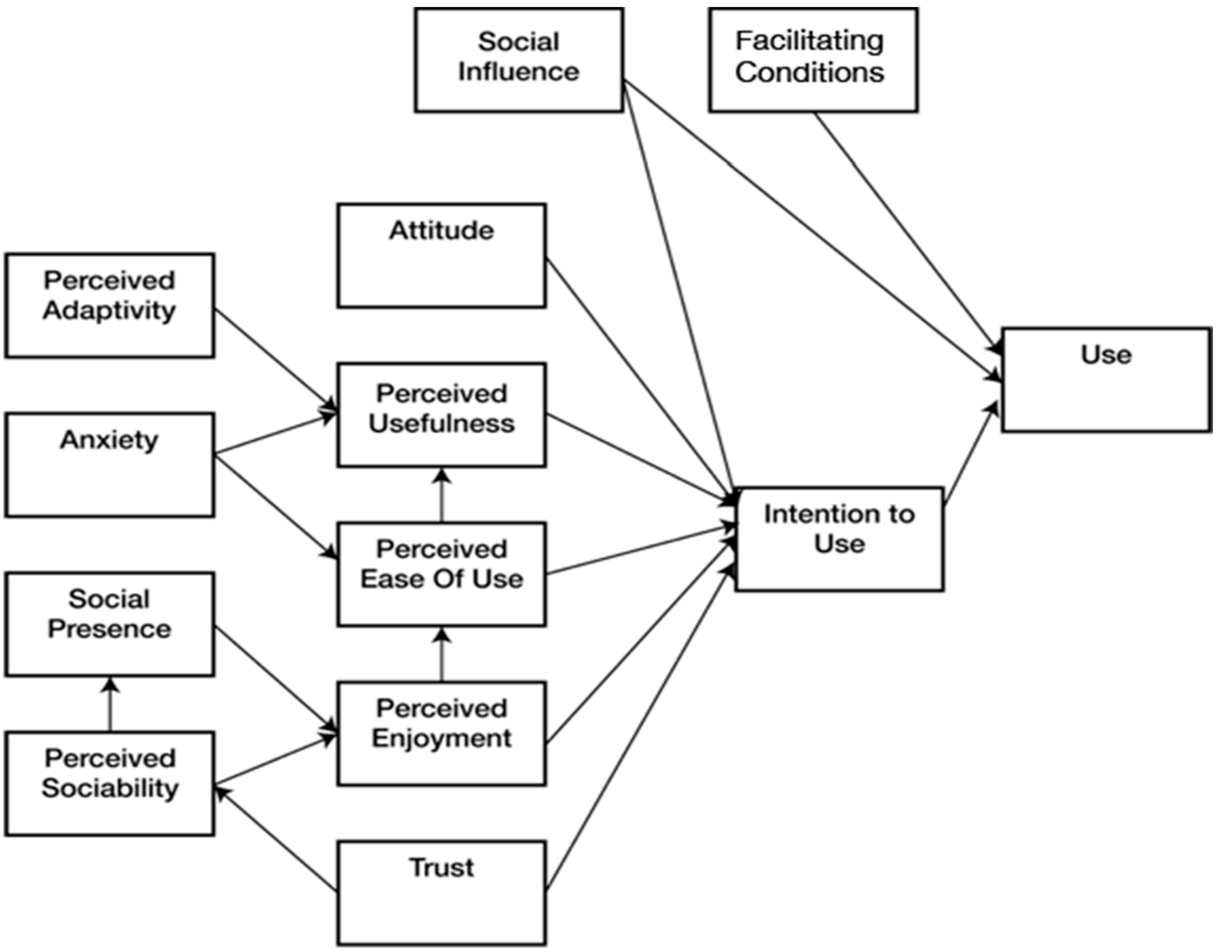

Figure 29 Almere TAM displaying the constructs leading to acceptance and use. A construct of note with this model is perceived adaptability, which affords consideration to the impact of ageing and change in condition or ability. This, in turn, supports modifiable elements to the technology in question.

Almere TAM constructs as described by Heerink et al., (2010):

- Anxiety—anxious or emotional reactions when using the system
- Attitude—positive or negative feelings about the application of the technology
- Facilitating conditions—objective factors in the environment that facilitate using the system
- Intention to use—The outspoken intention to use the system over a longer period of time
- Perceived adaptability—the perceived ability of the system to be adaptive to the changing needs of the user
- Perceived enjoyment—feelings of joy or pleasure by the user associated with the use of the system
- Perceived ease of use—the degree to which the user believes that using the system would be free of effort
- Perceived sociability—the perceived ability of the system to inform sociable behaviour
- Perceived usefulness—the degree to which a person believes that using the system would enhance his or her daily activities
- Social influence—the user's perception of how people who are important to them think about him/her using the system
- Social presence—the experience of sensing a social entity when interacting with the system
- Trust—the belief that the system performs with integrity and reliability
- Use—the actual use of the system over a longer period of time

Heerink et al. (2010) detailed that the model was validated and tested. Smarr et al. (2014) indicated a positive critique of the model stating that it was a succinct self-report quantitative measure of older adults' technology acceptance and that it is applicable to several assistive social agents.

4.2.6 Senior Technology Acceptance Model (STAM)

Chen and Chan (2014) developed the Senior Technology Acceptance Model (STAM) to consider older adults and age-related aspects not covered by previous TAMs. This model proposes that physical, psychological and social characteristics associated with ageing affect older adult interactions with technologies, specifically in the context of gerontechnology.

STAM is also an evolution of UTAUT (Venkatesh *et al.* 2003). Figure 30 details STAM, including the constructs and their relationship with perceived usefulness, usage behaviour and perceived ease of use, and their relationship with attitude towards use. In the model, dashed lines denote less significant paths in the model. STAM was developed following a 12-month study of user behaviour with a wide range of electronic products.

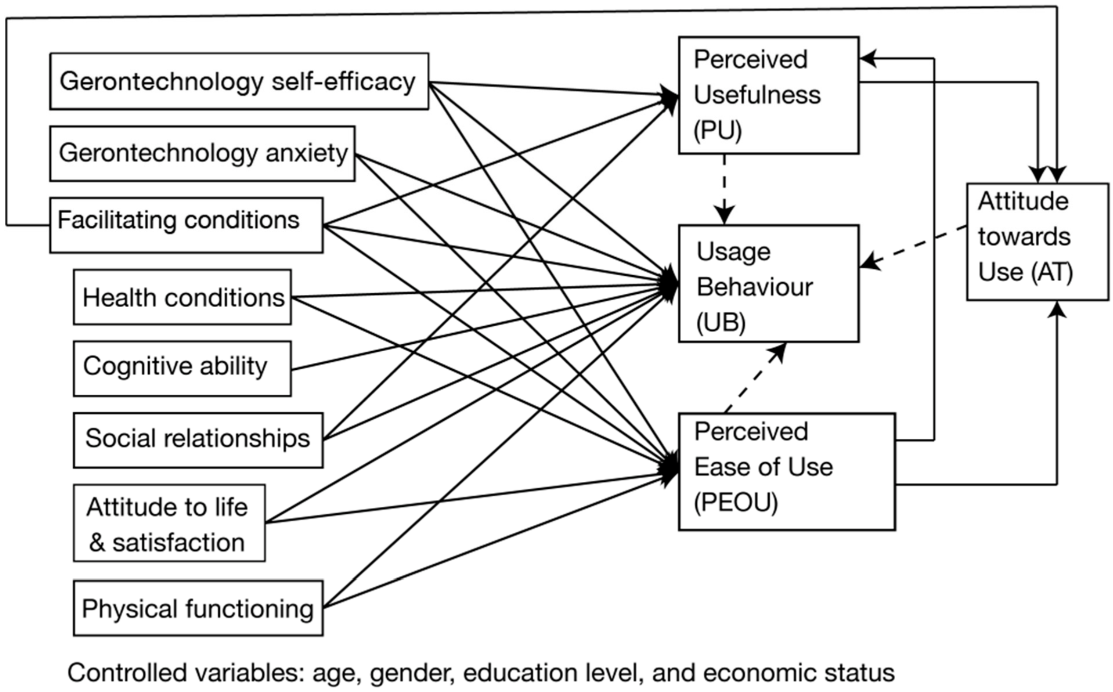

Figure 30 Senior technology acceptance model (STAM). Chen and Chan propose that physical, psychological, and social characteristics associated with ageing may affect how an older adult interacts with technology and devices.

4.3 Discussion

4.3.1 TAMs and Assistive Technology Models

This commentary discusses technology acceptance models and their relation to older adults and assistive exoskeleton design. Other AT models e.g., HAAT (Cook and Polgar, 2015), MPT (Federici and Scherer, 2012) are intended to be used to assess the suitability of assistive devices for people with disabilities in the context of the activities in which they engage (Lenker and Paquet, 2003). However, as a means to optimise and enhance adoption of exoskeletons by older adults, there is a need to develop a broader technology acceptance model that gauges perceptions and long-term use experiences by older adults. To date, a literature review has not revealed a technology acceptance model that gauges acceptance of exoskeletons. It is predicted that exoskeletons may be common devices seen and worn by people in everyday settings in the coming years (Young and Ferris, 2017).

Cook and Polgar (2015) suggest that older adults in the age group of 65–70 have some prior use and knowledge of technology; however, they may express some fear with regard to learning a new technology, e.g., fear of breaking it, or the cost of repairs if they are responsible for damaging it. This can be exacerbated by a decline in sensory, motor or cognitive skills as ageing progresses. For this reason, TAMs may be an informative tool that broadens the acceptance and use of new technology-assistive devices such as exoskeletons.

Table 7 compares three shortlisted technology acceptance models by key evaluation criteria. As displayed, older adults' acceptance is evaluated by two models, Almere and STAM; however, Almere is the only model that considers adaptability and future thinking.

Table 7 Relationship matrix of technology acceptance models and older adults.

	Unified Theory of Acceptance of Technology (UTAUT)	**Almere Model**	**Senior Technology Acceptance Model (STAM)**
Evaluated older adult perceptions and user of technology	✗	✓	✓
Affords adaptability of technologies and future thinking	✗	✓	✗
Specific to robots/social agents	✗	✓	✗
Tested with users in social environments	✗	✓	✓

The evaluation methods used to prescribe assistive technologies are, in general, evaluated between users and healthcare professionals. This can present challenges to designers in understanding and applying the expertise of other disciplines. With that in mind, it is important to understand, and be guided by, outside disciplines to broaden user requirements for design. There is a need to evaluate further measures required to optimise acceptance and use by older adults (Cook and Polgar, 2015). This is where the constructs of an exoskeleton TAM could potentially bridge the gap of understanding between AT models and user-centred design. In turn, this presents challenges and opportunities for designers to develop a more tailored model that can measure acceptance and optimism to adopt assistive robots, and specifically exoskeletons.

4.3.2 User-Centred Design of Assistive Exoskeletons

Exoskeletons, when deployed as assistive robots for older adults or users with motor impairments, are intended to support the user's independence. The ultimate aim is to design assistive robots that enhance the user's capacity to perform and engage in daily activities, rather than replacing or undermining their abilities. The review of TAMs in Section 2 detailed the importance of usability across several of the constructs, especially for gerontechnology applications. High usability requires the application of user-centred design methodologies, placing, in this case, the older adult at the centre of the design process, often including them as co-designer.

Older adults believe that learning to use new technologies is important to avoid feeling alienated from society (Wu *et al.* 2015). They may also feel unable to cope with technology today (Newell, 2011). However, assistive robot usage can carry the stigma of being dependent or declining in abilities, with older adults perceiving such stigma as unacceptable; thus, it presents a barrier to technology adoption (Chen and Chan, 2014; Wu *et al.* 2014). User-centred design can also be used to de-stigmatise technologies, resulting in a greater probability of acceptance (Cook and Polgar, 2015). Motivation to use technologies can be further enhanced when the technology offers some alternative uses or functionalities aside from those related to healthcare or the provision of assistance (Wu *et al.* 2014).

4.3.3 Practical Approaches to User-Centred Design of Exoskeletons

The international standard ISO 13482 (2014) details fundamental safety requirements for the design of exoskeletons, but it does not explicitly detail user-centred design requirements. A number of authors offer user-centred design principles for older adults (Fisk *et al.* 2004; Newell, 2011), but there is very little by way of specific guidance for exoskeletons, particularly for older adult users. Norman (2007) states how everyday people will learn to use new generation intelligent devices by trial and error, hence, they need to be easy and comfortable to use. Charness and Jastrzembski (2009) state the importance of comfort, safety and efficiency in the design of products and processes for older adults to fundamentally improve quality of life and ADLs (Katz 1983). Older adults have a unique perspective on accepting and using assistive robots. Despite an acceptance of and curiosity about new technologies, they require extended time and practice in order to achieve competencies and autonomy of use (Farage *et al.* 2012). Guidance on usability testing of older adults (Rubin, 2008) is also offered, again highlighting the unique requirements older adults have for design. However, there is still a gap in user-centred design guidance for assistive robots, in particular exoskeletons for older adults. A variety of research methods may be used to address this knowledge gap to explore user design requirements with respect to assistive robots, from quantitative methods (De Looze *et al.* 2016) such as questionnaires, to qualitative methods such as semi-structured interviews, and observation in participants' natural settings (Blomberg *et al.* 1993). Direct involvement of older adult users is crucial to successfully drive the user-centred exoskeleton design process, maximising the potential for uptake and acceptance (Pirkl, 1994; Fisk *et al.* 2004; Power *et al.* 2016). This enquiry could reveal insight and new knowledge that creates a new technology acceptance model. This may be an adaptation of Almere or STAM, or a new model that measures more specific features of exoskeletons, use such as cost, control of the exoskeleton, and acceptance of an additional device such as an exoskeleton and crutch.

4.4 Conclusions

This article makes an important contribution to the topic of user-centred design of exoskeletons and prospective approaches for studying technology acceptance of such devices by older adults. This commentary summarises the evolution of TAMs relative to gerontechnology applications. It discusses the importance of AT models to assessing the suitability of devices for a person with a disability. A clear outcome of the research is the need for empirical research into older adults' use and perceptions of exoskeleton technologies to further our understanding of theoretical and design factors that affect their adoption.

We note that there are relatively few TAM assessment methods available. Those outlined here are somewhat general with respect to the acceptance of technology as a whole. This commentary identified a preference for the Almere and STAM models for application to technology use by older adults. There is a requirement to develop a TAM that specifically evaluates the acceptance criteria and expectations of older adults using exoskeletons. In particular, qualitative studies of technology acceptance can be very beneficial in this respect.

A central conclusion from this commentary is that there is a distinct lack of user-centred design guidance for exoskeletons, and specifically for older adults. This is a barrier to the development of user-appropriate and user-friendly concepts that are needed to grow the acceptance and desirability of these concepts in the market.

4.5 Acknowledgments

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Conflicts of Interest: The authors declare no conflict of interest.

4.6 Research development & context

This study revealed literary evidence that identified a gap in relation to exoskeleton acceptance by older adults. There were three models identified that could assist with development of a design solution that would capture attitudinal measure of exoskeleton acceptance by older adults, namely UTAUT (Venkatesh *et al.* 2003), Almere model (Heerink, 2010) and STAM (Chen & Chan, 2014). This knowledge, combined with evidence of the initial fieldwork (Chapter 3) and review of the literature (Chapter 2) established the strategy to approach and undertake a refined, focussed study. It would again rely on qualitative approaches and grounded theory to spend time out in the field with older adult participants. The purpose would be to connect and gather knowledge about older adults perceptions to assistive technologies and their considerations of robotic assistance and exoskeletons.

5. Investigating perceptions related to technology acceptance of wearable robotic assistive devices by older adults.

Study rationale: This study had new momentum and conviction in its approach to exoskeleton acceptance by older adults. The previous studies and research had defined strategy and approach to this fieldwork. It required a broad qualitative approach, relying on the freedom to explore and to be led by the participants as they shared and expressed their perceptions towards wearable robotic devices and the ageing experience. Finally in order to undertake this major body of work, approval was sought and granted from the ethics committee, University of Limerick.

Purpose: The purpose of this chapter is to document a fieldwork study that investigated the perceptions older adults have to current and emerging technology including exoskeletons.

Background: In addition to the constant comparison, memo writing and other sources, time was spent out in the field with 24 older adult participants. This journey and approach has been evidenced through peer review presentation and publication.

Novelty & contribution to knowledge: Five main themes emerged from analysing and interpreting the fieldwork data. The themes that emerged influenced and generated three novel and original constructs not previously seen or applied in TAMs. In addition, it was noted that typical TAMs and usability tests require broader understanding when measuring or seeking attitudinal insights to acceptance of exoskeletons. Currently, we are unaware of any tool that facilitates this measure and approach from older adults towards exoskeletons or exosuits.

****Supplemental Appendix:** A paper presentation was delivered to the Design Research Society (DRS) annual conference in June 2018 (Appendix 3). It presented preliminary findings that documented the process of developing themes from categories and codes with 8 of the 24 participants. The presentation afforded time to share responses from eight of the participants in a rich and insightful way.

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Study 3: Technology acceptance and perceptions of exoskeletons by older adults - A qualitative study using a grounded theory approach

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Abstract

This study explored and interpreted insights expressed by a cohort of older adults related to their life experience, their experiences using or assisting someone with assistive devices, and their perceptions of robots and robotic assistive devices, including lower limb exoskeletons. A qualitative study using a grounded theory approach was undertaken with 24 older adult participants over the duration of five months. Five main themes emerged from this study – 1) Ageing & life stage experiences, 2) Quality of Life, 3) Assistive Technologies, 4) Health Conditions & Care, 5) Products & service Systems, which have influenced new constructs for a hybrid design tool that incorporates stages of Usability and TAMs (Technology Acceptance Models) to gauge a) Perception, b) Experience and c) Perceived Impact by older adults of lower limb exoskeletons. Emerging technologies such as robotic assistive devices require specific enquiry to understand how best to optimise acceptance by older adults and avoid feelings by them of frustration, embarrassment and ultimately abandonment of these devices.

Keywords: Technology Acceptance; Older Adults; Exoskeletons; User Centered Design; Grounded Theory.

5.1 Introduction

People of all ages are benefitting from the intervention and assistance provided by robots and exoskeletons in clinical and home settings (Smarr *et al.* 2014; Backonja *et al.* 2018). Physical assistant robots and exoskeletons could improve Quality of Life (ISO, 2014; McGinn *et al.* 2018) and it is stated that there is a need to focus on technologies that can maintain health and prevent decline (Robinson *et al.* 2014).

However, older adults can experience the 'digital divide' (Newell, 2011) whereby the pace of emerging technologies does not always match ability to use these technologies. This can impact on day to day task management and experiences when interacting and using devices such as computers or mobile phones. In turn, this can become a source of frustration or reluctance to use these devices. The ongoing process of change that is experienced from conception to death (Baltes, 1987) and a 'lifespan approach' (Graafmans *et al.* 1996) to design can expedite acceptance by implanting adaptability and flexibility features that facilitate older adult use. It has also been stated that family members may influence older adults acceptance of technology (Luijkx *et al.* 2015). In addition, Graafmans, et. al., (1996) express the need for further development and understanding that outlines peoples acceptance and use of technology that is beyond chronological age. User centered design determines a requirement to involve, identify and define user needs in the process of research and design (Dreyfuss, 1955; Papanek, 1985; Norman, 2002; Fisk *et al.* 2004; Farage *et al.* 2012). Other disciplines discuss 'client-centred' approaches and how clients must be part of decision making and tailoring of therapy and support programmes (Van De Velde *et al.* 2016).

Exoskeletons are expected to become a common assistive technology within the years to come (Young and Ferris 2017), with the potential for wheelchair users to adopt exoskeletons as mainstream mobility devices (Wolff *et al.* 2014). A lower limb exoskeleton, as is the focus with this research, is defined as a:

> "*multi joint orthosis that uses an external power source to move at least two joints on each leg, which is portable and can be used independent of a treadmill or body-weight support*"
>
> (Louie *et al.* 2015)

These emerging robotic assistive devices are further developing to include soft robotic features that will enhance wear ability and acceptance. XoSoft (2016-2019) is one such soft robotic lower limb exoskeleton under which the current research was motivated and funded. Older adults have been identified as one of the user groups that can benefit from intervention and assistance wearing soft lower limb exoskeletons such as XoSoft, to assist mobility and ambulation.

A review of the literature about Technology Acceptance Models (TAMs) (Davis, 1985; Davis, 1989; Venkatesh *et al.* 2003; Heerink *et al.* 2010; Chen and Chan 2014; Shore *et al.* 2018) and robotic assistive devices identified gaps perceived that would be critical to underpinning and optimising acceptance of lower limb exoskeletons by older adult users (Shore *et al.* 2018). In addition it was noted that there are generally few studies relating to perceptions and acceptance of robotic assistive devices by older adults (Frennert and Östlund 2014), with many related studies limited to internet use and access (Age UK 2009). A number of limitations of TAMs have been documented such as a dependence on user self-reporting and short exposure to such technologies. However, it is also acknowledged that TAMs have influenced design and design terms such as 'user-acceptance', 'diffusion', and 'adoption' (Salovaara and Tamminen 2009). Our review of the literature (Shore *et al.* 2018) did not identify any specific TAMs relating to acceptance of exoskeletons by older adults. TAMs that were deemed helpful to this research were ones that measured older adults' acceptance of social robots and everyday technology devices (Heerink *et al.* 2010; Chen and Chan 2014).

Our previous review (Shore *et al.* 2018) identified a knowledge gap and a justification for a qualitative study of and with older adults. The challenge was to capture and analyse factors related to experience and acceptance of assistive technologies and perceptions of soft lower limb exoskeletons by older adults.

5.2 Methods

The purpose of the study was to extract and interpret insights expressed by older adults related to their life experience, their experiences using or assisting someone with assistive devices, and their perceptions of robots and robotic assistive devices, including lower limb exoskeletons. This research was conducted using grounded theory (Thomas and James, 2006; Birks and Mills, 2015) with a philosophy based on a 'constructivist' approach, whereby data and analysis were generated from the interactions and experiences with participants, and other sources of data (Charmaz, 2014). There is a difference between the gathering, and rigour of quantitative & qualitative studies (Maher *et al.* 2018).

Constructing grounded theory (Charmaz, 2014) requires crucial elements as a means to display rigour to the research and its outcomes, they include the following:
Memo-writing, research question(s), recruitment and sampling of participants, data collection, initial coding, focussed coding and categorisation, build of theory (displayed in Figure 31). Constant comparison is ongoing and continues throughout the data collection to the build of theory.

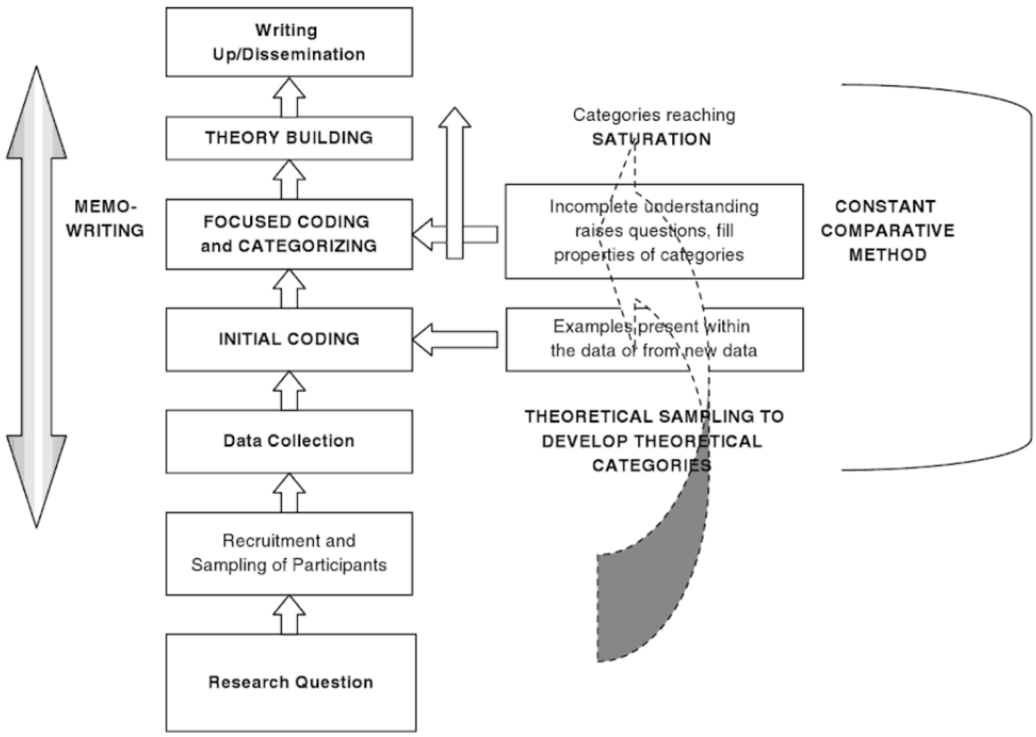

Figure 31 Visual representation of a Grounded theory (Charmaz, 2014).

There are a number of Computer Assisted Qualitative Data AnalysiS (CAQDAS) software packages available to assist the steps and stages of qualitative data gathering and analysis (Saillard 2011). In the present study Nvivo (QSR International) was used in conjunction with traditional qualitative gathering and analysis methods to analyse and interpret data.

5.3 Participants & sampling method

A purposive sampling method (Luborsky and Rubinstein 1995; Higginbottom 2004) was used to recruit 24 older adults. Participants were sourced through local community groups in Ireland. The local community groups were specifically approached based on members profiles (typically older adults) or health groups related to another of the Primary User (PU) types identified from the XoSoft project (e.g. Stroke support groups). In addition, snowball sampling (Oppenheim 1992) was initiated as a means for engaged participants to inform appropriate individuals they knew about the study and invite those individuals to contact the researcher if they wished to participate. Publicly available contact details were used by the lead researcher (LS) to make contact with local community group organisers, who were requested by the researcher to:

- Notify their members of the opportunity to participate in the study,

or offer that:

- The researcher would attend a group meeting to provide a brief introduction to the XoSoft project, inviting members to participate or to decline participation in the study.

For the purpose of this study, older adult candidates were identified as, 60+ years, living independently within the community, and with no cognitive impairment.

The study was approved by the University of Limerick Research Ethics Committee.

5.4 Data collection

Prior to the beginning of each session, the participant was issued with an information and informed consent form, and were invited to complete a Mini-Cog assessment (Cordell *et al.* 2013). This was administered to determine the presence or absence of cognitive impairment. It was understood that, should there be a negative response to the Mini-Cog assessment, this would exclude the participant, and they would be thanked for their time and advised that on this occasion it would not be possible to continue with the session. All 24 participants passed the Mini-Cog assessment, and the sessions proceeded in each case.

Each session was recorded using audio and image capture, as advised on the information sheet, and consented to by the participants. All participants were anonymised, and a code was applied as a reference to each, e.g. XOKKQOF14.

Intensive interviews (Charmaz, 2014) 'into the wild' (Chamberlain *et al.* 2012) were held with participants in their own home, or a place of their choosing. There were nineteen sessions in total conducted between May and October 2017. The sessions involved 24 participants (see table 8) with a mixture of one to one or conjoint interviews.

Table 8 Overview of participant and session types.

Session participants	Number of participants	Number of sessions
Male	4	4
Female	10	10
Male & Male	2	1
Male & Female	8 (4M + 4F)	4
Total	24	19

Each session was opened informally by the researcher engaging with conversations about the journey, or weather, or other aspects deemed comfortable to develop rapport. A template was used for memo-writing. It included six open-ended questions. These questions were developed as per title of research and to advance emerging ideas (Charmaz, 2014), and were led by the participants expression and insights:

1. What are your experiences using or helping someone to use assistive devices and/or technologies such as1) glasses or hearing aids, 2) computers or smart phones, 3) rollator or wheelchairs?
2. Describe any difficulties or barriers to using a technology device?
3. If you are/were to experience reduced mobility, how does it/would it affect your quality of life?
4. When I mention robotic assistive devices, describe what that means to you?
5. What is your opinion of older adults being supported by robots to do tasks and activities?
6. How do clothing and dressing options change as we age?

Rich in-depth understanding was gained of older adult experience and perceptions towards technologies, emerging technologies, ageing and life-stage changes. Each interview was recorded on a digital file (for transcribing verbatim). In addition, the template was used by the researcher during each interview to memo and document the progress of each session. Memo-writing according to Charmaz (2014) "*affords an interactive space and place for exploration* *and discovery*". This memo-writing assisted with transfer of thought to action and new topics to introduce during the following interview sessions with new participants.

Memo-writing in the context of this research and as per a grounded theory approach was captured through interview notes, reflective journaling and visualisation or mapping by hand to drawing sheets and digital infographics.

The audio files from each session were uploaded to Nvivo. In addition, image and video files were coded, anonymised and stored securely on the University server. Nvivo was used to build a database of material and data gathered. In addition, a more standard action was used to develop theory e.g. post-it notes, affinity diagramming and further memos supported the interpretation of the data (see codebook Appendix 4)

5.5 Data Analysis

Line by line examination of the data are required for a grounded theory approach (Saillard 2011). Coding is considered the first step of data analysis, (Birks and Mills, 2015).

Saillard (2011) discusses how the interactive activity of going through categories from codes to build theory is an analytic process and traditionally the researcher will identify words from the interview transcripts that have relevance or meaning. Nvivo is a software programme typically used by researchers interpreting grounded theory or mixed methods data (QSR International ; Saillard, 2011).

It was used to assist with developing the codes into categories and themes, in conjunction with traditional manual methods of memo-writing, mapping and affinity diagramming. This activity ensured rigour and applied constant comparison as categories developed. Each of the transcribed interviews were uploaded to Nvivo. Each interview was then coded on a line by line basis, identifying each code by a relevance to a comparative category that developed alongside the other interviews as they were transcribed.

5.6 Results

This study was conducted with independent living older adults in a number of locations in Ireland. Over 976 minutes of conversations were recorded and transcribed verbatim. The transcribed interviews were uploaded to Nvivo for line by line coding. In total 1391 codes were generated from over 8000 lines of text. This activity induced review and reflection time to pursue thought and interpretations of data. It required action to visualise the codes out of the digital space and use additional methods on wall space (post-it notes, affinity diagramming, mapping) to develop these interpretations.

This activity assisted understanding and thinking through the emerged codes and interrelations that would develop interpretations of data. An example of this code to theme development is displayed on Table 9.

Table 9 Example of analysis as it developed from lines of transcript, through to codes, category and theme.

Excerpts from interview sessions	Code (Examples)	Category	Theme
M01: But as things change, the system will change, and the nurse will be, told. Oh, the blood pressures high or whatever it could be.	Robotic Trousers– **'Monitoring'**	**Robotic Trousers** **Description:** Lower limb exoskeleton was a term not used during conversations settling more for robotic trousers based on literature reviewing and initial questionnaire discussions with older adult groups. Perceived usefulness and stigma were discussed, as well as perceptions and enhancement/quality of life.	**Assistive Technologies** **Description:** Existing assistive devices such as wheelchairs, hearing aids are captured here as well as perceptions to the emerging technologies and robotic devices that could be part of the assistive technology assistance in the future.
F28: I suppose if I take my aunt again it's her legs are weak so if there was a robotic type thing that would hold her up and give her the strength and maybe it would be connected to her legs that would support her and then she'd actually be able to move with the support of it.	Robotic Trousers – **'Perceptions'**		
M03: I'd love to go that way, you know, rather than a wheelchair, I could walk around my own house, it gives me more opportunity to stay in my own house, if I want to make my own tea. Because it gives you back your lot of independence, you know what I mean? (if you had robotic trousers)	Robotic Trousers – **'Perceived Usefulness'**		
F23: And then you could control him (robotic trousers) rather than if you were employing someone to do your home, it's not quite the same is it! So that they would obviously be, it would be important, that they fit you very well.	Robotic Trousers – **'User Expectations'**		
Summary of workflow from Codes to Categories to Themes:			
The complete study referenced over 8000 lines, defining 1389 codes.	The 1389 codes developed 85 different categories	The Category *'Robotic Trousers'* contained 18 codes (four example codes in second column) relating to understanding and perceptions of these emerging technologies.	The theme *'Assistive Technologies'*, had two main core categories within the theme, namely: *'Assistive Devices',* and *'Robots & RADs' – robotic trousers was within this category.*

Five main themes emerged from the data, which are detailed in Table 10 along with descriptions. The five themes are presented, including a selection of highlighted categories or codes considered relevant to understanding how older adults engage in day to day activities, and how they would see a world with reduced mobility or robotic assistance.

Table 10 Five main themes emerged relating to the purpose of enquiry.

Theme	Description
Ageing & life stage experiences.	How the ageing experience is shared by day to day interactions with others, ability and self-awareness.
Quality of Life (QoL)	How Quality of Life is impacted as a result of day to day activities or experiences, as per ADLs (Activities of Daily Living (Katz *et al.* 1963)) and interactions. Ageing impacts e.g. physical decline on our ability to enjoy or have a QoL.
Assistive Technologies	Existing assistive devices such as wheelchairs, hearing aids were discussed with views to self-use and assisting others use these devices. Perceptions to the emerging technologies and robotic devices that could be part of the assistive technology assistance in the future were expressed with views to their benefits and likewise concerns.
Health Conditions & Care	Many topics (own health conditions, family members e.g. dementia) were discussed and how these health conditions are experienced throughout life. In addition, the management and monitoring of these conditions, as well as interactions and relationships with family, health professionals and appointments.
Products & Service Systems	Various product and service system topics discussed and the benefits but likewise challenges of using such as mobile phones, plugs and technology.

5.6.1 Theme 1: Ageing and life stage experiences

Participants discussed their ageing experience, sharing how they go about day to day tasks. '*Accessibility'* described how it can challenge or empower older adults. Getting into and out of buildings, cars or accessing public transport, computers, and packaging were frequently commented on. Difficulties accessing doors, baths, public spaces were often related to as mobility challenges. In turn, an awareness of 'slowing down' was documented –

> **F26:** "*I've slowed down so much as regards walking it's driving me mad".*
>
> **M19:** "*I'd be too tired to do anything the next day you know.*" (session note - effects of post-stroke when doing day to day tasks).

Mobility was noted as critical to maintaining day to day tasks and interactions with others. Having the ability to go for walks, or to drive a car distinguished a sense of autonomy and independence. *'A fear of…'* was consistently discussed of developing Dementia – Alzheimer's. Stories were shared of siblings or other family members that had Alzheimer's and how it had affected the individual as well as the worry and concern the family felt supporting and caring for their loved one.

Ageing was sometimes commented as a pleasurable stage of life. Expression was shared about freedom, and not feeling bothered or upset by events that perhaps would have been worrisome at a younger stage of life. There was evidence of enjoying the value of time and social outings. Relationships with friends, neighbours and family members were discussed as well as the joys and lows of family interactions, e.g. not wanting to become a burden to children; being helped with technology such as computers and internet apps – banking, flights.

Self-Identity, with awareness to ageing, e.g. participants would discuss the 'granny' look or how others were 'old' (despite referred persons being of a similar age).

> **F23:** *I wear jeans, all of the normal stuff. I don't believe in that 'granny thing'.*

In addition, image was expressed particularly in relation to the way the body changes. Female participants discussed items such as under-garments – foundationwear (roll-on/corset) that were viewed as enhancing body image when they were younger.

The risk of falls was another concern about ageing, and one that sometimes was not accepted or perhaps recognised -

> **F17:** *"no, I don't fall over"*, (session note - participant has had at least two falls in five years, and uses a walker/stick to assist mobility).

The results of this theme suggest how the experience of ageing can be a pleasurable one, but also one that has concern to health, relationships and self-awareness. By offering supports and enhancements, where required and mindful to ensuring self-efficacy for the older adult, products and service systems can be supportive to the ageing experience.

5.6.2 Theme 2: Quality of Life

Quality of Life was determined by the participants as an ability to choose and do things as they wished, having choice in their lives. Gardening offered pleasures of work satisfaction with resulting growth, smells and sounds of bees and birds. Gardens were often noted as places that had been adapted or were being planned to, with solutions such as raised beds to facilitate ease of movement. In addition, perceived risk of falls within the home, particularly bathrooms was noted with many participants opting to adapt or plan trips to the bathroom;

> **M14:** *"and if (wife) is away, I would put the phone on the floor of the bathroom"* (session note- fear of falling and not being able to call for help).

Or removing their bath and choosing to install a shower.

Pleasures of life were documented in almost a reflective satisfied perspective:

> **M15:** *"So that is a lot to do with, once you get, say you get to a certain age, I mean, your mortgage is paid off, your kids are gone, they're married, all mine are married, and gone, and um, so there's only my wife and myself, and eh, we're managing quite well."*

However some participants had concerns about money which appeared to limit choice of preferences to do things, with some participants experiencing anxiety regarding moneys and money management.

Identity and stigma of labelling self, or others was also captured and evidenced in this theme:

> **F16:** *"he's more, a manual worker;"* (session note - wife explaining how husband has less interest in technology).

It also appeared that using an assistive device such as a wheelchair can affect self-identity and perceived acceptance (or not) to be social. Participants had witnessed or experienced reluctance to use assistive devices such as wheelchairs; often because of a sense that it identified you as needing help and unable to operate independently.

A further aspect of self-perception was image and opinion to clothing that is worn as we age, topics such as style, colour, comfort and safety were discussed;

> **M15:** *"Velcro straps are fine, I don't mind; they're actually… laces are a damn nuisance because they tend to eh, unravel, and you could step on the damn things"* (shoelaces, and tripping over).

Colour was discussed with impressions that colour can reflect how the wearer is feeling, e.g. having a mood, or being depressed (wearing black). Other participants noticed the colours they preferred now, but not when younger. Example of 'comfort' was shared; wearing fine clothes when out socially but enjoying more comfortable styles once at home.

Technology was a source of satisfaction to in-home activities such as browsing on computers, listening to music or connecting with loved ones not living close-by,

> **M16:** *"during the winter months now, I'd probably stay on that,* (iPad) *I'd probably spend from 6 o'clock in the evening, till about half ten,* (on iPad in Winter months) *then I'd watch a bit of television"*.

Computer use was often accessed independently, but on occasion; assistance and trust was transferred to seeking help from family members to book flights or banking.

Some participants had inherited smart phones from family members, or family members purchased computer tablets for participants as a means to improve inter-family connectivity and technology use.

The above comments express the importance of Quality of Life as shared by the participants. Tasks, activities and technology play important roles in how Quality of Life is experienced and enjoyed, or not.

5.6.3 Theme 3: Assistive Technologies

This theme relied on discussions around existing assistive devices (e.g. wheelchairs, hearing aids, glasses) to explore future and emerging devices that involve robotic assistance. The most common conversations regarded glasses and hearing aids, followed by wheelchair use and experience. With regards to everyday use of such devices, there was an appreciation of the assistance they offer; however, some challenges were noted also:

Glasses: experiences wearing glasses with hearing aids was often a cause of discomfort. Options of varifocals, Bi-focals and contact lenses at times presented challenge to usability, and disorientation of vision while adjusting to wearing and use. There were negative and positive comments regarding image and how glasses can enhance or influence someone's 'look'.

Hearing aids: Discussion about these assistive devices included commentary about cost, service system, and purchase options. A number of participants had purchased them and abandoned them, leaving the hearing aids in the packaging or drawers. Problematic factors were documented: wearing hearing aids with glasses are a challenge for some who indicated that they sometimes cause discomfort and contribute to sweating. In addition the main difficulty and reason hearing aids were abandoned was a sense that they did not accommodate layers of conversation, where more than one person spoke in a group. This experience led to frustration for participants. It was often noticed by people close to them that they were not wearing the hearing aid, due to the fact the person with hearing loss would sometimes interrupt or miss the topic of conversation. At times these devices had been an expensive investment with a participant sharing they had cost her €4,500. Other participants mentioned a grant they could avail of from the state to assist with this cost.

Wheelchair: Participants discussed wheelchairs, and their use more from the perspective of having helped others, or witnessed family members in wheelchairs. Comments frequently were about the changes and adaptations (e.g. cars, home) that are necessary if mobility is reduced. Two participants shared experiences of using wheelchairs temporarily, mainly when on outings, or travelling abroad. The participants were married and had other conditions (male; heart attacks, diabetes, female; stroke x2). The option to use wheelchairs was dependent on either family members or airport staff etc. being arranged to assist the couple. Generally on a day to day basis they would use an adapted car, and walking sticks to assist mobility. In their home they also had a stair-lift installed which opened up full access to their home again.

Conversations about robots and robotic assistive devices were varied. At times, participants appeared challenged mainly because robotic assistive devices are not yet as familiar as established assistive devices e.g. hearing aids or wheelchairs. Some considered them ‘hard to imagine’ because they had never seen them. Others believed them to be a prosthetic of sorts that replaced a limb or a joint. During sessions where participants were unsure and perceptions of robotic assistive devices were asked, items such as stair lifts, mobility scooters, and kitchen devices (electronic can openers) were identified by participants as likely to have robotic features and capacity. This appeared to connect the perceived usefulness robots and robotic assistive devices could have. There was an assumption that robotic assistive devices would be expensive, with a view by some that they could not afford it. Participants were asked about what life might be like with assistive robots and would they be accepting of these in an older adults world. Generally there was a positive view of their potential and how they could support day to day activities such as toileting, gardening and cooking. Robots potentially were seen as companions, or a ‘butler’ (worker) type; which at times challenged the ‘trust’ to immerse and avail of the ability and service the robot could provide. In relation to robotic trousers, participants appeared happy with the concept of a pair of trousers that could offer mobility assistance. Some indicated they would like them worn under existing clothing, citing reasons such as:

Not wanting to be noticed as wearing or appearing to wear the same clothes all the time.

Maintaining a choice to select outer layers was preferred.

To be autonomous and selecting a fashion or style preferred by the individual, and not dictated by the robotic trousers.

Participants indicated that they had a preference for robotic trousers to be tailored. This expression appears to be linked with optimising trust in the device. Other reasons cited included - ageing and body change, and new or existing health conditions that cause change or require adjustment and tailoring specific to the individual.

5.6.4 Theme 4: Health conditions and care

Each participant discussed openly the various aspects of their health, and experiences in hospitals or clinics as well as relationships with health professionals, doctors etc. In addition, the organising and taking of medication for some was a regular response, with tablet splitters, 30-day organiser containers and pharmacist support noted.

Some participants had experienced falls (n=6), and at times blamed themselves e.g. over burdening themselves with items that blocked their view and disoriented their footing (carrying bedding and a bed-sheet straggling on the floor). Participants sometimes commented as having 'wobbly feet', blaming this for falls or near-falls. Others commented that getting up too quickly after sitting or lying down could lead to a wobble or a fall.

A story was shared about the impact of wearing or not personal alarm pendants in relation to falling;

> **F14:** "*Yes, 'um that came about because we had at least three people in our group who were saved because of it, and we had one lady who didn't ever wear it but she had it on the table beside her bed and she fell out of the bed on top of it, and um it went off, but she didn't* (trigger it) *and she rolled in underneath the bed* (session note - participant is involved in one of the social groups visited. After this episode was shared with the group, she noticed change in behaviour with an increase in people wearing personal alarms.) *"her daughter came as a result of the call and when she arrived to her house they couldn't find her, they knew she had pressed it* (personal alarm) *and only for that, it would have been, maybe the been the next day before somebody would have been in the house. You know that was a really big lesson".*

The above narrative is an example of the influence incidents can have on wear and use behaviour and how this experience influenced a social group to begin wearing personal alarms. At times these alarms are devices that some people are reluctant to adopt or accept for fear of triggering them unnecessarily and troubling the support network/provider. Others view of personal alarms is as a badge that highlights a persons' vulnerability. It would appear that items such as personal alarms need to display real benefits, that exceed the reluctance for them to be adopted and used as assistive devices.

A number of the participants discussed experiences of hospital or medical appointments. In relation to staying in a hospital due to illness or surgery, there appeared to be an effort by participants not to be a burden, or to be a "*good patient*" and not bother the staff. One episode shared by a male participant was of having a fall while in the shower during a hospital stay, commenting,

> **M17:** *"There was, but I didn't use it."* (an alarm in the shower area of hospital) *"I fell over in the shower. I was just finishing, believe it or not I finished showering, I finished shaving, I put paper towels on my head, I put my pyjamas back on and I walked back to the ward. I had* (got) *7 staples in my head"* (as a result of the fall).

This was one interview with a married couple, and both of them interviewed on separate days. A few days later on return to meet the gentleman's wife, she brought up the same incident, and almost with disbelief and empathy at how he had managed the episode. She reflected –

> **F27:** *"But why didn't he go to her* (nurse)*?"* (session note - participant confused why husband fell in hospital and didn't immediately ring alarm or go to nurse for assistance).

Other experiences that were documented, were feelings that sometimes the nurse knew more about the participant and could suggest more relevant devices based on 'knowing the patient'. This appeared to enhance the trust between the nurse and participant. Other episodes of the community nurse paying visits to assist with caring for loved ones at homes, helping management of 'PEG' - feeding, (feeding by tube and bypassing the mouth) or managing infection etc.

5.6.5 Theme 5: Products & Service systems

Various products and service systems were discussed during each of the sessions, alternating from current experiences with cars, electric plugs, telephones, mobile phones, computers, computer tablets and apps. When it comes to future design and thinking about robots, perceptions and comments varied from "*amazing*" to "*frightening*". Regarding computers and computer use, commentary appeared at times to be self-critical and judgemental of the participants capacity to learn, stating a sense of being "*too old to learn*" . Learning to use a computer sometimes presented a fear that the participant might break it if they pressed the wrong button. In addition, a number of participants stated a preference now to use computer tablets, due to flexibility of use and being less cumbersome than a PC or laptop.

Other reasons a computer tablet was preferred at times to a phone for internet or browsing and viewing use, related to usability – ease of use, comfort with screen size and vision, as well as more space to place fingers for browsing, typing etc. Typing and texting on phones presented a challenge to vision and dexterity.

Texting was not used by a number of participants, with a preference to talk on the phone, especially at night or in poor light –

> **M19:** *"At night-time now I'd have to get my glasses, I wouldn't be able to read a text now"* (on mobile phone).

Not using the texting option on phones was viewed by many as a challenge because they did not do it frequently enough, therefore forgetting how. In addition there was a fear that despite delivery confirmation, perhaps a text could be sent to the wrong person. Voicemail, and accessing messages left by callers, presented difficulty to some participants stating they felt embarrassed to admit that they did not know how to access their voicemail.

Comments were made in some of the locations visited about internet availability. This related to service, or options such as satellite, dongle or general broadband service. Most participants had good internet connection quality. One participant that was living in a rural location felt somewhat frustrated that the service was not strong or reliable enough for streaming or more complex options (he operated a business). Participants also discussed owning and using landline phones and mobile phones. The usability of landline handsets was sometimes preferred to mobile phones with perceptions about them being easier and offering further features; e.g. speed dial and convenience to browse phone contacts. A number of participants no longer had a landline handset in their homes, or broadband. These participants tended to prefer a mobile phone. This preference on occasion was associated with cost, and the convenience to operate just one phone that enabled flexible and mobile use.

Going out and about when not choosing to walk often involved conversations relating to using a car. Getting in and out of vehicles presented challenges particularly to participants with foot problems, e.g. plantar fasciitis. In addition, a comment was noted by one participant that he recalled collecting his elderly mother in his jeep. His mother had mobility limitations, but found to his surprise that she experienced ease getting in and out of a higher type vehicle than a standard car.

5.7 Discussion

The aim of this study was to explore and interpret insights expressed by a cohort of older adults related to their life experience, their experiences using or assisting someone with assistive devices, and their perceptions of robots and robotic assistive devices, including lower limb exoskeletons. The themes revealed how ageing can be challenged or enhanced by accessibility and mobility. When this challenge impedes on Quality of life it can be a cause of limitation for the older adult. Technologies and assistive devices are intended to be supports that enhance life and the lived experience. TAMs have had numerous models developed as a means to optimise adoption of technology. We know that there are few TAMs that measure this adoption by older adults, and none have been revealed to consider emerging robotic assistive devices e.g. lower limb exoskeletons.

When reviewing literature it became apparent that traditionally TAMs had been applied in work settings to gauge acceptance of technology applications by users. They have in recent times become tools to measure technology acceptance by people in home or social settings. The ageing population will continue to increase in the coming years (Guzman *et al.* 2012) and technologies will continue to be developed and emerge to market (Norman 2007). Acceptance of these technologies will be critical to them fulfilling design intent; that is, to assist and enhance the lived experience of people.

There are currently some models that are specific to older adults and acceptance of technologies (Heerink *et al.* 2010; Chen and Chan, 2014). New constructs for a new Technology Acceptance Model are required that can assist with understanding users unmet needs during development of lower limb exoskeletons.

Tools of acceptance and guidance are available for health care professionals when assessing suitability of existing assistive devices (e.g. wheelchairs) by users, e.g. HAAT (Cook, 2015), MPT (Federici and Scherer, Eds, 2012). Robotic assistive devices such as lower limb exoskeletons are emerging and innovative. They are not currently mainstream. No design tools currently support interactions between design teams and test users/participants as tools that measure user acceptance and experience. Typical usability tests are limited to exploring instances of experience with no perceptive or reflective stages recorded. There is guidance to safety requirements for the design of exoskeletons (ISO, 2014) but not specific user centred design guidance. User involvement and consideration to design requires an awareness to current situations or practices as well as contemplating future situations and applications (Steen, 2008). The design teams of complex wearable lower limb exoskeletons need to understand and learn from what the user is experiencing and recording this experience formally as a means to efficiently conceptualise and develop the device further.

This research has identified how older adults perceived emerging and robotic assistive technologies. It was clear and evidenced that participants felt challenged or unsure when asked about what a robot or robotic assistive device was.

The five themes that emerged from analysing and interpreting the fieldwork, provided broad understanding of expression by older adults about the acceptance of lower limb exoskeletons. The themes holistically generated knowledge that was the basis for 3 new constructs as part of the development of a new TAM that measures acceptance by older adults of lower limb exoskeletons. These new constructs are: 1) Experiential Perception (EP), 2) Self-Liberty (SL), and 3) Quality of Life Enhancement (QOLE).

5.7.1 Construct One: Experiential Perception

Experiential perception is defined as 'the perception the older adult has of the interaction with the lower limb exoskeleton when using and wearing it'. It requires the older adult to express a view of what it might be like to try the lower limb exoskeleton, prior to the usability testing of it. It is anticipated that expressed opinions will assist with reducing fear or anxiety, or gauge excitement and curiosity about the lower limb exoskeleton (as discussed in Theme 3, 4 & 5).

5.7.2 Construct two: Self-liberty

The research also revealed insights of older adults experience and understanding that influence by others using devices or being trusted to assist with using technology can enhance adoption and use. In addition, a desire to be independent and not a burden was commonly expressed. The new construct identified called 'self-liberty' applies items in it that enquire after the usability testing the older adults intention to consider or desire to have a lower limb exoskeleton assist with day to day tasks and activities. It is defined as 'autonomous perceptions of control by the older adult when using or wearing the lower limb exoskeleton'. Specifically it asks the older adult to express their belief whether they can independently manage the service system and operation of a lower limb exoskeleton (as discussed in Theme 1, 2 & 3).

5.7.3 Construct three: Quality of Life Enhancement

A further new construct was identified following the numerous expression of ability and choice about daily interactions and life. The construct 'Quality of Life Enhancement' specifically enquires to what value wearing and using a lower limb exoskeleton would bring to life and daily experience. Could a lower limb exoskeleton potentially enhance Quality of Life for the older adult? It is defined as 'relating the use of the lower limb exoskeleton to activities and instrumental activities of daily living' - ADL, IADL (Katz *et al.* 1963; Lawton and Brody 1970) (as discussed in Theme 2, 3 & 5).

In addition to these new constructs, it is envisaged a number of familiar constructs used in existing TAMs will support the creation of this new model, that is intended for use by design teams when developing lower limb exoskeletons with older adult users. It is believed that further development of this tool will support adaptation to measure acceptance of other emerging technologies with different user groups.

Emerging technologies may need to be learned by trial and error (Norman, 2007), however older adults are also conscious of maintaining competencies as a means to not feel alienated or redundant from society (Wu *et al.* 2015) therefore, these technologies need to be easy and comfortable to use (Norman, 2007). The involvement of people in the process of design is seen as critical for acceptance of lower limb exoskeletons (O'Sullivan *et al.* 2017).

5.8 Conclusion

It is clear that in the coming years emerging technologies such as lower limb exoskeletons will become a part of everyday lives for people to assist with maintaining health and lifestyle. Soft robotics will broaden the abilities of these devices to become wearable garments. In addition, the technology required to manage these garments, such as robotic trousers need to be accessible; and not so complex to leave user groups such as older adults feeling excluded, and unable to engage and use these technologies. Technology Acceptance Models have traditionally been tools that predict acceptance of technology by user groups. Currently there is no TAM or measure to gauge what older adults deem acceptable when using or wearing lower limb exoskeletons. Robotic assistive devices have the potential to inspire and encourage a Quality of Life without barriers or stigma experienced. In addition, adaptability of robotic assistive devices is required, regarding a person's changing health or life condition which, in turn ensures maintaining good experience to enhance living and day to day activities. The service system for the robotic trousers would need to manage and notify people regarding problems or issues. Cost is critical to accessing and availability to purchase or use for all not just those that are financially able – this could limit the marketability of robotic trousers. However, if design teams do not identify the unmet needs older adults have to accepting and using/wearing these devices, then there is also the potential for frustration, embarrassment and ultimately abandonment of these devices.

5.9 Acknowledgements

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5.10 Research development & context

This study presented evidence of perceptions older adults have to robotic assistive devices including exoskeletons. It interpreted and defined key themes and concept direction regarding phases of interactions that potentially offer and measure attitudinal insight of exoskeletons by older adults. There was momentum, energy and enthusiasm to design a new approach that would include approaches of TAM and usability application, whilst remaining focussed on older adults' commentary about their experiences and perceptions to technology. In addition, the development of specifics about this new approach and its association with existing design and technology measurement application, led to the introduction of IDAM and Exoscore. This creative action and activity generated the momentum to plan a pilot study. This study would offer introduction and descriptive statistics about older adults' perceptions to exoskeletons during a live concept testing session of the gamma prototype of XoSoft.

6. Pilot study of Exoscore.

Study Rationale: At this time during the research, energy and momentum was driving the enquiry to explore and test this new approach. There was excitement, and anticipation towards the acceptance, success or failure of this new approach. The challenges were to translate and administer the phase questionnaires in German, because the pilot study would be conducted in two locations: Switzerland and Germany. The researcher sought the skills of interpretors and XoSoft colleagues for this assistance. Again, ethics approval was sought and granted at the test site locations.

Purpose: The aim of this study was to introduce Exoscore as a design evaluation tool that can assist exoskeleton and exosuit development.

Background: Exosuits and exoskeletons are predicted to become common assistive devices within the medium term. There is a need to identify and define measures that can support and assist exoskeleton and exosuit development. There is currently a lack of evaluation tools specifically used to measure attitude and perception of lower limb exoskeletons by older adults and applied by design teams.

Novelty & contribution to knowledge: This study was the first occasion to apply the Exoscore tool in a lab setting with design team and older adult participants. The hybrid features of Exoscore are new and original to technology acceptance; by integrating Usability and Technology Acceptance Model aspects, a new and original concept can offer phases of perception, experience and perceived impact that can efficiently be fed back into exoskeleton and exosuit concept development in an efficient and considered way. The Iterative Design Assessment Model, affords aspects of action, reflection and interactions between design teams and participants that support and loop into the Double Diamond (Design Council, 2005).

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Study 4: Exoscore – A design tool to evaluate factors associated with technology acceptance of soft lower limb exosuits by older adults.

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Abstract

Objective This pilot study proposed and performs initial testing with Exoscore, a design evaluation tool to assess factors related to acceptance of exoskeleton by older adults, during the technology development and testing phases.

Background As longevity increases and our ageing population continues to grow, assistive technologies such as exosuits and exoskeletons can provide enhanced quality of life and independence. Exoscore is a design and prototype stage evaluation method to assess factors related to perceptions of the technology, the aim being to optimise technology acceptance.

Method In this pilot study, we applied the three-phase Exoscore tool during testing with 11 older adults. The aims were to explore the feasibility and face validity of applying the design evaluation tool during user testing of a prototype soft lower limb exoskeleton.

Results The Exoscore method is presented as part of an iterative design evaluation process. The method was applied during an exoskeleton design R&D project. The data revealed the aspects of the concept design which rated favourably with the users, and the aspect of the design which required more attention to improve their potential acceptance when deployed as finished products.

Conclusions Exoscore was effective to apply three phases of evaluation during a testing session of the soft exoskeleton. Future exoskeleton development can benefit from the application of this design evaluation tool.

Application This study reveals how the introduction of Exoscore to exoskeleton development will be advantageous when assessing technology acceptance of exoskeletons by older adults.

Keywords: Usability/acceptance measurement and research, designing for the elderly, product design, home health, wearable devices.

Precis: Exoskeleton and exosuit development can benefit from user-centred approaches that document participants' experiential insights throughout the design process. This paper introduces the Exoscore evaluation tool and results from a pilot study in the application of the method with users as performed during the design of a soft lower limb exoskeleton.

6.1 Introduction

Exoskeletons and exosuits have the potential to improve mobility and augment human performance in a meaningful way (Robinson, MacDonald, & Broadbent, 2014; Bhatnagar *et al.* 2017; Borisoff, et. al., 2017; Yandell, et. al., 2017; Huysamen *et al.* 2018a; Fosch-Villaronga and Özcan 2019) . There is increased focus on exoskeletons as mobility aids for specific cohorts, such as older adults (O'Sullivan *et al.* 2015; XoSoft 2016; Shore, et. al., 2018a). Reduced ability is a major factor that can impact on independence and autonomy to conduct daily activities (Bedaf et al., 2017; Mitzner *et al.* 2018). Longevity is increasing (World Health Organisation, 2018) and despite challenges to mobility, there is still opportunity to enjoy a good quality of life as we age (Rowe and Kahn 2015; Stones and Gullifer 2016). People who experience physical limitation due to injury or disability can be supported by exoskeleton interventions to engage in rehabilitative exercises and activities (Huysamen *et al.* 2018b).

The acceptance of emerging technology by older adults may be affected by a number of factors (Heerink *et al*., 2010), such as perceived usefulness (Czaja *et al.*, 2019) and trust of the technology (Sanders *et al.*, 2019). Older adults often require a perception of need (Hanson *et al.* 2013) before adoption of a technology.

Recent developments of Technology Acceptance Models (TAM) consider specific users, such as older adults and technologies like social robots, computer tablets and mobile phones, often in home or social environments (Heerink *et al.* 2010; Chen & Chan, 2014; Luijkx et al., 2015; Chen et al., 2017; Czaja *et al.* 2019) whereas TAMs were traditionally developed to gauge and assess acceptance by users, often in work environments (Davis, 1985; Venkatesh and Davis 2000; Venkatesh et al., 2003).

Literature review of TAMs have detailed constructs to explain how older adults adopt gerontechnology in home and social settings (Heerink *et al.* 2010; Chen & Chan, 2014). The following constructs have been proposed to explain acceptance of exoskeletons by older adults: Perceived Usefulness (PU) (Davis, 1985; Venkatesh *et al.* 2003), Effort Expectancy (EE) (Venkatesh *et al.* 2003), Anxiety (ANX) (Venkatesh *et al.* 2003; Heerink *et al.* 2010; Chen & Chan, 2014), Gerontechnology Self-Efficacy (SE) (Chen & Chan, 2014), Attitude Towards Technology/Attitude Towards using the Technology (ATT, ATUT) (Venkatesh *et al.* 2003; Heerink *et al.* 2010), Behavioural Intention (BI) (Venkatesh *et al.* 2003), Perceived Adaptiveness (PAD) (Heerink *et al.* 2010), Social Influence (SI) (Venkatesh *et al.* 2003) and Trust (TRUST) (Davis, 1985; Davis, 1989; Venkatesh and Davis 2000; Heerink *et al.* 2010; Chen & Chan, 2014). Trialability (Rogers, 2003) is also highlighted as a relevant feature, particularly associated with a user centered design approach to developing complex wearable technologies such as exosuits and exoskeletons.

Understanding and involving users in design is crucial to identifying and defining user needs and gaps in meeting their requirements (Dreyfuss 1955; Norman, 2002; Väänänen-Vainio-Mattila *et al.* 2009; Czaja *et al.* 2019; Fosch-Villaronga and Özcan 2019). The authors here previously performed a qualitative study using a grounded theory approach, to understand ageing, technology acceptance and perceptions of exoskeletons and robotic assistive devices (Shore, et. al., 2018b; Shore, et. al., 2019). That fieldwork revealed three new constructs that we believe are relevant to the perception of a soft lower limb exoskeleton by older adults, namely: 1) Experiential Perception [EP], 2) Self-Liberty [SL] and 3) Quality of Life Enhancement [QoLE] that have not previously appeared in Technology Acceptance Models.

Usability is a critical factor of concept development and understanding the needs, requirements and experience within a context of use by a person (ISO 2018b). Usability testing is iterative and evolves as design teams learn about the user interactions and experiences of products or service systems, including applications with various user groups, such as older adults (Nielsen 1993; Jordan et al., 1996; Wickens et al., 2003; Krug 2006; Pullin 2009; Shore et al., 2015).

Based on these findings and previous relevant studies by the authors (Shore, 2015; Shore, et. al., 2018a; Shore, et. al., 2018b; Shore, et. al., 2018c; Schülein *et al.* 2019), a new design model was developed to apply during development of exoskeletons with older adult participants. Figure 1 details this Iterative Design Assessment Model (IDAM, Shore *et al.,* 2019), which incorporates methods of usability and TAMs as a combined hybrid design approach. The process of creativity and design is captured within the double diamond (Design Council, 2014), furthermore, this iterative innovation building activity is expressed and encouraged in other theories and methods (Rogers, 2003; Wickens, et al., 2003).

The Iterative Design Assessment Model is a design approach that captures reflective practice, interactions and engagement between designers and participants throughout each evaluation phase. As part of this development, we introduce here a new evaluation tool, Exoscore, based on our previous research (Shore, et. al., 2018a; Shore, et. al., 2019).

In this study, we present the Exoscore evaluation tool and results from a pilot study in the application of the method with users as performed during the design of a soft lower limb exoskeleton.

6.2 Method

6.2.1 Exoscore exoskeleton evaluation tool

Exoscore gauges older adults' perceptions and perceived impact of exoskeletons as assistance options for enhanced/increased mobility. Figure 32 & 33 displays how Exoscore fits within the Iterative Design Assessment Model. It is a three-phase tool: 1) Perception, 2) Experience and 3) Perceived Impact. All three phases include an introduction and communication to participants about the tasks at hand (completion of questionnaires, tasks, etc.). Three questionnaires were detailed/selected, one for each phase. Some of the items within the constructs of the questionnaires (e.g. Perception – ANX) were negatively worded; in such instances, a reverse scoring system was used. Reverse items are often used in questionnaires (Xijuan *et al.* 2016). Refining the Exoscore tool will include reviewing all items to present results, easily scored and interpreted by design teams. The Experience phase for the purpose of this study relied on an existing usability tool, the System Usability Scale (SUS) (Brooke 1996). The final version of Exoscore is intended to have criteria to facilitate interpretation of scores, such as in the SUS. Future work is necessary to apply the method and collect further data with a large sample of end users to validate any such criterion.

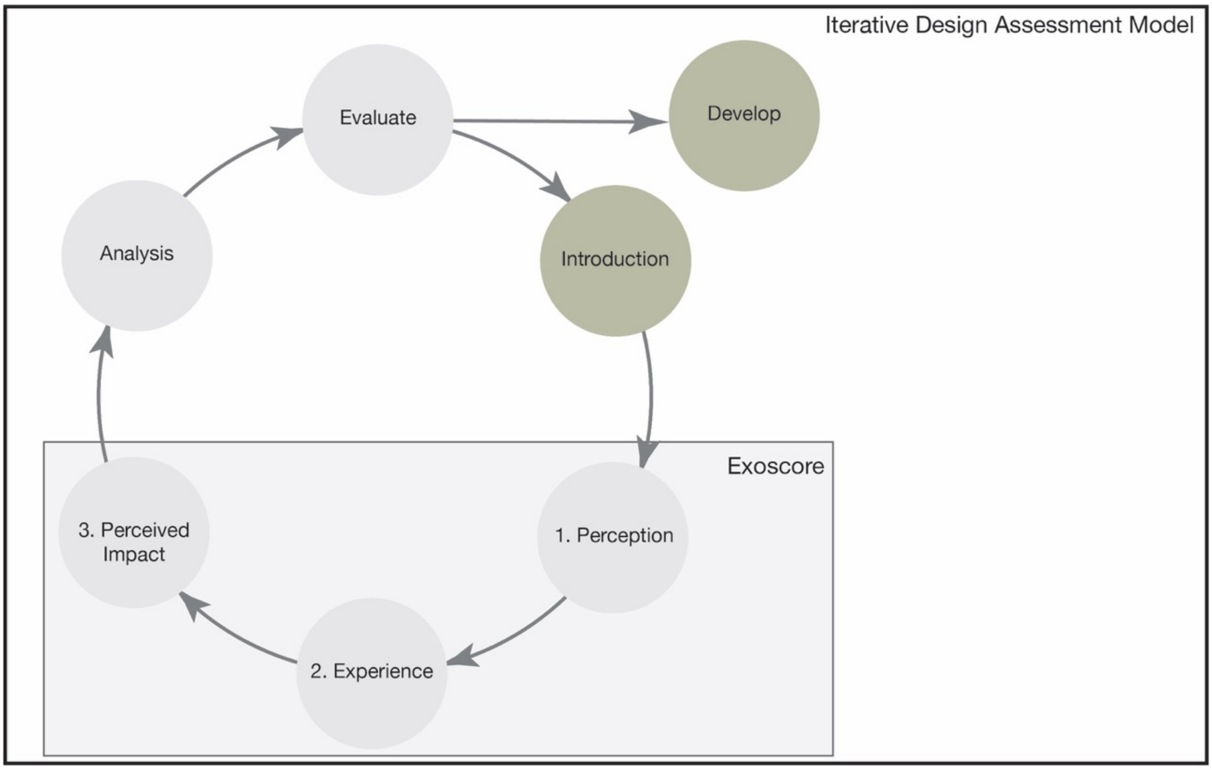

Figure 32Work phases of Iterative Design Assessment Model (Shore, et. al., 2019). The three phases of Exoscore are included here: 1. Perception, 2. Experience, 3. Perceived Impact.

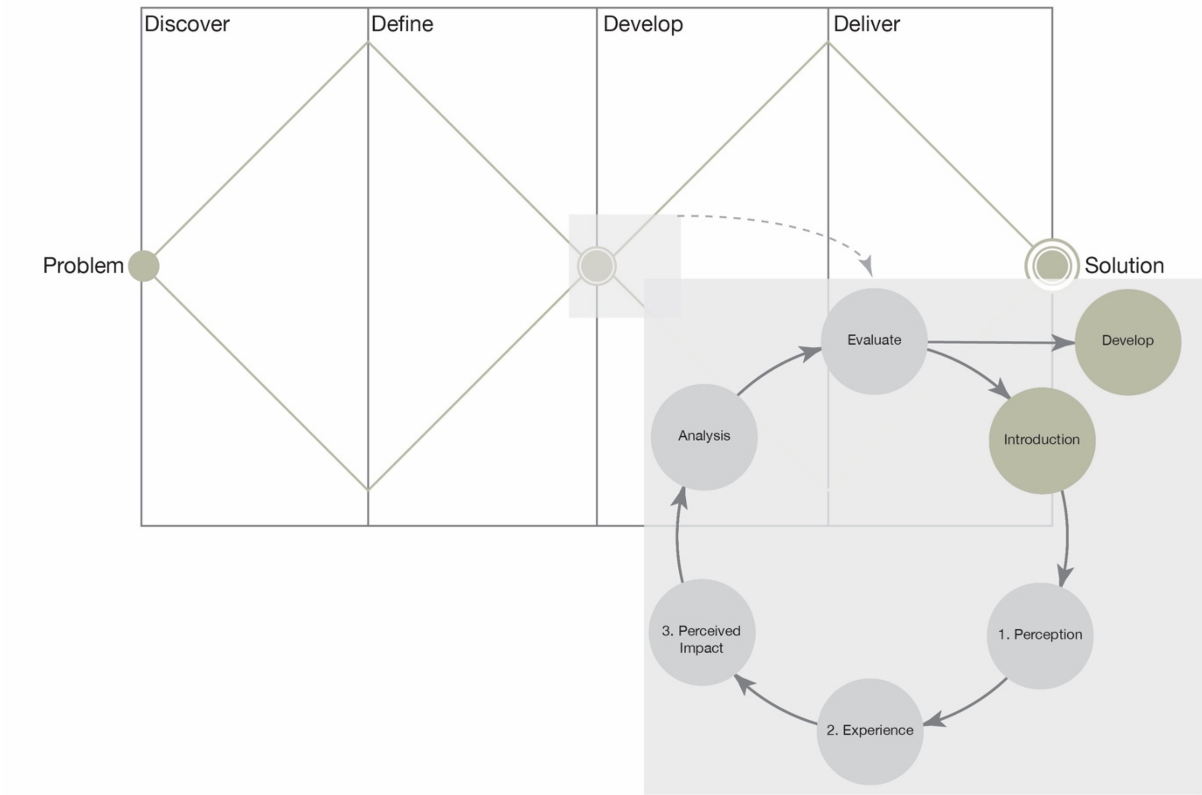

Figure 33 Placement of IDAM within the Double Diamond (Design Council 2014) process.

The phases for each session are as follows:

- Perception Evaluation Phase – This phase is undertaken prior to experience and use of the exoskeleton by the participant. The participant is either shown the actual exoskeleton prototype/design or images and video of it while at concept development stage. They complete the review questionnaire based on the information provided.
- Experience Evaluation Phase – The participant performs usability testing with the exoskeleton concept and then completes the review questionnaire.
- Perceived Impact Evaluation Phase – After the usability testing, the participant completes this review questionnaire to ascertain the perceived impact that the concept could have on them.

6.2.2 Perception Evaluation Instrument:

The perception questionnaire is divided into five constructs, as detailed in Table 11, along with their sources and descriptions. Four of these constructs were previously detailed in other TAMs (Davis, 1985; Venkatesh *et al.* 2003; Heerink *et al.* 2010; Chen & Chan, 2014). Each construct had items amended to include the term exoskeleton, in place of previous terms of TAMs mentioned, such as system, robots and technology.

Experiential Perception (EP) was included as a new construct to consider how the participant might anticipate using and wearing the exoskeleton. During fieldwork (Shore, et. al., 2019), older adults expressed opinions relating to factors such as noise of an exoskeleton, weight of an exoskeleton, and self-image associated with wearing an exoskeleton. These factors were not specifically addressed as measurable in the existing TAM constructs and were deemed necessary to include as a means to optimize user acceptance. Table 12 details the Perception Evaluation questionnaire.

Table 11 Perception Evaluation, constructs, descriptions, sources and adapted items.

Construct	Description	Items
Perceived Usefulness | PU	The degree to which an individual believes that using a system would enhance his/her job performance (Davis, 1985; Venkatesh *et al.* 2003).	1. Wearing the exoskeleton would assist with my mobility. 2. Wearing the exoskeleton would increase my mobility. 3. Wearing the exoskeleton would enhance my life.
Effort Expectancy | EE	The degree of ease associated with the use of the system (Venkatesh *et al.* 2003).	1. Learning to use the exoskeleton would be easy for me. 2. The exoskeleton would be easy to use and wear. 3. I would be afraid to make mistakes using the exoskeleton.
Gerontechnology Self-Efficacy | SE	Gerontechnology self-efficacy involves a sense of being able to use the technology successfully (Chen & Chan, 2014).	1. I would need help from someone to use or wear the exoskeleton. 2. I could call on someone if I needed help using the exoskeleton. 3. I would like a help-manual for the exoskeleton.
Anxiety | ANX	Evoking anxious or emotional reactions when it comes to using the system (Chen & Chan, Venkatesh *et al.* 2003; Heerink *et al.* 2010; 2014).	1. I feel scared to wear the exoskeleton. 2. I would worry about the mistakes I could make wearing the exoskeleton. 3. I would look silly wearing the exoskeleton.
Experiential Perception | EP	The perception of the interaction by the person with the system (Shore, et. al., 2019).	1. It is important the exoskeleton operates quietly when I wear it. 2. I would feel embarrassed wearing the exoskeleton. 3. The exoskeleton would be too heavy for me to use. 4. The exoskeleton looks exciting to wear and use.

Table 12. *Questionnaire issued to participants for completion in the Perception Evaluation Phase.*

PERCEPTION | Completed <u>before</u> testing with the exoskeleton					
Items	Strongly Disagree				Strongly Agree
	1	2	3	4	5
Wearing the exoskeleton would assist with my mobility					
Wearing the exoskeleton would increase my mobility					
Wearing the exoskeleton would enhance my life					
Learning to use the exoskeleton would be easy for me					
The exoskeleton would be easy to use and wear					
*I would be afraid to make mistakes using the exoskeleton					
I would need help from someone to use or wear the exoskeleton					
I could call on someone if I needed help using the exoskeleton					
I would like a help manual for the exoskeleton					
*I feel scared to wear the exoskeleton					
*I would worry about the mistakes I could make wearing the exoskeleton					
*I would look silly wearing the exoskeleton					
It is important the exoskeleton operates quietly when I wear it					
*I would feel embarrassed wearing the exoskeleton					
*The exoskeleton would be too heavy for me to use					
The exoskeleton looks exciting to wear and use					

*Items require score to be reversed (e.g. 1 = 5, 2 = 4, 3 = 3, 4 = 5, 5 = 1)

6.2.3 Experience Evaluation Instrument:

Experience Evaluation in Exoscore is based verbatim on the SUS (Brooke 1996). The SUS was used for the Experience phase as it had been used during previous testing of exoskeletons (Huysamen *et al.* 2018a; Huysamen *et al.* 2018b), and also during the XoSoft project. It is one of a range of testing tools that has been applied to test user interaction as development of the XoSoft concept. The SUS was developed for use with computer systems, and usually is completed by participants after they have interacted or used the prototype (Jordan, 1998). It comprises ten statements that participants indicate preferences (or not) from 1 (strongly disagree) to 5 strongly agree (see Table 3).

In this pilot study, SUS scores are calculated by totalling the score (0-4) for each item and multiplying the sum of the scores by 2.5. This output provides the overall SUS score. A score of 70 is considered acceptable, while a score of below 70 indicates concerns about the usability of a system that require addressing (Bangor, Kortum & Miller, 2009). The SUS method, as used in the Exoscore Experience evaluation instrument, is detailed in Table 13.

Table 13. *Exoscore Experience Evaluation Phase using the System Usability Scale items (Brooke 1996).*

Items	Strongly Disagree				Strongly Agree
	1	2	3	4	5
I think that I would like to use this system frequently					
I found the system unnecessarily complex					
I thought the system was easy to use					
I think that I would need the support of another person to be able to use this system					
I found the various functions in this system were well integrated					
I thought there was too much inconsistency in this system					
I would imagine that most people would learn this system very quickly					
I found this system very cumbersome to use					
I felt very confident using the system					
I need to learn a lot of things before I can get going with this system					

6.2.4 Perceived Impact Evaluation Instrument:

As a type of reflective practice to assess how participants envision an exoskeleton in their lives, the participants completed the ‘Perceived Impact’ questionnaire. This evaluates the following constructs: ATUT (Venkatesh *et al.* 2003), ANX (Chen & Chan, Venkatesh *et al.* 2003; Heerink *et al.* 2010; 2014), SE (Chen & Chan, 2014), BI (Venkatesh *et al.* 2003), PAD (Heerink *et al.* 2010), SI (Venkatesh *et al.* 2003; Heerink *et al.* 2010), SL (Shore, et. al., 2019), QoLE (Shore, et. al., 2019), TRUST (Heerink *et al.* 2010), (Table 14). Items were adapted to include the term exoskeleton as appropriate.

Two new constructs are introduced based on the fieldwork research 1) Self-Liberty (SL) and 2) Quality of Life Enhancement (QoLE) (Shore, et. al., 2019).

SL is described as the perceptions of control the user has to be autonomous and selective regarding how they use or experience the system. It differs from the existing construct Gerontechnology Self-Efficacy (SE) (Chen & Chan, 2014) by extending beyond using the technology successfully. SL is intended to measure the participant’s self-intent and self-perceived capacity to manage the exoskeleton, as well as the service system.

QoLE measures how the older adult believes the exoskeleton can be a supportive and enhancing device when conducting everyday tasks and activities, both inside the home or out socially. The Perceived Impact Evaluation Instrument is detailed in Table 15.

Table 14. *Perceived Impact Evaluation constructs, descriptions, sources and adapted items.*

Construct	Description	Items
Attitude Towards Using the Technology | ATUT	Individuals overall affective reaction to using the system (Venkatesh *et al.* 2003).	1. Wearing an exoskeleton is a good idea. 2. Exoskeletons are a bad idea as an aid to mobility. 3. I would wear an exoskeleton to help me with tasks.
Anxiety | ANX	Evoking anxious or emotional reactions when it comes to using the system (Chen & Chan, Venkatesh *et al.* 2003; Heerink *et al.* 2010; 2014).	1. I look silly wearing an exoskeleton. 2. Exoskeletons scare me. 3. I would make mistakes wearing an exoskeleton.
Gerontechnology Self-Efficacy -| SE	Gerontechnology self-efficacy involves a sense of being able to use the technology successfully (Chen & Chan, 2014).	1. I could use an exoskeleton without another person's help. 2. I would need help when I am wearing an exoskeleton. 3. I would need an aid such as a walking stick when I am using an exoskeleton.
Behavioural Intention | BI	Behavioural Intention will have a significant positive influence on technology usage (Venkatesh *et al.* 2003).	1. If I needed an aid to help with my mobility, I would choose an exoskeleton. 2. I could imagine people with limited walking ability using an exoskeleton in 6 months' time. 3. I could imagine people with limited walking ability using an exoskeleton in 24 months' time.
Perceived Adaptiveness | PAD	Perceived ability of the system to adapt to the needs of the user (Heerink *et al.* 2010).	1. An exoskeleton can be adapted if my condition changes. 2. I can use the exoskeleton to assist my mobility, where necessary.
Social Influence | SI	The impact of social influence on behavioural intention will be moderated by gender, age, voluntariness and experience (Venkatesh *et al.* 2003; Heerink *et al.* 2010).	1. Family and carers would like me to use an exoskeleton. 2. People who are like me should use an exoskeleton.
Self-Liberty | SL	Autonomous perceptions of control by the person (Shore, et. al., 2019).	1. I am curious about using an exoskeleton. 2. I could use an app on my smart phone/tablet to monitor how the exoskeleton helps me. 3. I could manage the basic upkeep (e.g. washing, changing battery) of the exoskeleton, independent of my family/carers.

Quality of Life Enhancement | QoLE	Relating gerontechnology usefulness to IADL (Lawton and Brody 1970) & ADLs (Katz *et al.,* 1963) (Shore, et. al., 2019)	1. An exoskeleton would assist my ability to do tasks in the home. 2. An exoskeleton would assist my ability to do tasks outside the home. 3. I feel confident that I would not get harmed wearing the exoskeleton to perform day to day tasks. 4. I could attend more social events if I am wearing an exoskeleton.
Trust | TRUST	The belief that the system performs with personal integrity and reliability (Heerink *et al.* 2010).	1. I would trust my mobility when wearing an exoskeleton. 2. I would trust the information/advice the exoskeleton system would give me.

Table 15. *Questionnaire as issued to and completed by participants during the Perceived Impact phase.*

PERCEIVED IMPACT | Completed after testing with the exoskeleton					
Items	Strongly Disagree				Strongly Agree
	1	2	3	4	5
Wearing an exoskeleton is a good idea					
*Exoskeletons are a bad idea as an aid to mobility					
I would wear an exoskeleton to help me with tasks					
*I look silly wearing an exoskeleton					
*Exoskeletons scare me					
*I would make mistakes wearing an exoskeleton					
I could use an exoskeleton without another person's help					
*I would need help when I am using an exoskeleton					
*I would need an aid such as a walking stick when I am using an exoskeleton					
If I needed an aid to help with mobility, I would choose an exoskeleton					
I could imagine people with limited walking mobility using the exoskeleton in 6 months' time					
I could imagine people with limited walking mobility using the exoskeleton in 24 months' time					
An exoskeleton can be adapted if my condition changes					
I can use an exoskeleton to assist my mobility, where necessary					
Family and carers would like me to use an exoskeleton					
People who are like me should use an exoskeleton					
I am curious about using an exoskeleton					
I could use an app on my smart phone/tablet to monitor how the exoskeleton helps me					
I could manage the basic upkeep (e.g. washing, changing battery) of the exoskeleton independently of my family/carers					
An exoskeleton would assist my ability to do tasks in the home					
An exoskeleton would assist my ability to do tasks outside the home					
I feel confident that I would not get harmed when wearing the exoskeleton to perform day-to-day tasks					
I could attend more social events if wearing an exoskeleton					
I would trust my mobility when wearing an exoskeleton					
I would trust the information/advice the exoskeleton system would give me					
*Items require score to be reversed (e.g. 1 = 5, 2 = 4, 3 = 3, 4 = 5, 5 = 1)					

6.2.5 Pilot study of Exoscore

The purpose of this study was to pilot test the initial version of the Exoscore tool. This was performed by applying the three elements of Exoscore during design concept testing of a soft lower limb exoskeleton for older adults as part of the EU project XoSoft (XoSoft 2016). Figure 34 is an example of participation during testing of the soft exoskeleton in a gait lab.

Figure 34. *Participant and Administrator during Pilot Study of Exoscore and Testing of XoSoft.*

Approval for the study was obtained from the relevant local research ethics authorities, as part of the approval for the wider XoSoft testing protocol: Clinical Ethics Committee of the Faculty of Medicine, Friedrich-Alexander University Erlangen-Nürnberg, Germany (No.72_18B), and Kantonale Ethikkommission des Kantons Zürich (Study-ID: BASEC-Nr. 2016-01406). Informed consent was obtained from each participant to participate in this research, and for this research to be submitted for publication. Participants were recruited during laboratory and clinical testing of the XoSoft prototype in Switzerland (Zürcher Hochschule für Angewandte Wissenschaften) and Germany (Malteser Waldkrankenhaus St. Marien), respectively.

6.2.6 Participants

Participants were eligible for inclusion if they presented clinically with mild-to-moderate mobility impairment. Participants were excluded if they presented with other conditions that would preclude them from safely completing the testing protocol (e.g. severe visual or cognitive impairment), were unable to walk under supervision for 10m, or had an acute illness that precluded safe participation.

Consideration was given to the size of sample as a means to investigate the feasibility (Johanson and Brooks 2010) of Exoscore, with a sample size of 10-15 being deemed as a sufficient size (Hertzog 2008). Eleven participants (six females, five males) took part in the study. Participants' characteristics are displayed in Table 16. Participants' primary diagnoses varied, as did the precise nature of their mobility impairments, however, all participants had Functional Ambulation Category (FAC) scores of five, indicating that they could walk independently on any surface (Holden, et al., 1986).

Table 16. *Summary of participants' characteristics.*

Participant	1	2	3	4	5	6	7	8	9	10	11
Gender	M	M	M	F	M	F	F	F	F	F	M
Age	69	79	72	52	58	48	85	68	82	54	76
Diagnosis	Stroke	Hereditary spastic spinal paresis	Incomplete spinal cord injury	Incomplete spinal cord injury	Stroke	Incomplete spinal cord injury	Gait impairment, falls	Post-polio syndrome	Spinal stenosis	Myasthenia gravis	Spinal stenosis
FAC	4	4	4	4	4	4	5	5	5	5	5

6.3 Results

6.3.1 Study Approach

The XoSoft soft lower limb exoskeleton concept was introduced to the participants, after which they completed the Perception phase evaluation questionnaire. The Usability/Experience phase consisted of testing the feasibility of the XoSoft prototype by comparing the participants locomotion pattern prior to and during wearing and testing of the XoSoft prototype. The participants then engaged in locomotion tasks while wearing the Xososft prototype that related to daily life, but in a lab setting (e.g. donning, doffing, walking). The testing/wearing elements of the test session lasted approximately 20-30 minutes with the prototype and 40-50 minutes without, between each task a break of two minutes was also allowed. Following the tasks, the participants completed the Experience phase/SUS questionnaire. After testing, following some time to reflect on the concept and their experience, they completed the Perceived Impact Evaluation questionnaire. Testing sessions overall typically lasted up to 2.5 hours in total.

The data were reported as simple descriptive statistics and scores. It is suggested that pilot studies should rely on descriptive statistics, since the small sample size may preclude the valid use of other statistical methods (Lee *et al.,* 2014).

6.3.2 Perception Phase Evaluation

The descriptive statistics and scores from the Perception Phase Evaluation are detailed in Table 17. All 11 participants completed the questionnaire independently.

Perceived Usefulness score (70) would indicate a positive perception to using and experiencing XoSoft. Effort Expectancy scores indicate small challenges when wearing and using the exoskeleton (65), but an expectation that learnability (84) and errors (84) would not detract from this.

Gerontechnology Self-Efficacy scores indicate a belief that some supports (persons, manual) will be required in order to adopt and use the exoskeleton (e.g. on average the sample had a low subscore (64) when it came to belief in their ability to operate the exoskeleton).

Anxiety scores would indicate some concerns felt by the participants regarding the operation of the exoskeleton, however, the aesthetics of wearing an exoskeleton were of a lesser concern (53).

Experiential Perception subscore of 67 indicates a perception of the experience of an exoskeleton. Factors such as noise (85), weight (67) and self or social perception while wearing the exoskeleton (69) indicate priorities and preferences to optimize experience. A score of note was the aesthetics of the exoskeleton, on this the score of 45 would indicate a need to review the visual appeal of wearing and using the exoskeleton.

Table 17 Descriptive statistical results from the Perception Phase Evaluation of Exoscore.

Construct	Item		Mean	Standard Deviation	Score
PU	Wearing the exoskeleton would assist with my mobility		3.55	1.13	71
	Wearing the exoskeleton would increase my mobility		3.45	1.13	69
	Wearing the exoskeleton would enhance my life		3.54	1.21	71
PU Subscore mean			3.55	1.13	70
EE	Learning to use the exoskeleton would be easy for me		4.18	1.25	84
	The exoskeleton would be easy to use and wear		3.27	1.42	65
	I would be afraid to make mistakes using the exoskeleton	RQ Adjusted	3.19		84
		Raw	1.81	1.25	
EE Subscore mean		RQ Adjusted	3.54		78
		Raw	3.08	.92	
SE	I would need help from someone to use or wear the exoskeleton		2.64	1.36	53
	I could call on someone if I needed help using the exoskeleton		3.45	1.44	69
	I would like a help-manual for the exoskeleton		3.45	1.75	69
SE Subscore mean			3.18	1.12	64
ANX	I feel scared to wear the exoskeleton	RQ Adjusted	3.73		95
		Raw	1.27	.65	
	I would worry about the mistakes I could make wearing the exoskeleton	RQ Adjusted	3.09		82
		Raw	1.91	1.30	
	I would look silly wearing the exoskeleton	RQ Adjusted	2.64		53
		Raw	2.36	1.57	
ANX Subscore mean		RQ Adjusted	3.15		76
		Raw	2.69	.79	
EP	It is important the exoskeleton operates quietly when I wear it		4.27	1.27	85
	I would feel embarrassed wearing the exoskeleton	RQ Adjusted	2.45		69
		Raw	2.55	1.44	
	The exoskeleton would be too heavy for me to use	RQ Adjusted	3.36		67
		Raw	1.64	1.43	
	The exoskeleton looks exciting to wear and use		2.27	1.49	45
EP Subscore mean		RQ Adjusted	3.08		67
		Raw	2.68	.78	
Valid N = 11 (listwise)					

6.3.3 Experience Phase Evaluation

The experience phase results are detailed in Table 18. The results are the total score values for each participant, individual item scores are not meaningful on their own (Jordan et al., 1996). Results greater than 70 (Bangor, Kortum & Miller, 2008) indicate good usability of a system.

Table 18 Results for Experience phase as per SUS scoring.

	Experience (SUS)
1	95
2	55
3	17.5
4	60
5	42.5
6	82.5
7	80
8	47.5
9	7.5
10	95
11	40

6.3.4 Perceived Impact Phase Evaluation

The Perceived Impact Phase results, including sub scores for each construct, are displayed in Table 19. Adjusted scores are also displayed regarding items that were negatively worded and reverse scored according to assist interpretation. The subscores presented again are indicators of reflection and experience of the exoskeleton during the pilot study and by a small sample of participants. However, there was a good indication of a positive attitude towards the exoskeleton, ANX score reduces after the experience of the exoskeleton, (Perception = 76 Perceived Impact = 70). An important consideration about constructs such as ANX would be the scoring application that a high score of ANX should alert the design teams that there is a matter to address with the exoskeleton design. This could be interpreted as a valid construct to apply pre and post Experience phase. TRUST with a score of 75 is regarded a positive result whereby the participants after the experience of the exoskeleton felt it was a device that they would rely on for mobility and information support. PAD was very positive scoring 84, the participants perceived it to be adaptable and a feature of support to health condition changes. The construct SL presented the top result (88) indicating a sense of autonomy by the older adult to manage and operate the exoskeleton and system independently.

The lowest result was SI with average or below average scoring and a subscore of 57 which could indicate a reluctance to be perceived as dependent on or influenced by family/carers to wearing the exoskeleton. Overall this group had a sense that the intervention of an exoskeleton to support mobility could enhance quality of life (QoLE = 77). Again, these results cannot be relied upon as 'proof of concept' given the nature of sample size, testing environment and newness of the technology

Table 19 Descriptive statistical results for the Perceived Impact Phase Evaluation of Exoscore.

Construct	Item		Mean	Standard Deviation	Score
ATUT	Wearing an exoskeleton is a good idea		3.82	1.40	76
	Exoskeletons are a bad idea to mobility	RQ Adjusted	2.73		75
		Raw	2.27	1.10	
	I would wear an exoskeleton to help me with tasks		4.18	.87	84
ATUT Subscore mean		RQ Adjusted	3.57		78
		Raw	3.42	.52	
ANX	I look silly wearing an exoskeleton	RQ Adjusted	2.45		49
		Raw	2.55	1.57	
	Exoskeletons scare me	RQ Adjusted	2.82		76
		Raw	2.18	1.25	
	I would make mistakes wearing an exoskeleton	RQ Adjusted	3.27		85
		Raw	1.73	1.10	
ANX Subscore mean		RQ Adjusted	2.84		70
		Raw	2.15	.90	
SE	I could use an exoskeleton without another person's help		3.73	1.27	75
	I would need help when I am using an exoskeleton	RQ Adjusted	2.45		69
		Raw	2.55	1.44	
	I would need an aid such as a walking stick when I am using an exoskeleton	RQ Adjusted	2.27		65
		Raw	2.73	1.62	54
SE Subscore mean		RQ Adjusted	2.81		70
		Raw	3.00	.71	60
BI	If I needed an aid to help with mobility, I would choose an exoskeleton		3.36	1.36	67
	I could imagine people with limited walking mobility using the exoskeleton in 6 months' time		3.54	1.44	71
	I could imagine people with limited walking mobility using the exoskeleton in 24 months' time		4.27	1.01	85
BI Subscore mean			3.73	.81	74
PAD	An exoskeleton can be adapted if my condition changes		4.18	.87	84

	I can use an exoskeleton to assist my mobility, where necessary	4.00	1.09	80
PAD Subscore mean		4.09	.77	82
SI	Family and carers would like me to use an exoskeleton	2.64	1.50	53
	People who are like me should use an exoskeleton	3.10	1.14	62
SI Subscore mean		2.86	.84	57
SL	I am curious about using an exoskeleton	4.27	1.19	85
	I could use an app on my smart phone/tablet to monitor how the exoskeleton helps me	4.27	1.27	85
	I could manage the basic upkeep (e.g. washing, changing battery) of the exoskeleton independent of my family/carers	4.72	.65	94
SL Subscore mean		4.42	.75	88
QoLE	An exoskeleton would assist my ability to do tasks in the home	3.82	1.60	76
	An exoskeleton would assist my ability to do tasks outside the home	3.64	1.63	73
	I feel confident that I would not get harmed when wearing the exoskeleton to perform day-to-day tasks	4.82	.40	96
	I could attend more social events if wearing an exoskeleton	3.09	1.76	62
QoLE Subscore mean		3.84	1.16	77
TRUST	I would trust my mobility when wearing an exoskeleton	3.73	1.62	75
	I would trust the information/advice the exoskeleton system would give me	3.73	1.55	75
TRUST Subscore mean		3.73	1.44	75
Valid N = 11 (listwise)				

Table 20 displays each of the participants' scores for each of the phases. The results of this pilot study display a number of variances that require further testing to understand and refine Exoscore. The scores presented in the Experience phase would indicate a positive usability experience for four of the participants (1,6,7,10) (above 70). However, there are inconsistencies between each of the phases (e.g. participant 8). Reasons such as personal ability, user expectations being met/unmet, or other personal factors not yet defined may explain these results. Further refinement of Exoscore may help with determining consistencies that are considered more reliable.

Table 20 Score results for each phase of Exoscore and for each participant.

Participant	Perception	Experience (SUS)	Perceived Impact
1	84	95	74
2	55	55	52
3	55	17.5	53
4	62	60	70
5	57	42.5	84
6	56	82.5	68
7	52	80	79
8	77	47.5	68
9	66	7.5	66
10	56	95	78
11	65	40	78

6.4 Discussion

As a pilot study, and the first occasion to put into practice the Exoscore tool, the focus of this study was learning (Lee *et al.* 2014) about what was experienced and expressed by administrators and participants to the Exoscore phases and application. In accordance with the ethics application, the participants involved in this pilot study were:

- Reasonably healthy (no recent stroke, incomplete spinal cord injury episode).
- Walking without physical assistance from another person (walking aids were allowed).
- Able to read and understand the questionnaires and execute commands re tasks.
- Able and willing to participate in the study (signed consent form, etc).

To our knowledge, this is the first phased design evaluation tool that measures acceptance of emerging technologies such as lower limb exoskeletons. Furthermore, it is specifically designed to gauge and assess exoskeleton acceptance by older adults (Shore, et. al., 2018a). Exoskeletons are predicted to become a common assistive technology within the medium term (Young and Ferris 2017). Usability tests (Brooke 1996; Krug 2006; Reiss 2012) and TAMs (Davis, 1985; Venkatesh *et al.* 2003; Heerink *et al.* 2010; Chen & Chan, 2014) offer reliable insights and assessments of user interactions with technologies in a number of contexts. Healthcare professionals currently avail of assessment tools (Scherer and Craddock 2002; Cook 2015) when assessing suitability of assistive technologies for people.

We identified a lack of evaluation tools specifically used to measure attitude and perception of lower limb exoskeletons and exosuits by older adults and used by design teams. We developed three new constructs, previously not used in TAMs (Shore, et. al., 2019) and introduced them as part of Exoscore. This new design evaluation tool is embedded within an IDAM (Shore, et. al., 2019) which encourages iterative and involved design phases between design teams and participants. This design paradigm sits within an established and proven design process (Design Council 2014).

The exoskeleton as a wearable device will to some degree become an embodied appendage at times; design teams require understanding of that experience for the person who wears and uses the device. As discussed earlier and based on findings from our fieldwork (Shore, et. al., 2019), the wearability experience and factors such as noise of the exoskeleton operating can now be a measurable attitude (EP, Perception Phase).

Lower limb exoskeletons typically will be used by people who require assistance with mobility. Such users may have other health or lifestyle conditions that need to be considered. The construct PAD (Table 8, Perceived Impact) documents this requirement to adapt exoskeletons if there are changes to the older adult's condition or mobility.

6.4.1 Pilot Study Feedback:

Upon completion of the Exoscore pilot study, the administrators shared their experience applying Exoscore and some observations from the participants:

- It was described as 'easy to use'.
- It could be improved by revising some of the terminology and improving the introduction phase to enhance understanding of exoskeletons by the participants.
- The Perceived Impact Phase questionnaire made more sense to the participants, following the experience of the exoskeleton.
- In order to relate real-world experience and use of an exoskeleton in the home or social settings, it is suggested that a tool to test home use is developed.
- As a testing session with participants can take up to 2.5 hours, an awareness of this timeframe is needed and the possibility that the participant may experience fatigue or hurriedness when completing some of the questionnaires e.g. Perceived Impact.

6.4.2 Scoring

Because a pilot study is more about understanding and implementing the tool, it was interesting to note the results presented. The participants could perceive the exoskeleton to be useful. The score for ANX could indicate a perception of a sense of anxiety to individual use of the exoskeleton. As we age, anxieties may become more alarming or concerning than to our younger selves (Ostir and Goodwin 2006; Wuthrich *et al.* 2015). This construct results both during Perception and Perceived Impact Phases, which would indicate it as an important one to capture a sense of confidence or not by an older adult while being assisted by the exoskeleton. At initial viewing and prior to experience, EP construct (Perception Phase) the item concerning the look of the exoskeleton appears to have a lower result and could be down to the aesthetics of the exoskeleton, or other factors not yet defined. The 'look' of the exoskeleton may be a critical measure to evaluate acceptance or not of the exoskeleton.

6.4.3 Future opportunities

The iteration and development of Exoscore will include a specific introduction/module to the concept of exoskeletons and exosuits in general, and how they can assist people. Opportunities to facilitate interactions between participants and designers as exoskeletons is to be encouraged. Further testing with a larger sample size is required across several exoskeleton projects as a means to validate the approach. In addition, as testing of exoskeleton concepts are undertaken in lab settings, and similar to technology and TAMs (Venkatesh *et al.* 2003), an addendum will be developed for applying Exoscore to testing that is conducted in home or social settings (Heerink *et al.* 2010).

However, lower limb exoskeletons will be controlled in multiple ways:

- The hardware required to interact with and manage the system (i.e. mobile phone, tablet, PC).
- The software, how will the system be viewed and used to manage frequently, particularly if changes or updates are required to the exoskeleton?

A specific design tool offering phased insights to understanding and iterating to user needs can efficiently adapt and apply changes to exoskeleton concept iteration. Exoscore was developed as a result of fieldwork analysis and results are based on older adult perceptions. However, there is an opportunity to generalize and open this tool as a mainstream tool for all user groups participating in testing and development of exosuits.

We believe a hybrid model that incorporates stages of usability testing, as well as self-reporting TAM phases, provides richer and efficient feedback at concept and iterative stages of design. Once the results are satisfactory, Exoscore affords the opportunity to proceed with developing a lower limb exoskeleton that ultimately has involved both users and design teams in a very user-centric way.

Exoscore goes beyond a typical usability test or technology acceptance assessment by encouraging participants to be expressive about exoskeleton assistance for their mobility requirements. As part of a User Centered Design process, it is an iterative model that facilitates discovery and definition of needs requirements to development of concept, optimizing the exoskeleton for delivery to market.

6.4.4 Limitations

Our small sample size limited concise results regarding reliability and validity of Exoscore. In order to validate Exoscore, it is critical that further studies have larger sample sizes and perhaps more than one exoskeleton project. Terminology of some of the items, particularly at Introduction and Perception Phase was confusing to some of the participants. These areas require revision to ensure improved experience and clarity of answers by participants.

6.5 Conclusions

Exoskeletons and exosuits will become a familiar technology in our day-to-day settings within the medium term. We introduced version 1 of Exoscore, a specific design evaluation tool that can assess acceptance of lower limb exoskeletons by older adults. Future day-to-day situations we experience as we age can be enhanced by lower limb exoskeleton interventions. Our fieldwork and literature review revealed gaps in current TAM's. This provided an opportunity to review the design process and how it can offer guidance to exoskeleton and exosuit development as a means to optimize older adult use, acceptance and experience of these robotic assistive technologies. We have introduced three new constructs to apply as part of a new design evaluation tool to measure attitudes of acceptance by older adults of exoskeletons.

Exoskeletons and exosuits that are trusted, useful and enriching to assisting with day-to-day tasks offer optimal value and quality of life experience for users of these emerging technologies.

6.6 Acknowledgements

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6.7 Key Points

- There is a requirement to understand and apply user insight and knowledge to exoskeleton design, specifically with older adult users.
- Older adults who experience reduced mobility, also experience a reduction in independence and autonomy to conduct daily activities, in turn affecting their quality of life.
- Current knowledge of technology acceptance indicates a requirement to introduce phases of evaluation and assessment of perceptions to lower limb exoskeletons by older adults.
- The complexity of exoskeletons and their acceptance in day-to-day living situations requires an iterative assessment and opportunity to analyse a concept during development, highlighting specific areas to address challenges or opportunities presented.

6.8 Research development & context

This study was the final one for this particular research, it required completion and conclusion as a means to state and define the merits of the constructs, IDAM and Exoscore. The descriptive statistics and feedback from the administrators and participants offer optimism that indeed with further research and refined application of Exoscore, this can become a mainstream approach to exoskeleton design and development.

7. Discussion

The aim of this chapter is to review and discuss the motivation and the key findings from each chapter of this thesis. There were three main findings to this research, 1) three new constructs introduced for attitudinal measure of exoskeleton acceptance, 2) IDAM, 3) Exoscore. This was overarched by a drive to explore and learn about the perceptions older adults have towards the use of exoskeletons using a grounded theory approach. The initial journey of this research began with a research statement that established the field of enquiry:

> This research proposes to develop empirical evidence that will lessen negative product related stigma and improve technology acceptance for older adults with reduced mobility that wear a soft robotic biomimetic exoskeleton when conducting everyday tasks and activities.
>
> (April 2016)

In order to pursue a grounded theory approach (Charmaz 2014) for exoskeletons that are not commonly available as everyday wearable devices just yet (Young and Ferris 2017) a number of methods (e.g. literature reviewing, spending time with older adult participants and constant comparison) were relied upon as a means to gain knowledge and insight to the emerging theory.

7.1 Backdrop

The older adult population globally is expected to exceed 2 billion by 2050 (UN, 2015). As we age we may experience disability which manifests itself as a mobility impairment. In addition, ageing can also result in higher rates of illness, quality of life and social isolation (Manini, 2013). Hearing loss and vision decline are noted aspects of ageing and though age is not an impairment, it has been a noted challenge factor on tasks e.g driving (Wickens *et al.* 2003). Today's ageing population is more active into older age, more diverse, more educated and working to a later stage in life (Czaja *et al.* 2019). These considerations inspire and demand design solutions that can assist and enhance life stages and experiences (Newell, 2011; Stuck and Rogers 2018; Marston *et al.* 2019). Older adults can benefit from good design interventions in the context of their day to day interactions and environments (Charness and Jastrzembski 2009).

Older adults would like to try newer technologies e.g. touchscreen mobile devices, however, they may rely on previously used technology due to the uncertainty of understanding the new technology (Page, 2014). The new field of assistive technology – robotics has the potential to enhance the lives and experiences of older adults (McGinn *et al.* 2014; Bedaf *et al.* 2017).

There is a need for older adult insights as a means to optimise robotic device use and acceptance (Fosch-Villaronga and Özcan 2019). Usability testing has sometimes been adapted to facilitate older adult participants (Pullin 2009).

Technology Acceptance Models were typically relied on as tools that could measure or determine prospective acceptance and use by users of a specific technology. To date, few models have evolved that measure attitudinal insight by older adult towards acceptance of everyday technology devices or robotics.

Exoskeletons will potentially become common robotic assistive devices in the coming years, there is a need to understand how people will interact and accept this technology (Young and Ferris 2017). Exoskeletons can also provide mobility assistance to people who experience limitations as a result of stroke or spinal cord injury (Walsh, 2018). Exoskeletons to date are not currently mainstream, however, they have the potential to enhance the lived experience as we age. There are currently no design tools that measure the interactions during concept development between design teams and older adults to ensure optimisation and acceptance of these devices. The perceptions older adults have to exoskeletons requires understanding, measure and application in both a lab setting and home context, over time this will assist with knowledge and insight that enriches exoskeleton developments.

Four studies were undertaken during the course of this research. The intention was to enhance current knowledge and identify gaps as a means to optimise older adults' acceptance of technology.

Study 1 (Chapter 3) – time spent 'out in the wild' with 22 older adult participants over a period of five weeks to understand and gain insight about Quality of Life and mobility of older adults (2016).

Study 2 (Chapter 4) – A literature review as a means to reveal knowledge gaps about TAMs and user centred design guidance in relation to older adults and acceptance of exoskeletons.

Study 3 (Chapter 5) – A further episode of fieldwork spent out in the wild, this time with 24 new cohort of older adult participants and a scope of enquiry that investigated perceptions older adults have to emerging technologies, including exoskeletons (2017).

Study 4 (Chapter 6) – The episodes of fieldwork and literature review were analysed and interpreted to reveal original and novel outputs of the research, of which a Pilot study was undertaken with descriptive statistics and outputs discussed.

7.2 Exoskeletons and older adults

7.2.1 Exoskeleton benefits as mobility supports

Exoskeleton use has potential application beyond healthcare and where it might not be classed as a medical device (ISO, 2014) but a lifestyle option for mobility support. The literature review revealed the benefits of wheelchairs as enablers to promoting social activities of daily living and social inclusion. However, there is a strong desire for users to engage in daily activities and tasks, whilst, standing or walking. In turn this can improve physical functioning and maximise rehabilitation outcomes (Wolff *et al.* 2014; Pazzaglia and Molinari, 2016).

7.2.2 Limited empirical evidence

To date information about users perspectives of exoskeleton technology is limited, with no literary evidence of user involvement in the development or design of exoskeletons (Hill *et al.* 2017). Older adults often require a perception of 'need' before adoption of a technology (Hanson *et al.* 2013). In relation to perceptions and acceptance of technology or robotics devices there was a limited number of studies (Age UK, 2009; Smarr *et al.* 2014; Marston *et al.* 2019), and none that were found, were related to exoskeleton acceptance or perceptions by older adults.

7.2.3 Position of TAMs in relation to 21st Century technologies and wearables

TAMs were developed towards the end of the twentieth century and related to the measure of acceptance and interactions between a person and a technology (Venkatesh and Davis, 2000). Users of wearable technologies may in the future have elements of embodiment (Pazzaglia and Molinari, 2016). This requires multi-dimensional understanding and knowledge by design teams (e.g. exoskeleton control platforms managed on devices such as mobile phones or tablets). The experience of wearing an exoskeleton by the older adult and the support elements to the service design, highlight the need for a new approach to wearable and exoskeleton development. This is an identified gap that requires development.

7.2.4 Research evidence of experiences and perceptions by older adults

Two separate qualitative studies were undertaken with older adult participants who were deemed independent and living in the community. During the research studies, evidence was displayed and expressed of challenges the older adult participants experienced in relation to ageing and technology perception and use. The Co-Design symposium discussed in Chapter 3 presented the findings based on a field study enquiry about older adults' insights regarding mobility and age friendly environments. In relation to technology, (Chapter 5 & Appendix 3) there was evidence of heirloom or sharing of devices. For example, mobile phones being passed to or handed on from other family members. Online services were at times reliant on and conditional to, help or intervention by family members, sometimes by choice, but at other times through lack of confidence by the older adult.

Robots and exoskeletons were introduced and discussed. The participants expressed some fears related to trust, confidence and wearability of an exoskeleton. In addition, the personalising of the exoskeleton was an appealing factor to some participants and it could be interpreted as a feature that would enhance trust of the device. Regarding robots, there was speculative discussion in relation to human features and how robot acceptance might be enhanced, particularly if it looked similar to a loved one (now passed away). Image of self was important in general, particularly in relation to comfort and colour of clothing chosen as we get older.

7.3 Factors affecting technology acceptance of exoskeletons by older adults

This study applied a grounded theory approach to learn and build knowledge as a means to develop theory. Figure 35 (from Appendix 4) documents the methodological approach as per a grounded theory. The findings present possibilities that optimise older adult acceptance of exoskeletons. Design teams require current and ongoing awareness of older adults needs requirements in order to satisfy and meet older adults' expectations, support and comfort when engaging in ADLs and IADLs. The new knowledge outcomes highlight key findings that emerged.

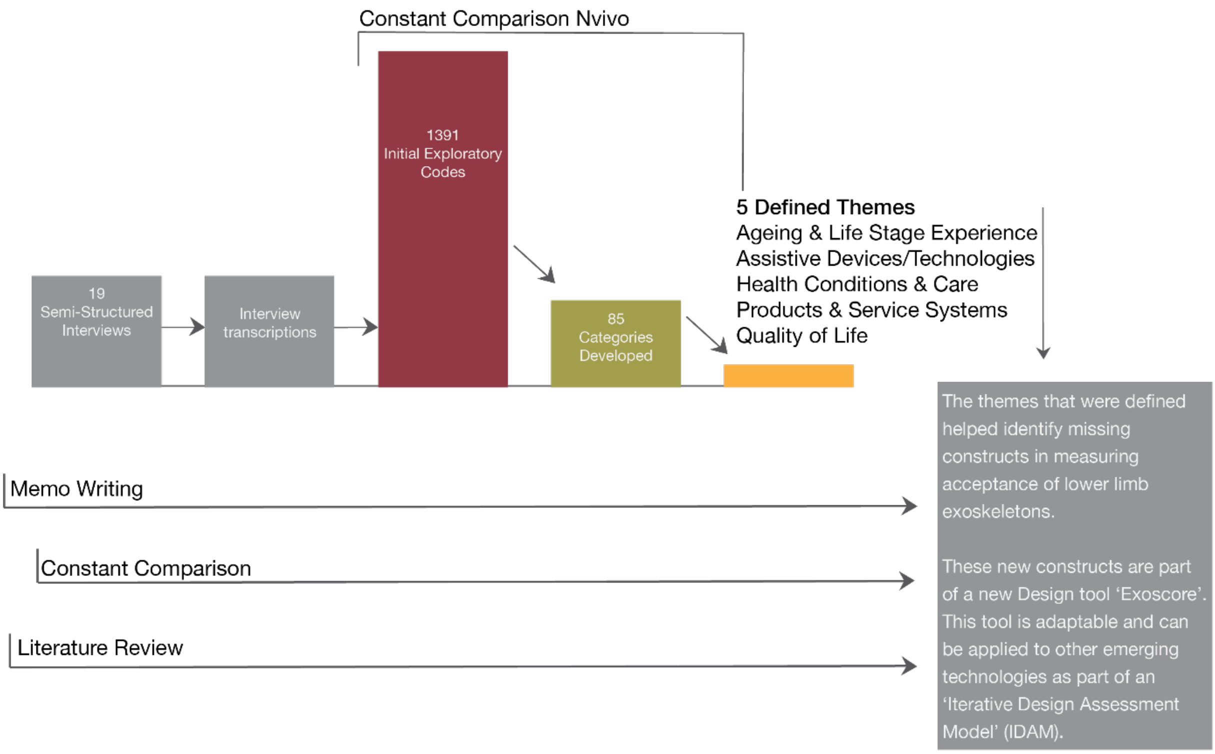


Figure 35 Overview of the research undertaken 2016-2019.

7.3.1 New attitudinal measure constructs

The literature review highlighted beneficial aspects of TAMs, usability and guidance about older adults and technology acceptance. However, in relation to wearable robotic devices, there was a gap in the knowledge regarding anticipation and experiential aspects of wearing and using exoskeletons. Five themes: 1) Ageing & Life Stage Experience, 2) Assistive Devices/ Technologies, 3) Health Conditions & Care, 4) Products & Service Systems, 5) Quality of Life, emerged from analysing and interpreting the research. The themes that emerged did not have existing corresponding constructs that could be applied to attitudinal measure of exoskeleton acceptance by older adults. TAMs up to now have typically relied on adjusted or updated themes adapted sometimes to included specific devices e.g. social robots (Heerink *et al.* 2010). The themes that emerged are rich in insight and share of a number of aspects of ageing. In addition, the context of enquiry to understand and define gaps towards exoskeleton design led to the development of three original constructs. These new constructs are introduced in order to assist with understanding the various aspects of acceptance criteria older adults have towards exoskeletons.

- Experiential Perception
- Self-Liberty
- Quality of Life Enhancement

7.3.1.1 Experiential Perception

Definition: The perception the older adult has of the interaction with the lower limb exoskeleton when using and wearing it.

Items:

- It is important the exoskeleton operates quietly when I wear it.
- I would feel embarrassed wearing the exoskeleton.
- The exoskeleton would be too heavy for me to use.
- The exoskeleton looks exciting to wear and use.

The items in this construct are intended to be perception based and to measure the older adults' feelings prior to the wearing of an exoskeleton. In this regard factors such as noise or stigma can be documented in a quantitative way.

7.3.1.2 Self-Liberty

Definition: Autonomous perceptions of control by the older adult when using or wearing the lower limb exoskeleton.

Items:

- I am curious about using an exoskeleton.
- I could use an app on my smart phone/tablet to monitor how the exoskeleton helps me.
- I could manage the basic upkeep (e.g. washing, charging/changing battery) of the exoskeleton, independent of my family/carers.

It was observed through fieldwork interactions that infantilising was sometimes unintended, e.g. whereby the older adult expressed a reliance and trust of others was a factor towards their decision making. Infantilising is often intended and expressed as a form of care or love for the older adult, but it is often believed and accepted by the older adult. Sometimes older adults expressed a sense of not wanting to be a burden to others. Self-liberty intends to enhance the older adult's perception of self and their autonomy. It differs from self-efficacy previously a construct used in some TAMs because it encourages expression by the older adult, and after the experience of trying the exoskeleton.

7.3.1.3 Quality of Life Enhancement

Definition: Relating the use of lower limb exoskeleton to activities and instruments of daily living (ADLs & IADLs).

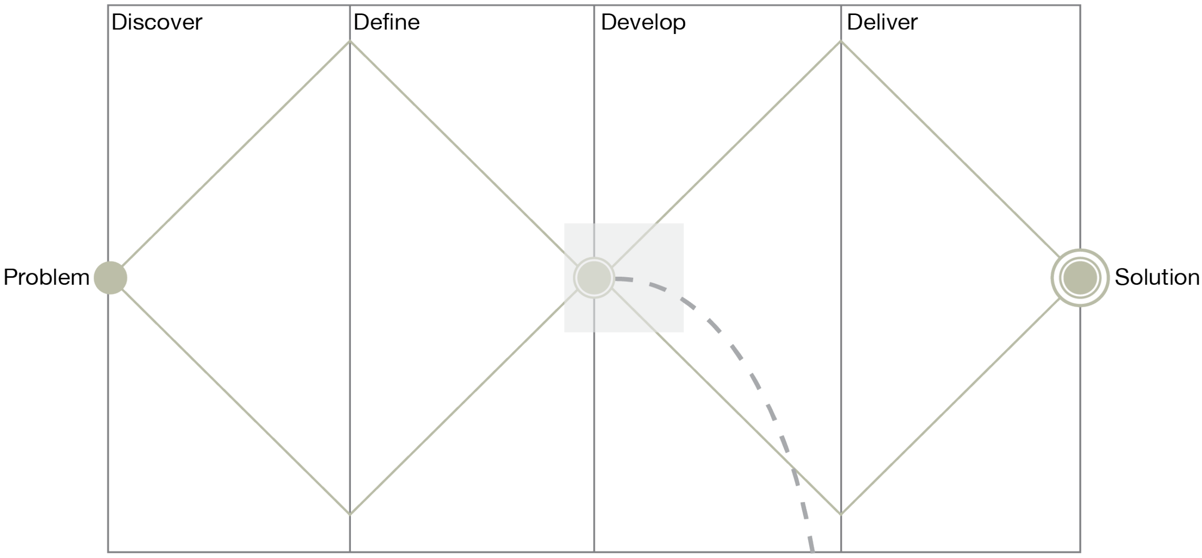
Items:

- An exoskeleton would assist my ability to do tasks in the home.
- An exoskeleton would assist my ability to do tasks outside of the home.
- I feel confident that I would not get harmed wearing the exoskeleton to perform day to day tasks.
- I could attend more social events if I am wearing an exoskeleton.

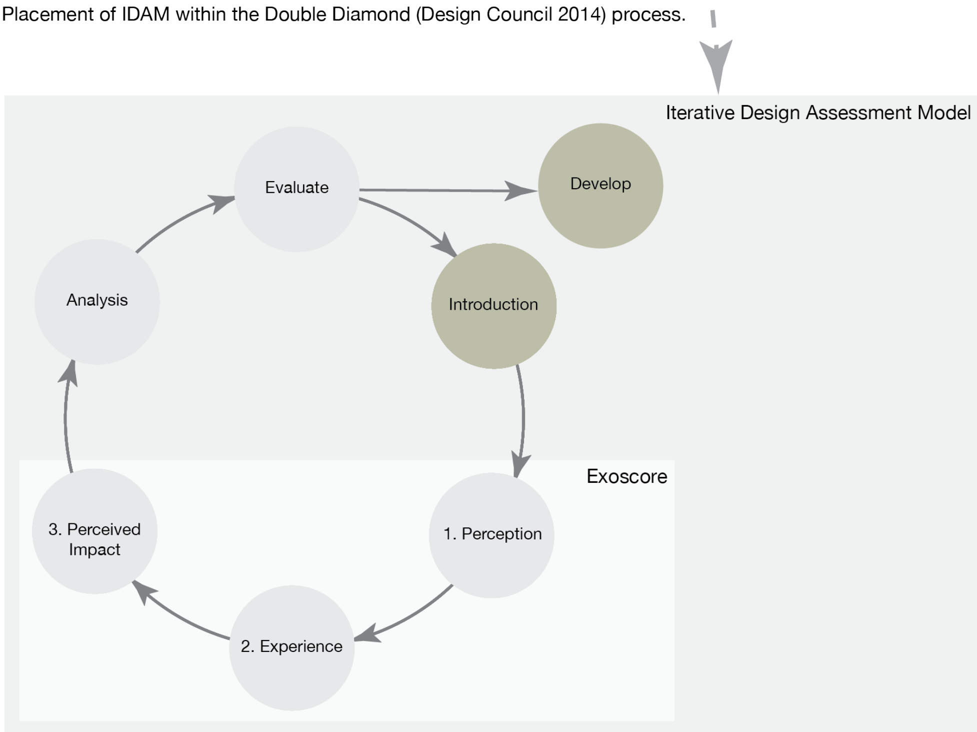
As we age, we are sometimes limited by cognitive or physical ability. This can impact on our mobility, sense of self and engagement with community and society. Tasks such as driving can cease and in turn some interaction socially outside of the home. Exoskeleton use by enhancing and assisting our mobility, can be a factor to our gerontological health and wellbeing.

7.3.2 Iterative Design Assessment Model

Grounded Theory was a suitable method when exploring older adults' perceptions to emerging technologies such as exoskeletons. However, these technologies are not fully mainstream. Little is known about user insight and view of their place in someone's world. Design teams are familiar using methods such as user-centred design, to date there has been no single tool that could document or offer strategy to design development of exoskeletons. One reliable design process was the double diamond (Design Council, 2015). Iterative approaches are a useful resource to innovation and development (Rogers, 2003). In order to develop a new design model and tool specific to exoskeletons, the process was broken down into phases that highlight iterative design approaches. The Iterative Design Assessment Model (IDAM) Figure 36, affords action and reflection as a design concept is developed. It sits within the intersection between the Define and Develop parts of the Double Diamond. This is a new and novel iteration which sits within the Double Diamond and relies on the interactions between participants and design teams as a means to measure acceptance of technology.



Placement of IDAM within the Double Diamond (Design Council 2014) process.



Iterative Design Assessment Model (IDAM) work phases

Figure 36 IDAM affords action and reflection as a design concept is developed.

7.3.2.1 IDAM Phases

IDAM is cyclical with an entry point (see Figure 36) – *Introduction* whereby the participant meets with the design team to discuss the strategy, and engage in any ethics documentation or study requirements with an option to engage, or choose not to become part of the study. As the process advances Exoscore is introduced through three different phases of work between the participant and the design team (Perception, Experience, Perceived Impact), including experiencing the wearing or using of the exoskeleton as well as questionnaire completion. The responsibility of the design team is to ensure each phase is completed or documented when not. In addition, any observations and informal interactions are included as well as the completion of the questionnaires by the participant. Upon completion of a test session, the participant is thanked for their time and invited to remain connected with the study or project or similar types of study on a secure database.

Analysis - after the test activity is complete, scores are compiled and analysed by the design team. *Evaluation* - scores and findings are presented and discussed with any other relevant stakeholders to the project whereby agreement is made to re-iterate the concept and begin further testing, or to move on to Develop the exoskeleton to a point that can be considered almost market ready or depending on device type – clinical trials.

7.4 Exoscore Design Evaluation Tool

Exoscore is a novel hybrid of existing methods to assess or measure attitudinal insight to technology. It relies on the experiential phase as per usability testing, but also captures the critical measures similar to TAMs. This hybrid approach offers a design tool that measures and captures rich insight and perception towards the exoskeleton concept. There are three phases to Exoscore; Perception, Experience & Perceived Impact.

7.4.1 Perception Phase

Older adults had expressed a difficulty visualising and thinking about the exoskeleton during fieldwork. Traditionally, TAMs would evaluate and measure attitudinal responses relating to the interaction between the person and the technology, however, the novel approach of Exoscore is that it facilitates anticipatory feelings towards exoskeletons and how the older adult is affected and motivated towards the anticipated trial and test session. The Perception Phase of Exoscore acquaints the older adult to an exoskeleton, in addition, it captures expression of anxiety, credibility and belief to the exoskeleton by the older adult.

7.4.2 Experience Phase

The opportunity to trial and measure the experience an older adult has when wearing and using an exoskeleton has the potential to direct further iterative development of exoskeletons. It documents the experiential comments about how the experience or trying an exoskeleton is for the older adult. The pilot study relied on an existing scale, the System Usability Scale (Brooke 1996). As discussed in Chapter 6, this resource, though useful would require a customised series of tasks and interactions specific to people and exoskeletons, not just systems. Exoskeletons as wearable robotic devices have aspects of service system use and layers of wearability features that require specific measure and understanding of the user groups that they can potentially assist.

7.4.3 Perceived Impact Phase

As we age, we reflect on past actions and experiences. Some therapies e.g. dementia rely on reminiscence. In this way Exoscore, Perceived Impact Phase offers older adults some reflective expression to share their impression and perceived impact towards the potential of wearing and using an exoskeleton in their world. Would it offer the potential to enhance quality of life for example? It is believed that the Perceived Impact phase is a critical aspect of Exoscore, that will impact and influence design considerations to the concept development of exoskeletons.

7.5 Fieldwork and Positionality

The experience of spending time 'out in the wild' on two occasions, with two different groups of participants, added and enhanced knowledge and awareness of the ageing experience and daily interactions by older adults. Documenting these experiences and stories was a challenging undertaking. It was intense and at times generated emotional surges of passion within. This interplay, whereby, the researcher actively responding and working with the data is necessary to the generation of data from the field (Birks and Mills, 2015). With regard to positionality (St. Louis and Barton, 2002), the practice and application of affinity diagramming, building a verbatim database in Nvivo and constant comparison methods ensured discipline and delivery of rich data. This was a very insightful part of documenting and analysing the participants insights and share of their world.

The generation of over 1390 codes dictates other research opportunity and elaboration. Over time this will become more apparent, however, one particular code that was stored digitally and interpreted using Nvivo software was 'Feelings'. Over 240 expressions of various feelings from happiness, frustration, joy and hurt were expressed by the participants. This has inspired thought direction and passion to share this code and perhaps others, in a more concise and insightful book format as a means to assist education of design students towards understanding users or context of life. As per grounded theory, figure 37 is drafted directly from a memo in one of the researcher's journals that documented and reflected the research journey:

03.03.2018
"Coding makes you realise how emotionally you are invested in your participants and their worlds…
I was working today on another section of interview that involved a couple discussing the impact of Alzheimer's – the Husbands brother was living with the condition.
Around the time the codes were all around expressions – feelings…
Feeling, caring, challenged, fulfilled, intimidated, loved, reassured, pro-active, fear, a burden, a nuisance, etc., etc.,
I felt upset – overwhelmed and tears were gently easing from my heart through my head…
I love this work; I feel privileged to hear and witness intimate expressions from others…
How lucky am I?

Figure 37 Direct reference from journaling, and memo writing regarding the code 'feelings'.

It is clear there are very relevant outcomes about the need for optimising acceptance of exoskeletons by older adults, as documented. However, the journey of the research and the fieldwork itself is in fact another facet, and outcome to share.

7.6 Key Contributions and advancement to knowledge

Study 1: Older Adult Insights for Age Friendly Environments, Products and Service Systems.

- This study documented a journey of collaboration and action involving a coalition from a number of academic institutions in Ireland and ISAX, an ageing think tank organisation based in Ireland.
- It documents fieldwork and the approaches that were undertaken with 22 older adult participants.
- The placement of an undergraduate student with an experienced researcher was expressed as a positive experience for both the student and also the participants. This

approach also instils ability of the student to develop empathy and ethical concerns regarding work of this nature.

- The paper documented ageing experiences as design concerns, e.g. 1) the complexities of accessing and taking a bus ride 2) the challenges faced with arthritic hands and how access to the medication in blister packs is almost impossible, and painful.
- The paper discusses the process of collaboration and documents how a Co-Design symposium develops outputs that benefit people.

Study 2: Technology Acceptance and User Centred Design of Assistive Exoskeletons for Older Adults: A Commentary.

- This narrative review offers chronological commentary to TAM development and evolution.
- The published paper has had a number of citations referencing the validity of this paper.
- To date no TAM or design model was identified to measure acceptance of exoskeletons by older adults.
- This paper identifies a distinct lack of user-centred design guidance for exoskeleton development. This in turn presents a barrier to understanding and defining needs requirements and criteria of exoskeleton acceptance by older adults.

Study 3: Technology acceptance and perceptions of exoskeletons by older adults - A qualitative study using a grounded theory approach

- This paper documents the second fieldwork study undertaken with 24 older adult participants.
- User testimony is documented in a unique way, highlighting a combination of design and social science methods in order to develop the codes, categories and themes.
- The development of newly identified constructs: 1) EP – Experiential Perception, 2) Self-Liberty, and 3) Quality of Life Enhancement were introduced as major outputs.
- A multi phased approach to design of exoskeletons was proposed, based on the ageing experiences discussed and the appeal to try something with the support of trusted or expert people.

- Perceptions in relation to wearable technologies and exoskeletons were discussed and documented e.g. functional features, dressing and colour preferences.
- Experiences using or assisting somebody with assistive devices e.g. wheelchairs has been documented.
- Abandonment of devices e.g. hearing aids was documented as a concern in relation to wearable and expensive emerging technologies such as exoskeletons.

Study 4: Exoscore – A design tool to evaluate factors associated with technology acceptance of soft lower limb exosuits by older adults.

- To our knowledge, this is the first study of its kind that is documented and discusses the pilot study of a new three phase design tool Exoscore.
- This paper shares new knowledge and provides Exoscore version 1 construct questionnaire and items publicly.
- Descriptive statistics are provided as evidence of application and approach that highlight new learning and understanding towards the introduction of Exoscore.

7.7 Opportunities for future research

There are a number of opportunities for future research. In the context of ageing and life experience, technology interventions including robotics and exoskeletons can enhance quality of life and mobility. The new hybrid design approach - IDAM has been introduced as a major output of this research. This current body of work has included a pilot study of Exoscore with 11 participants in a lab setting during a live concept testing session of XoSoft.

The value Exoscore can bring to exoskeleton development needs further and more elaborate testing in order to validate a scoring method that is reliable, consistent and efficient. It is necessary and intended that Exoscore is developed further for both laboratory and home setting testing with exoskeleton design teams and older adult participants. Furthermore there is opportunity to develop and evolve Exoscore and its name into a series of testing applications that involve participants and design teams of other emeging technology or wearable devices.

IDAM & Exoscore were developed as a result of insights and perceptions from the fieldwork studies with older adults. Future opportunities should apply this new design approach with different user groups also.

The Exoscore constructs and items within the phases of Perception and Perceived Impact currently state and facilitate quantitative capture of attitude before and after the experience of wearing an exoskeleton. It would be envisaged, particularly for the experience phase that qualitative commentary and expression is linked and related to the analysis and evaluation phases of IDAM in the future. Terminology and understanding of each construct and items require review across language and geographical boundaries in order to ensure consistent meaning and interpretation.

The fieldwork and the rich insights that were shared and interpreted provided an invaluable source of knowledge. There is opportunity here to draft a book or a series of publications intended for undergraduate students as a learning tool for ethical design research approaches and co-design methods. This series of publications could also be facilitated as part of seminar or workshop programmes within learning and testing environments.

Further oportunities are intended to consider the life cycle of technical wearable garments and exoskeletons, in relation to impact on costing, ownership, manufacturing, life, and disposal or sustainable features of exoskeletons.

In addition to technical wearable garments, how does fashion influence clothing choices as we age, and if we experience mobility and agility challenges. Clothing items such as female undergarments, socks, and trousers have been documented as dressing challenges. An example narrative from previous research highlights how cold weather and cold homes can sometimes motivate an older adult to get straight into bed to keep warm rather than to spend time, and to experience difficulties with undressing.

Exoskeletons offer great benefits to older adults who experience mobility challenge, however, future reseach opportunities should explore how do we maintain physical ability, mobility and dexterity across the life course. A multi disciplinary approach could investigate collectively, or as a longitudinal study topics such as nutrition, hydration, food shopping/foraging, physical ability and exercise for all.

The impact of a longer life, and longer or multiple careers across the lifespan, what technology interventions can enhance or ensure this as a life choice and a possibility?

Finally, our homes and where and who we live with? How does this impact or affect Quality of Life and happiness? In addition products that typically are identified as ‘assistive aids’ e.g. grab bars, how in the future can we ensure homes have a standard of acccessibilty for all, and do not flag or highlight people of vulnerability in their own homes?

7.8 Limitations

There are a number of limitations to the results and any further work to develop Exoscore will need to consider the following points:

7.8.1 Early stage commentary and feedback

- The early stage of this research engaged with older adults where they expressed their perceptions towards exoskeletons. When asked about robots and robotic devices, some participants found it challenging to consider these technologies without a concept to try or see in front of them.
- Because Exoskeletons are not currently mainstream it presented challenge to display and discuss something tangible and interactive for the participants.

7.8.2 Application and testing of Exoscore

- To date no other models have been developed to measure attitudinal insight towards exoskeletons by older adults. There was no existing like for like model for comparison and therefore existing TAMs that gauged Technology Acceptance of devices and social robots were relied on to assist in the development of Exoscore.
- Sample size was a factor in developing a test strategy of Exoscore. The XoSoft concept was feasible for testing in lab settings and with older adult participants. However, Exoscore, as a new design tool would require a more rigorous approach to test its merits & limitations.
- The terminology for some of the items require a review to ensure transfer of intent and meaning across language, discipline and geographical boundaries.
- Knowledge limitation towards understanding a costing strategy and also a service system potential for exoskeletons would have been helpful as part of the fieldwork interactions.

8. Conclusions

This research began in 2016 with an ambition to explore and understand perceptions older adults have towards exoskeletons. The findings of this research have major contribution to offer in relation to exoskeleton development and design, particularly towards co-design oportunity whereby design teams can work with older adult participants as a means to optimise acceptance and use of exoskeletons. The results of the studies enhance knowledge and offer insights not previously known or stated. Perceived ease of use and perceived usefulness are necessary criteria to enhance exoskeleton acceptance by older adults. As a result of frailty, older adults may become vulnerable as a 'falls risk' and a desired feature would be that fall or collision detection is embedded within exoskeleton design.

There was evidence during the fieldwork of a desire to manage self and independence as we age. Autonomy and liberty are encouraged for the older adult to be the control master of the exoskeleton, as their wearable garment. Supports and transparency of the service system by the providers are critical in order to encourage straightforward communications and updates with the technology. However, where assistance is required or sought, the older adult should not become infantilised or overlooked when seeking support or help. The majority of the participants in both fieldwork studies experienced and managed existing health conditions such as arthritis, whilst remaining independent. In addition there was evidence of anxiety towards the onset of new conditions such as dementia. In relation to exoskeleton development, adaptability to an individuals changing health prognosis would be a benefit which would ensure continued familiarity with the wearable technology.

The invitation and encouragment by providers towards a trial of an exoskeleton would be seen as a positive opportunity for older adults to experience the benefits, if any, of enhancing their mobility by the intervention of an exoskeleton (e.g. the ability to socialise and dance, or walk longer outdoors when enjoying activities such as golf).

This research also gives prominence to preferences of clothing options as we age. Factors such as colour or patterning options were seen as desirable to wearable technology, as well as personalisation options such as pockets/packs or the naming of the device. It is believed that these features would instil emotional connection and trust of the device.

Finally, the complexity of exoskeletons and their acceptance in day to day living situations requires an iterative design assessment tool, that can be adapted and remains current to user acceptance criteria of exoskeletons.

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Appendices

Appendix 1


Age Friendly Environments
Co-Design Symposium
Savoy Hotel, Limerick
June 2016
University of Limerick
DESIGN FACTORS
designcore


CASE STUDY
Pill Packaging
University of Limerick
DESIGN FACTORS

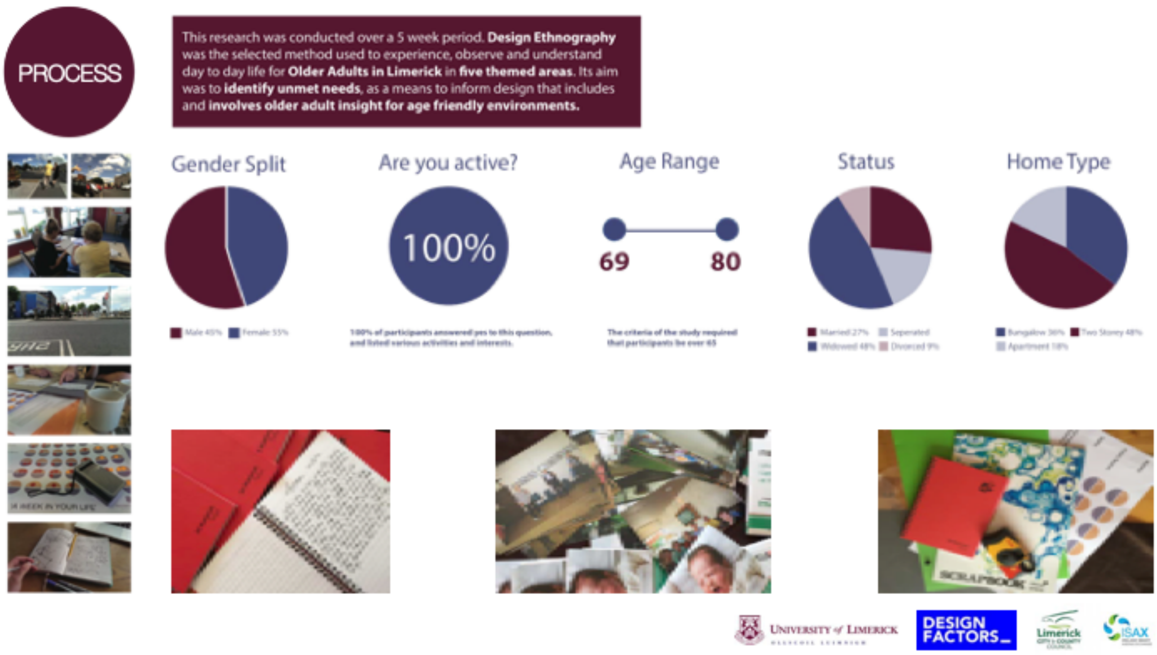
1. Participant has arthritis in her thumbs, she also shares she has macular degeneration which can affect vision.
2. She finds pain relief using gels and pills
3. Her pill medication recently was 'repackaged' and changed
4. The previous pill packaging was a light material and had black block writing which was easy to read.
5. The new packaging is a white background and font and writing is now less clear to read
6. It also has a new material casing which now as was displayed causes pain to the user when she attempts to open packaging and access her pills.
7. The pill that she requires for pain relief and comfort for her arthritis

There are risks to safety here including:

a. Someone who is not prescribed medication can access easily, including children.
b. A risk presents where there is no monitoring or awareness to frequency and dosage.

How could we improve this participants experience?

Age Friendly Environments
Co-Design Symposium
Savoy Hotel, Limerick
June 2016
ISAX
University of Limerick
DESIGN FACTORS
Limerick
designcore



PROCESS
This research was conducted over a 5 week period. Design Ethnography was the selected method used to experience, observe and understand day to day life for Older Adults in Limerick in five themed areas. Its aim was to identify unmet needs, as a means to inform design that includes and involves older adult insight for age friendly environments.
Gender Split
Are you active?
Age Range
Status
Home Type
100%
69
80
Male 45% Female 55%
100% of participants answered yes to this question, and listed various activities and interests.
The criteria of the study required that participants be over 65
Married 27% Seperated Widowed 48% Divorced 9%
Bungalow 36% Two Storey 48% Apartment 18%
University of Limerick
DESIGN FACTORS
Limerick
ISAX

22 Participants:

11 Informal interviews using audio and image capture
7 Task Observations with participants
11 Self Observation packs issued and returned

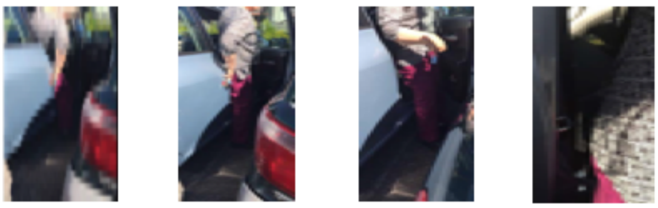
Five Themes

MOBILITY | PUBLIC SPACES | SAFETY | SOCIAL ENGAGEMENT | SERVICES & FACILITIES

MOBILITY

Accessibility Experience when Leaving your Home

NEED: **Improvement of accessibility** experience outside the home – Bus access, parking, cyclist awareness & pedestrian experience.



Parking

Pedestrian experience

Buses - **Moira's story…..**

PUBLIC SPACES

Older Adult Journeying Experience & Ease of use to Public Spaces.

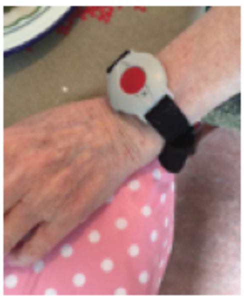
NEED: Older adults with reduced mobility and their carers require access to busy areas safely, efficiently and conveniently, as a means to conduct everyday tasks and social engagements.

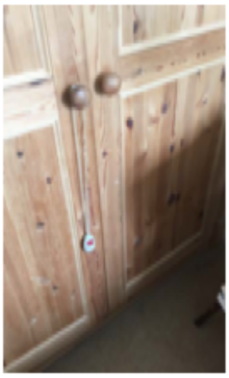
David's story…..

SAFETY

Home & Mobile Security

NEED: Older adult safety and reassurance when at home or out and about.





Betty's story…..

"In case of break ins [I] leave the radio on all night in my bedroom." - ULX04C

SOCIAL ENGAGEMENT

Supportive Communities

NEED: Interraction, support and communication across communities and generations.

Nel's story…..

SERVICES & FACILITIES

Management of Personal Affairs

NEED: Impartial trustworthy guidance to manage and plan finances and bills in the following areas: Banking, General Utilities, Mobile phone options & Estate Planning.

I ask then about gas and electricity providers, Participant shares he gets all his gas and electricity form Bord Gais, he is in receipt of a very generous gas allowance, however if he wanted to shop around and go elsewhere he expresses:

"If I moved my gas and my electricity to somebody else I would have to go through a big long rigmarole to claim back the allowance." ULX11L

I ask what would make it awkward to switch? The Participant shares he would have to fill in all the forms etc. He looked into it two years ago and with the amount of work and time involved etc. He felt it wasn't worth it. [excerpt ULX11L]

"Switching services or switching facilities is a tricky thing for people of my age." ULX06L

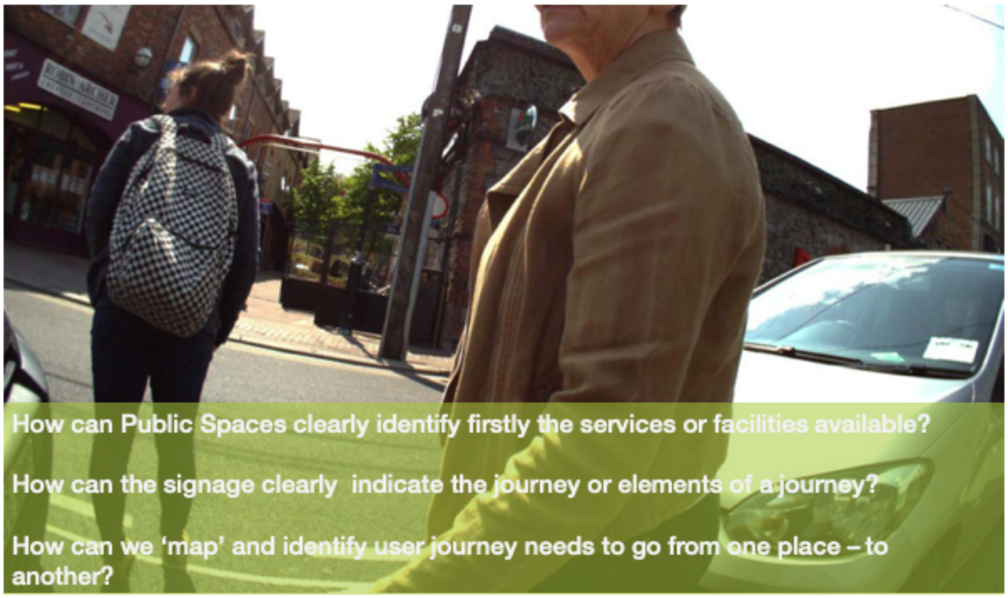
Participant would like there to be a one stop shop to 'switch', and advice on all services offered that have competitors.

What would suit this participant would be the opportunity to sit face to face and bring documentation. [excerpt ULX06L]

Jack's story…..

Participant comments about the local library toilet saying it is up some stairs. She is not sure if accessibility is considered (i.e. accessible toilet) – this will perhaps be followed up by task observation accompanying P to town for a trip that involves using and accessing the toilets in the library. (excerpt ULX01L)

I ask about buildings access, Participant feels the ones he visits are good, when I ask him about the Granary Library(as Participant had mentioned it's a place he visits and parks close by) he shares: actually that is a problem. Participants wife would have a problem there, main entrance has steps up or steps down to a lift. Then he shares, you can actually access the lift but you need to take a long detour, I ask is it a long ramp, and he shares no, you need to go down and around the building, and there's another – there's a nightclub there, when you go around you come to a courtyard, unless you know that you can get to the lift there are no signs, unless someone tells you,..
(excerpt ULX09L)



SINCERE THANKS
to all the participants.

You collectively shared stories that offered rich insight to the challenges and pleasures that can be experienced as we age.

Appendix 2

E&PDE'17 Special issue Design and Technology Education

EPDE'17 Organizers [a.kovacevic@city.ac.uk]
Sent: Thursday, September 07, 2017 1:04 PM
To: Linda.Shore
Cc: lindashore.DRC@gmail.com; Adam.DeEyto; Louise.Kiernan; ULStudent:DEIRBHILE.NIC A BHAIRD; anne@isax.ie; PJ.white@itcarlow.ie; tracy.fahey@lit.ie; Siobhan.Moane@lit.ie

Dear Linda Shore,

The organisers of the E&PDE2017 have agreed with the Design and Technology Association to be prepare a special issue in Design and TechnologyEducation: An International Journal, from papers of this E&PDE conference. This is an open access journal with a good impact factor.

The editors of the special issue are Lyndon Buck and Ahmed Kovacevic.

Based on the reviews we received for this this conference, we selected your and 10 other papers to be proposed for this special issue. We hope that you are as excited as we are about this opportunity. Certainly there may be many questions in regards to realisation on this issue which is planned forApril 2018. The papers will need to be extended to the journal level and willneed to go through a rigorous review process.
We propose to meet later today just before the conference dinner at thevenue of the dinner for 5-10 min in order to answer any quetsions you may have and to agree on actions to realise this special issue.

When you arrive at the dinner venue, please find either
Lyndon Buck, Erik Bohemia or me
and we will let you know where we are meeting.
Thank you in advance for

cooperation. Kind regards,

Ahmed Kovacevic

Appendix 3

Investigating perceptions related to technology acceptance & stigma of wearable robotic assistive devices by older adults – preliminary findings.

SHORE Linda[1*]; DE EYTO Adam[1] and O'SULLIVAN Leonard[1&2]

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Abstract

Longevity, and good Quality of Life enhances a positive ageing experience by post-retirement adults. However, physical decline and limitations may affect independence and autonomy to conduct and engage in day to day tasks and social activities. Assistive robots can offer support to assist, and become embodied features that are accepted and worn by older adults. To date, research is limited and little is known about older adults' opinions of assistance by robots in personal and home life. There are a number of Technology Acceptance Models (TAMs) presenting quantitative based questionnaires that attempt to gauge acceptance and usefulness of robots by older adults. This paper presents preliminary findings from a qualitative study with older adults. The findings discussed are from an initial cohort of 8 older adult participants, which are part of a larger, ongoing study. The purpose of the study was to understand older adults' perceptions relating to technologies commonly used and future technologies and their acceptance and usefulness. The preliminary findings are based on a cross section of eight participants, and their perceptions. The findings of the full study will inform and assist the user centred design of a soft robotic exoskeleton.

Keywords Older Adults; Assistive robots; stigma; Qualitative research.

Introduction

Baltes refers to lifespan development as an ongoing process of change, from conception to death (Baltes 1987). It is widely viewed that within a user centred design research project, the user needs, must firstly be identified, and secondly be involved in the process of research and design (Dreyfuss 1955)(Dreyfuss, 2012ed., Papanek 1985; Fisk et al, 2004; Farage et al, 2012; Norman, 2002).

The global population of adults aged over 60 is expected to exceed 2 billion by 2050 (UN, 2015). This demographic in 2013 represented 11.7% of total global population. By 2050 it is predicted to be as high as 21%. This growth, combined with the continuing decline of fertility and birth rates indicates that there will be a greater number of older adults than children aged <15 (UN, 2013).

Older adults are members of a disenfranchised group that collectively experience the ‘digital divide’ (Newell, 2011). The ‘digital divide’ refers to the pace of emerging technologies and the ability to use devices by groups such as older adults. It can impact on everyday task application experience, and challenge using technology such as ATM’s, mobile phones and computers. Assistive technology should enhance quality of life and support the limitations experienced by the user. It should not be a source of frustration that invokes a reluctance to use a device. This implies the need to pursue and crossover the digital divide by understanding the challenges faced by older adults using technologies.

Graafmans et.al. (1996) calls for a ‘lifespan approach’ to design that features and emphasises an adaptability and flexibility that matches the needs of the user. They further discuss the influencing factors that can encourage or dissuade older adults from using technology devices. They express that more development is required to define people’s acceptance and use of technology beyond their chronological age.

Technology, and its adoption or abandonment has had numerous models developed as a means to measure and identify the factors that optimise its acceptance [i.e. TAMs]. In more recent years such models have been adapted to include older adults, their home environments and social robots or technology devices (Heerink, 2010; Chen & Chan, 2014). These models typically compose of constructs with Likert scales that gauge the potential for acceptance. Generally, they are quantitative measures that do not always accommodate the expression or intimate thoughts of the older adult. TAMs are critiqued and discussed by many authors. Salovaara & Tamminen (2009) detail how TAMs have influenced design, attributing terms such as ‘user acceptance’ and ‘diffusion’ and ‘adoption’. However, they also share concerns to TAMs as tools that can predict acceptance of technology by people, and discuss the flaws of measures that depend on user self-reporting, and short user exposure to the technology in question.

There is a need to consider alternative ways to understand and evaluate older adult user needs in relation to the acceptance of technology, specifically assistive robots (Shore. et. al. 2018). Consideration is required to the new emerging technology forms and the experiences and opinions of older adults, who are often quite engaged with ICT. Chen and Chan (2014) discuss a qualitative study they undertook that highlighted the positive attitudes older adults in Hong Kong appeared to have, in relation to everyday technology devices. However, other factors influenced more negative attitudes to acceptance and use, i.e. health risks, social problems, environmental and complexity of the technology. Qualitative studies regarding acceptance of wearable assistive robots by older adults is scarce. It was identified by literature review that there was a need to enquire and develop understanding, in relation to the perceptions older adults have to the presence and use of assistive robots.

Robots can be an effective intervention to support a person with mobility limitations. Assistive robots typically are grouped into three categories: manipulation, mobility or cognition (Van der Loos & Reinkensmeyer, 2008). The mobility group of assistive robots includes gait training robots and exoskeletons. ISO 13482 (2014) presents specific safety evaluation criteria for the design of personal care robots, based on three categories or robots: mobile servant robots, physical assistant robots and person carrier robots. Physical assistant robots, in ISO13482 are not defined as medical devices, but devices that can improve quality of life. Under ISO 13482 exoskeletons are classified as physical assistant robots.

Exoskeletons are used typically in rehabilitation, military and industry environments. When we consider the needs requirements of older adults with limited mobility, an exoskeleton could potentially offer enhanced abilities to engage in Activities of Daily Living (ADLs - Katz,1963). This in turn could maintain autonomy and independence as ageing progresses. However, there are relatively few studies that engage researcher with older adult participants in their home and day to day settings. Age UK (2009) found that the majority of studies involving technology and older adults, focussed on internet use and access. Other commentators suggest that, in addition to developing robots that assist with current needs of a person, there is a need to focus on technologies that can prevent decline and maintain health (Robinson, et al. 2014).

The current authors embarked on a qualitative study involving twenty-four older adult participants in Ireland. The intention was to interact with older adults and understand their experiences of ageing and perceptions of wearable assistive robots. This paper discusses preliminary data based on analysis of eight participants.

2. Purpose of the study

The primary aim of this study was to increase understanding of day to day life and experience of adults aged over 60, and living independently in the community. Specifically, this enquiry would focus on use of technologies, activities such as dressing, and perceived barriers to adoption of technologies.

2.1 Design research and older adults

The design researcher looks beyond what people say, and captures also what people don't (or can't) do, and hearing what people don't say, (Brown, 2009). This focus and skill highlights the importance of quality, over quantity of information gathered during research. Design research can be the most thrilling ride when surprises and discovery happen. However, the designer's role as an impartial moderator (Demirbilek, 1999) also emphasises the responsibility a designer has to the participants involved in the study and their expressions and views.

The ageing global population are a cohort that will continue to grow over the coming years (UNFPA/HelpAge International, 2012). This highlights the need to consider this demographic as a group requiring design led enquiry and new product interventions that can enhance autonomy and independence. This ageing population may hold unprecedented concerns for the future. The European Commission have stated that in the future, young people (>14) and older adults (<65) may become "too heavy a burden on younger working age people (15-64) (EU, 2011)." Concerns are not just economic, and as a consequence of age, our bodies change and decline (Torge, J, 2014). As a result of longer lifespan and medical advances we are now living longer in our own homes, often with some form of functional limitation (Haak, et. al. 2007).

The requirement to involve older adults in the design process has been further discussed by numerous commentators (Fisk, et.al, 2004; Farage, et.al, 2012; Pirkl, 1994; Demirbilek, 1999; Newell, 2011) with Universal, Participatory and Co-design approaches recommended.

2.2 Technology

During literature review, numerous terms were offered when discussing 'new' technology for older adults, for example: assistive social agents, healthcare robots, personal care robots, domestic robots, assistive robots, socially assistive robots, robotic aids and assistive walking technology (Heerink, et.al. 2010; Broadbent, et. al; 2009; ISO, 2014; Smarr, et.al. 2013; Miller, 1998; Wu, et. al. 2014; Van der Loos, 2008; Feil-Seifer & Mataric´, 2005 and Tapus et.al, 2007). Generally, the association with each of these authors was the need to understand, evaluate and gauge acceptance and use of these technologies.

With so many terms applying to fundamentally similar technologies, this presents a challenge to designing a study, and its language 'out in the field' to communicate with participants. Language, when used in participatory design research has been shown to optimise user engagement by the spoken behaviour of the design researcher (Luck, 2007).

The purpose of the overall study (n= 24 participants) was to learn from older adults, their perceptions to new technologies, and language, critical to their engagement when they shared stories or experiences. It was considered the familiar assistive devices such as wheelchairs, walking sticks, hearing aids would be helpful to building rapport and receiving commentary from the older adult participants. However, when robotic devices would be mentioned, the term robotic assistive devices were used in the conversations with the participants. With consideration of exoskeletons and soft robotic trousers, the term 'assistive robots' appears to support the xosoft project outcome of a soft robotic exoskeleton. It correlates with Van der Loos (2008) who defines three areas of assistive robots, as manipulation, mobility and cognitive robots. Mobility assistive robots help a person move from place to place (Miller, 1998, Van der Loos, 2008).

3. Study approach

3.1 Methods

Creswell (2003) refers to the numerous methods that are available to researchers, namely quantitative, qualitative and mixed methods. This study will involve older adult participants and rely on their perceptions and experiences regarding wearable robotic assistive devices. For that reason, a qualitative study was undertaken with grounded theory and ethnographic strategies.

3.1.1 Grounded Theory

Grounded theory has evolved over the years. There are many commentators and authors of numerous articles and books defining grounded theory (Glaser & Strauss, 1967; Strauss & Corbin, 1994; Birks & Mills, 2015 ed; Charmaz, 2nd ed, 2014). For the purpose of this study a constructivist approach was undertaken. This approach would support the activity, where knowledge would be gained using methods such as coding, memo writing, and theoretical sampling. This in turn would be compared and contrasted to support the build of theory (2014, Charmaz).

3.1.2 Design ethnography

Ethnography is described as an "integration of both first-hand empirical investigation and the theoretical and comparative interpretation of social organisation and culture" (Atkinson & Hammersley, 2007). Ethnographic methods have been relied on as a design research tool. They are often recommended as a means to gather knowledge, and immerse researcher with participant in natural settings or environments, and needs to fit the requirements of the design challenge (Blomberg, 1993; Nesta, 2016; Salvador, et. al, 1999). Design ethnography affords the design researcher to understand what their participants do, how they think and what they say. It places the researcher in the context of the participants space or setting. To understand the lives and experiences of the participant, the researcher will enter the participants world with "an open mind, not an empty head" (Fetterman, 1998). Using ethnographic methods, the design researcher immerses themselves into the world of people, and discovers the participants desires and opinions of products, meanings and cultures. In addition, Salvador, et. al, note the value of other discipline influences such as anthropology, psychology and sociology (Salvador et. al. 1999).

For this study, the researcher spent time with the older adult participants in their homes. There were visits to social group sessions, and post stroke meetings in two counties. A qualitative approach of observation, audio and image capture, as well as semi-structured interviews were the main forms of knowledge capture during the five-month study period. In addition, opportunity presented to try or experience some products used daily by participants, as a means to deepen understanding e.g. a stair-lift (Figure 38). The audio files for each of the interviews were transcribed verbatim, noting observations of body language, participants tone or demeanour to different experiences or stories they shared.

Figure 38 Researcher experiencing a stair lift in participants home.

3.2 Participants

3.2.1. Recruitment strategy

Twenty-four participants were recruited for the overall study. Participants were sourced through community groups, where membership consists of older adults, e.g. Age Friendly Limerick and The Friendship Club. In addition, snowball sampling was used, where, word of mouth from one participant sharing with another, encouraged other older adults to participate. This afforded a good rapport and trust between researcher and participant. Visits to Post-stroke groups also supported participant recruitment. The full sample of participants varied in age from 60 to 87.

This paper will discuss preliminary findings from the sessions with eight of the participants. There is a gender balance mix of four male and four females, aged between 69 to 87. Four participants were married and four were widowed, and were living in rural and urban areas. Six of the homes they lived in were two-storey, with the remaining two homes classed as bungalows, or with no stairs. As required by ethics committee approval and research planning strategy, each participant was asked to complete the 'mini-cog' test (Borson, 2000). This was done prior to consent form being signed and agreed between researcher and participant.

3.2.2. Ethics

The study was approved by the Research Ethics Committee of the University of Limerick. The submission of the application included strategy and approach to observe, and spend time with older adult participants. It included the information and consent form templates that would be offered to participants to invite them to become involved. In addition, there was a consideration to the cognitive challenges that may present with ageing, and as a means to not unduly infringe or impose, a 'mini cog assessment' (Borson, 2000) was undertaken by each participant prior to consent form being signed. This is an evaluation tool to assess the participant's cognitive ability and their suitability to participate in the study. All participants passed the mini-cog test without stress or challenge. All participants were also advised (and, as stated on the information sheet) that at any time they could stop the session. In addition, image and audio capture was highlighted as tick boxes, that participants would acknowledge if they were happy for this or not, prior to signing the consent form. Each participant was anonymised, with an agreement that should imagery capture revealing background or personal features, they would not be visible, and would be blurred.

It was explained to each participant how their involvement was of importance to the understanding and development of soft robotic lower limb assistive concept. For the participants, this was described as a soft robotic trousers. It was explained there would be a total of six questions, on various aspects of life and experiences around technology and day to day life. Six questions were developed as conversation guides to the sessions, these questions were developed to optimise the interactions between researcher and participant. The questions are listed and displayed on Table 1:

Table 1 Fieldwork questions:

Question number	
1.	What are your experiences using or helping someone to use assistive devices and/or technologies? –sub a) Glasses or hearing aids; b) Computers or smart phones; c) Rollator or wheelchairs.
2.	Describe any difficulties or barriers to using a technology device?
3.	If you are/were to experience reduced mobility, how does/would it affect your way of life?
4.	When I mention robotic assistive devices, describe what that means to you?
5.	What is your opinion of older adults being supported by robots to do tasks and activities?
6.	How do clothing and dressing options change as we age?

4. Results

4.1 Semi-structured interview sessions

Six semi-structured interview sessions – 'conversations' were arranged with the eight participants. Two of these were conjoint; involving, one married couple, and the second involving two friends. One of the single participant interviews involved the participants daughter entering the room at various times and offering commentary with regard to whatever topic being discussed during the conversation. Prior to the session, each participant read the information and consent form. In addition, they completed the mini-cog test and were offered opportunity to ask any questions before beginning to record the session.

To portray activity and commentary during the sessions, the conversations were broad, and facilitated the older adult participant, the freedom to discuss ageing experiences and technology in general; and on their terms. This approach supported a user-led empowerment and the opportunity as a researcher, to see the world through the participants experiences and stories.

4.2 Findings

The preliminary findings were coded using Nvivo software (QSR International). A total of 341 codes were generated from 3,098 referenced comments from the eight participant's interview transcripts using line by line coding and generating open code techniques on Nvivo. From the initial open codes (phase one) [341], eleven categories (phase two) emerged which are displayed on Figure 39:

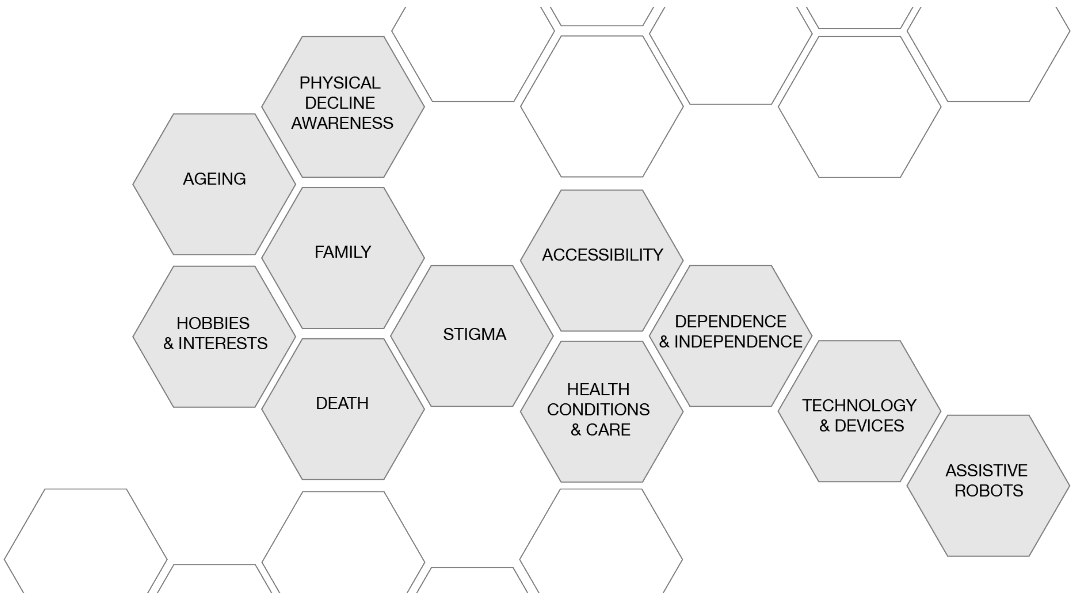

Figure 39 Categories emerged from initial open codes.

The eleven categories displayed have a number of sub-categories to each. Each one is displayed and defined in Table 2. The categories were generated from each code and based on the following criteria: a) volume or quantity of the recurring topics; b) quantity of comments to a particular code i.e. wheelchair use. A breakdown of codes to categories, with definitions are displayed in Table 2:

Table 2 Categories, definitions, sub categories.

Category	Definition	Samples of codes generated from transcribed interviews.
Accessibility	How accessibility is experienced to a number of places or settings.	Home; Home adaptation; Bathroom; Stairs; Steps; Stoves & Fires; Kitchen; Doors; Entry & Exit points; Nursing home or life planning; Ramps; Packaging; Furniture; Lifts; Product adaptation; Public Buildings; Road surface; Footpaths; Assistance or grants.
Ageing	The experience of ageing.	Daily activities & tasks; Dressing; Toileting; Travel; Transport; Reminiscence; Career or profession; Retirement; Accidents; Acceptance of ageing; Personal tasks; Trust/trust people; life adaptation; less active
Assistive Robots	How these new technologies are perceived.	User expectation of assistive robots; Barriers to adoption of; Positive perceptions; worn or carried devices; personalised or tailored; unsure of what an assistive robot is; emotional or personal connection.
Death	The effect and thoughts about death, or passing by self and others.	Coping after death of a life partner; Death of others; Death of self.
Family	How we interact and engage with family life and relationships.	Familial stories; non-family stories; Children; infantilising parent; children assisting parent; inherited devices; being a

		couple; being a burden; family trust; connecting and communicating; older adult parent supporting adult children.
Health Conditions & Care	Experiences using healthcare services, and the assistive devices and health conditions discussed by the eight participants.	Healthcare; Service systems; stories & experiences; dissatisfaction; relationships with health professionals; Hearing aids; challenges with hearing aids; Glasses; challenges with glasses; Experiences using assistive devices; experiences helping someone use an assistive device; wheelchair use; crutches; mobility scooters; personal alarms; shared stories; Health conditions – *Arthritis, Bladder, Blood pressure, Alzheimers, cancer, colostomy, diabetes, sleep apnoea, stroke, varicose veins, vision, hearing, DVT, Diabetes, Heart, leg, feet, spine, overweight, skin, pain, sleep,* memory, medication, *IBS.*
Hobbies & Interests	The social hobbies and interests that affect our daily experiences.	Holidays; Walking; Volunteering; Television, Reading; Dancing; Day trips; Tea & Coffee; Clubs & Groups; Cooking & Baking; Music; Being kept busy; Gardening; Keeping pets, Games.
Dependence & Independence	As we age and remain independent or begin to experience times when we can be dependent.	Quality of life; Fear; Anxiety; Loneliness; Being alone; Assistance; Not wanting to be a bother; appreciate help; embarrassment; self-critical; Empowerment; Limitations to independence; Accomplishments. Shopping; Assisted shopping; Costs & expense; Service providers; Bills & Utilities; Online shopping.

Physical Decline Awareness	How self-aware we are to the change that ageing may introduce to our lives.	Resilience; user adaptation with assistive devices; Mobility; Problems with mobility; Task planning because of reduced mobility.
Stigma	Times when experiences can be uncomfortable.	Perceived social barriers; Technology; Stories and experiences shared.
Technology & Devices	The numerous devices we interact with daily, and the technologies that support them.	Technology acceptance; Everyday Devices – Telephones, Mobile phones, computers, iPads, tablets; Internet; Usability & Function, Anxiety, Confidence, Technology Trust, Robot Trust; Social Influence.

The categories were then compared further with existing codes and refined to four distinct Themes (phase three), expressed by the data presented. The four themes namely are: Ageing, Health Conditions & Care; Technology & Devices; Quality of life. This process is visualised on Figure 40.

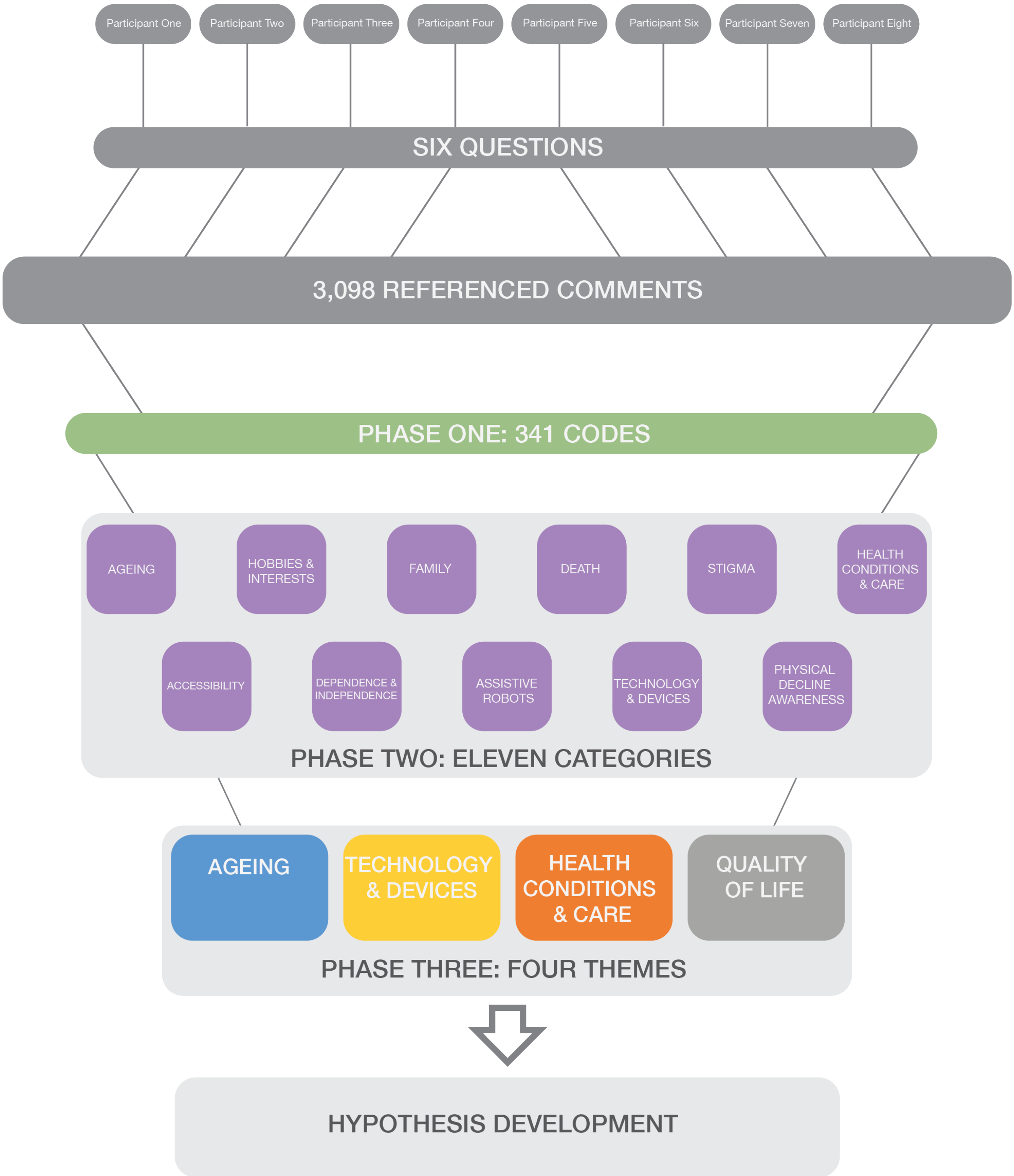

Figure 40 Four themes emerged from data.

As a means to display further the manual construct and endorsement of connections to each category and themes, from the codes, this work was mapped, and is displayed in digitally generated images, (Figures: 41, 42, 43, & 44).

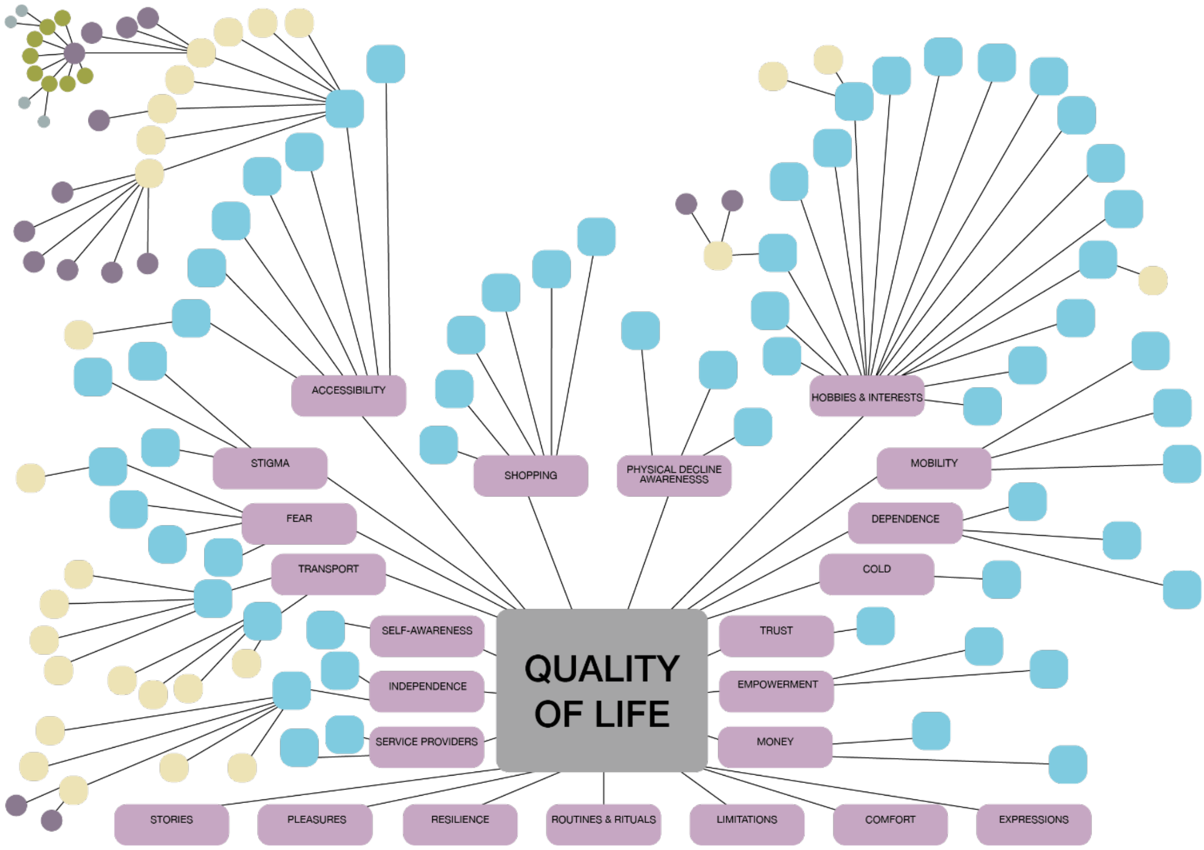

Figure 41 'Quality of Life' theme mapped connections from codes to categories, digital generated version.

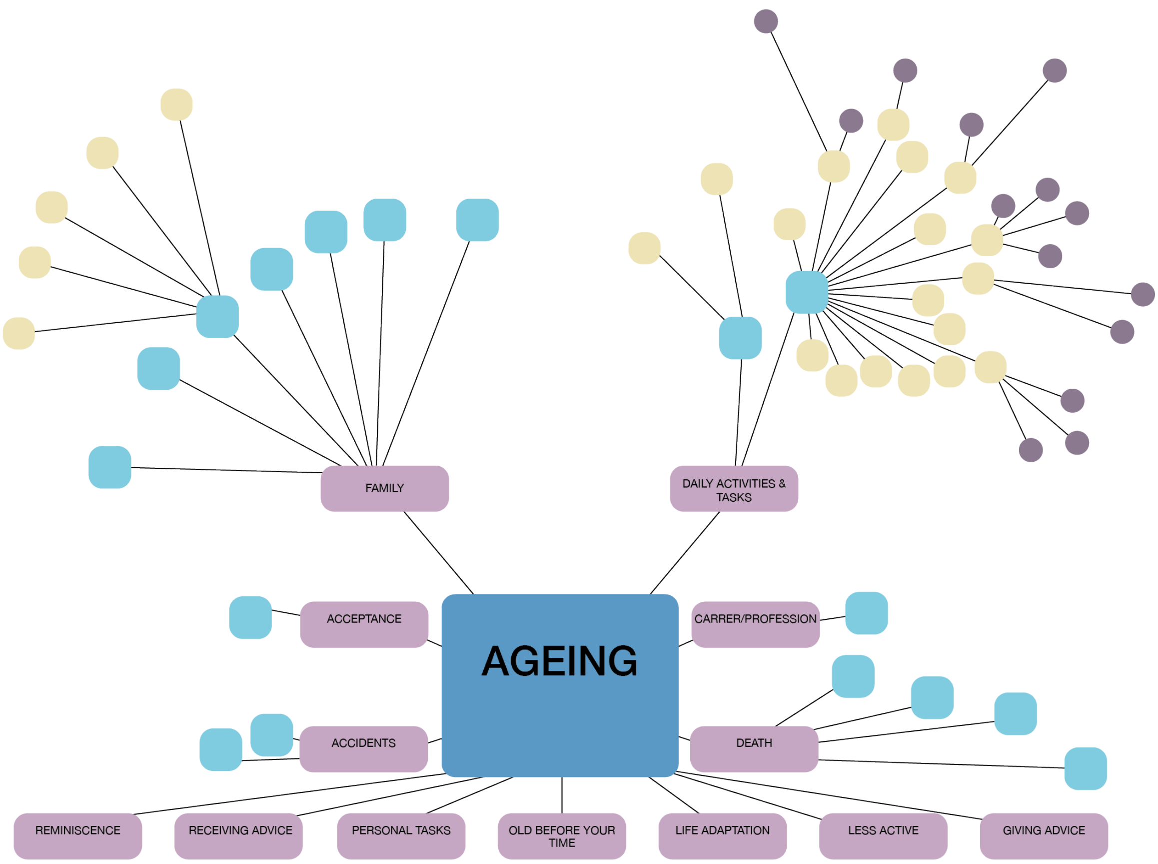

Figure 42 'Ageing' theme mapped connections from codes to categories, digital generated version

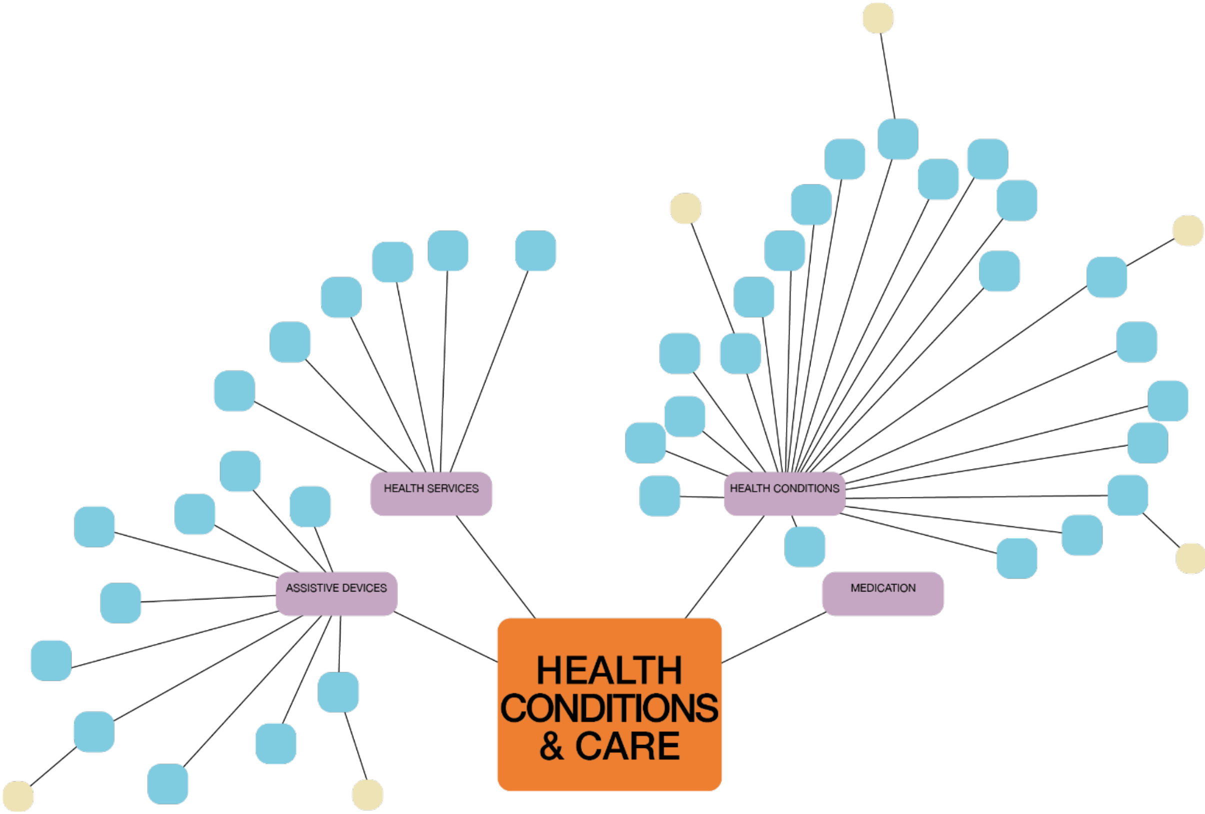

Figure 43 'Health Conditions and Care' theme, mapped connections from codes to categories, digital generated version.

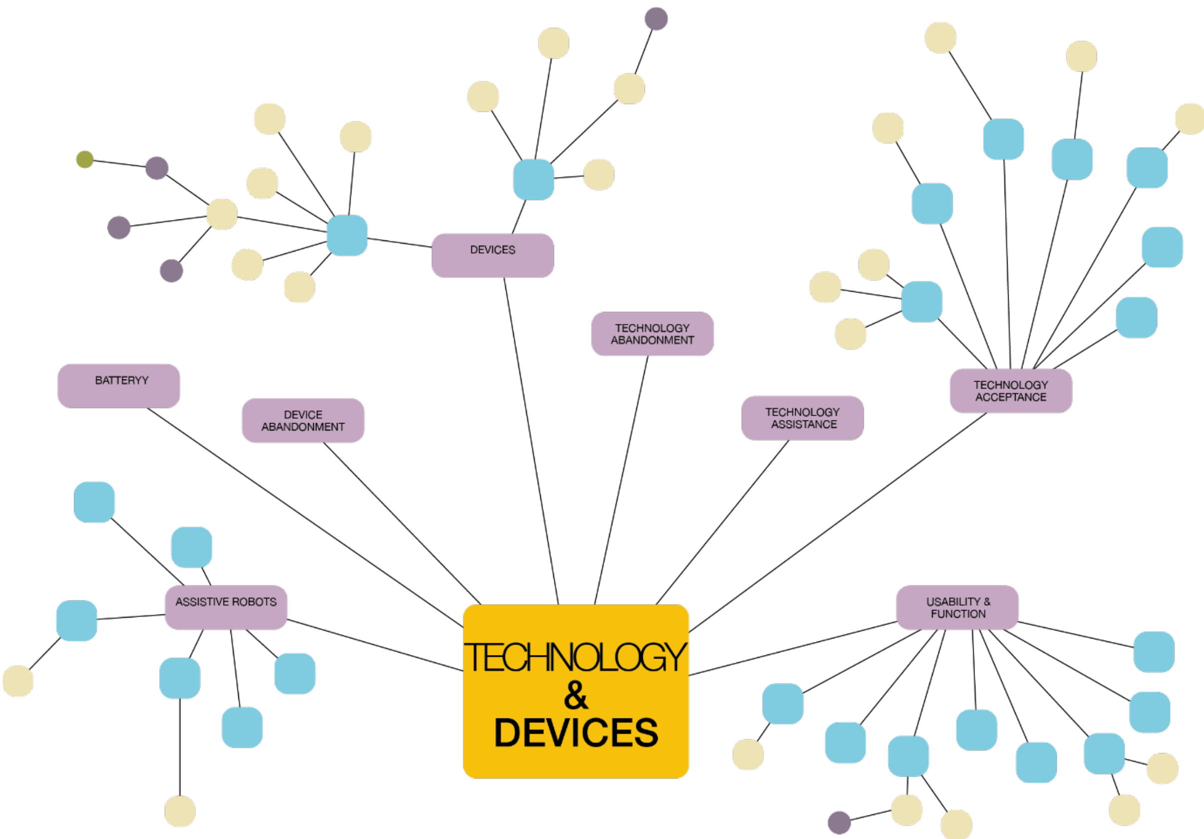

Figure 44 'Technology & Devices' theme, mapped connections from codes to categories, digital generated version.

Figures 45 and 46 detail the development graphically from **codes** (phase one) to **categories** (phase two) to **themes** (phase three). Starting from the outer circle the initial codes generated from transcribed interviews. The middle circle shows how the categories emerge, before finally the inner circle shows the themes. There are a series of one large and six smaller charts, the first showing the overall group and each of the six referring to each of the interview sessions (two were performed with 2 couples together).

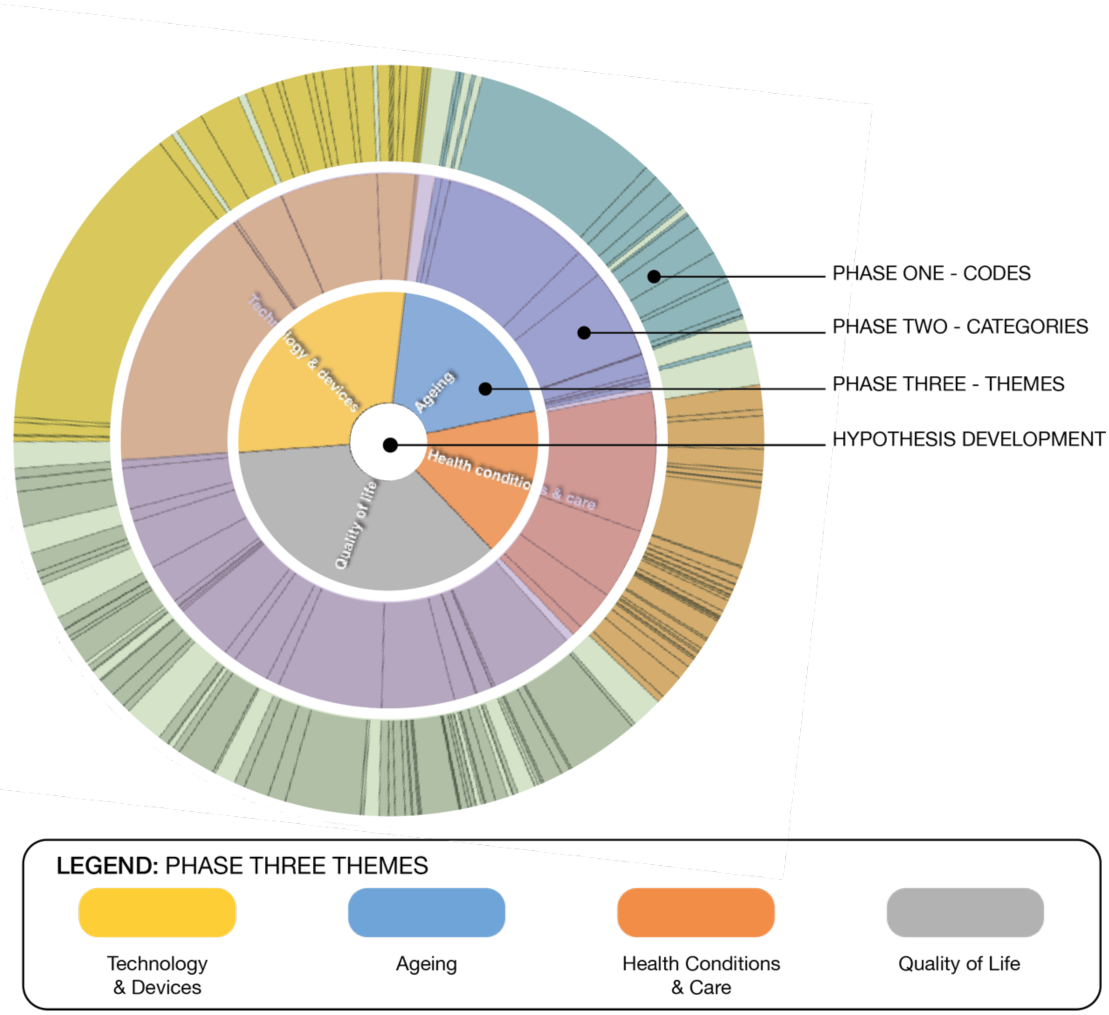

Figure 45 Graphical display of theme development from the overall group of eight participants, generated on Nvivo. Note how the outer circle (phase one) converges into phase two categories, and evolves finally, to the inner circle of themes.

Figure 46 Graphical display of theme development from each of the interview sessions, generated on Nvivo.

4.3 Session snapshots

As a means to share insight and the rich data expressed during the conversations, this section highlights and shares snapshots of responses by the participants (M= male; F= female).

Q1: What are your experiences using or helping someone to use assistive devices and/or technologies? –

Participant Eight (M) – "*He said [Consultant] I was severe sleep apnoea, and the next night was, now, we have to put you on machines and test, to see what strength you require, to tailor it [sleep apnoea machine], for my needs so, I rented it for the first year or two, then I thought, I'm renting this, and the man who supplies it – I asked - and what if I was to buy this? Well he said, I can sell you that machine, look it will do you for another two years, so half the price."*

Participant Three (F) – *"Oh, I have, they're left everywhere!"* [speaking of the numerous walking sticks in different areas of participants home].

Q1 a) Glasses or hearing aids;

Participant Four (F) – *"She [participants sister] takes it out [the hearing aid, when the participant phones her sister] she takes it out! And it's her family have told me what she's doing, but she won't admit it to me."*

Participant Seven (M) – *"I can hear the person beside me alright, if the person …people; if it's a babble of conversation and everyone's talking together, then I'm lost [problems trying to hear layers of conversation with hearing aids]."*

Q1 b) Computers or smart phones;

Participant Five (F) – *No, it's always on ringtone [mobile phone]. It fits in my pocket, it goes everywhere with me."*

Participant Six (M) – *"Another thing about the phone is, you have a line, that you, for medical reasons [or devices like personal alarms]no, but you can actually um, use, um, use other older aids if you like through the landline."*

Participant Two (M) – *"I have a smart phone, it's a hand me down from XXXX [daughter]."*

Q1 c) Rollator or wheelchairs.

Participant Eight (M) – *"I didn't realise how much you needed to know, how to balance a wheelchair, how to get it up and down."*

Participant Four (F) – *"I'll give you an example [helping someone in a wheelchair] about one particular man; he needed it [wheelchair] so badly, um, he got it, we were at a seaside resort and he got into the wheelchair and as he went down, closer to the house normally he would spend his holidays in. It was a B&B, he got out and he said, I don't want her [the landlady of B&B to see me [in a wheelchair] she mightn't take me."*

Q2: Describe any difficulties or barriers to using a technology device?

<u>Participant Eight (M)</u> – *"Doing things that involve money or cash, that mightn't be right, you hear so many things going wrong with that technology, you know what I mean? People scammed or doing this, you know what I mean? I'd be nervous in that sense to go that far, I should maybe, I should push myself more, not to bothering my kids, but they make it so easy for me."*

<u>Participant Five (F)</u> – *"I wouldn't be able to…" [fingers, isn't it Mum –participants daughter]* - participant has difficulty using key pads or any device that requires input with fingers.

<u>Participant Three (F)</u> – *"I don't understand them, and I have no use in … you know?"*

<u>Participant Seven (M)</u> – "If it operates on a battery it has to be regularly charged."

<u>Participant Two (M)</u> – "I suppose the, um, the eh, things are too small. [mobile phone screens] The fingers are too big. The numbers there you know? yeah and you know like, now they're big enough [directed to iPad screen] but if you're writing something, it's [the text] very small."

Q3: If you are/were to experience reduced mobility, how does/would it affect your way of life?

<u>Participant Eight (M)</u> - *"well there's only … I'd say you'd be trying to hide it more than anything, if you could, maybe that's not the right word 'hide' but sure look, pretend you're not as bad as you are. I wouldn't like to be a burden on my family."*

<u>Participant Five (F)</u> – *"It makes me feel bad that I can't do a lot of things for myself, you know, right now."*

<u>Participant Four (F)</u> – *"Well, I was to learn that very recently, I had, I pulled tendons and ligaments in my foot and eh, for me, it meant I couldn't leave the house without help. I live in the country [rural area] there is no public transport. I would be completely and utterly isolated."*

Q4: When I mention robotic assistive devices, describe what that means to you?

<u>Participant Three (F)</u> – *"It doesn't mean anything. I haven't seen them, I can't ever say I've seen them."*

<u>Participant Seven (M)</u> – *"I feel, well no, I think it's more than that, I think there's, eh, a personal relationship with these robots, unless; when they begin to break down, it's like a serious illness, you know; you almost know you need a new one. It's when your car gives you trouble, you need a new car, you have an attachment to the old car, but, at the same time, it's not as reliable, and you need something reliable."*

Participant Six (M) – *"Take the comparison like, what we were talking about earlier on; you needed to go to the toilet, or whatever it was. I don't think you would have any embarrassment about asking a machine to do it for you [assisting toileting]."*

Q5: What is your opinion of older adults being supported by robots to do tasks and activities?

Participant Eight (M) – *"Yes, to my family, I'd say, I'm with my… my friend [assistive robot] is with me today and they'd [family] say, oh you will be alright today, as I say, my friend is with me today, So, I'd accept it like, and the family would, yea, yea, 'Joe' [assistive robot] is with me, and we'd call him like…"*

Participant Three (F) – *"Sure it would get me to do more. I wouldn't be sitting down in the chair half the day sleeping, I'd love to be able to get around again. I'll never see 16 [again] anyhow."*

Participant Six (M) – *"let the person have that option, let that be one of their options [personalising or customising the robot] if they can take it from a photograph, whatever, and make him look like [for example] my husband, he's now doing things that he never did in his life when he was alive, so, you know, you know; yeah, mental, and physical, to their physical, emotional…"*

Q6: How do clothing and dressing options change as we age?

Participant Eight (M) – *"But, I mean if I don't, if I was I need something [shopping] I need milk or I think I need butter… If I have to buy another shopping bag, it'll kill me, so I got into the habit, I stick one [shopping bag] in the back pocket [of trousers]."*

Participant Five (F) – *"I know, yeah, going to the loo, trying to [remove tights] everything hurts [participant has arthritis in her hands]"*

Participant Four (F) – *"Well, things, you are trying to conceal, the bulges I suppose because they are there, and but eh, in addition to that you know, you don't have the curves that you had before so therefore you kind of tend to wear things that maybe are 'boxy' on you or maybe a little bulgy in the wrong places."*

Participant Six (M) – *"But, I think, colours express your mood as well. I think more so, again, with ladies, going… but you know, if you see someone in black all of the time, you can bet your bottom dollar that person's very down."*

The snapshots are brief insights to the descriptive answers by the participants, to initial six questions. Each session lasted between 40 mins and 1.5hours.

This study reveals many expressions and perceptions the older adult participants shared in relation to technology and its acceptance or abandonment. The participants expressed at times a sense of stigma, self; or observed, and likewise a dependence at times on others to support technology use and acceptance.

The participants expressed commentary on various technology devices and service systems. In relation to robotic assistive devices, there was a range of opinion, from not knowing or showing interest in the potential of robot assistance, to visualising an emotional connection and personalisation of them e.g. giving the robot a name. In relation to stigma, it appears that there is an attempt by some people to cover up or disguise a condition (e.g. poor hearing). However, becoming a burden is a worry and cause of anxiety among some of the participants. At times, some of the participants referred to older adults in a way that deflected from their ageing (e.g referring to 'granny shoes' they wouldn't wear; other older adult friends of a similar age, that needed their help). Personal appearance was perceived and expressed as a determinant sometimes of someone's mood (e.g. the colours they wore) and a conscious effort to feel comfortable.

5. Discussion

The preliminary findings presented in this paper offer insights to the rich content by contextual enquiry, that can be undertaken with a relatively small group of participants. It offers expression of an intimate nature at times. This requires the build of trust and rapport between researcher and participant. The stories and share are a valuable commodity to draw on throughout the process of design. They are to be valued and captured with both respect and concern that the participant is heard and their experiences voiced, with relevance to product or service system development. Participants can identify challenge or problems of use and experience with products or service systems. Designers' define and develop solutions that attempt to address the participants expressed problems. In addition, design research adds rigour by observing the unspoken, creatively logging and delivering insight that informs products and service system development that can enhance quality of life.

This study asked the older adult participants, what their perceptions were to newer technologies, by mentioning and discussing robots and exoskeletons. This introduction at times was challenging to visualise, and also insightful, with topics such as personalisation, colour, function and user-expectation being discussed. Existing TAMs that are designed to gauge acceptance and use of robots or technology devices by older adults afford some enquiry to constructs such as adaptability and trust, however the nature of a wearable exoskeleton (e.g. xosoft) may become, in effect an item of clothing with various features that require understanding and use potential & optimisation. Examples of some of the questions raised by the participants in this study:

- How to put it on and take it off?
- Would it be noisy?
- How fast would it go?
- What would it cost?
- How would it operate (e.g. battery) – does it need to be charged? And remembered to?
- Wearability – People wearing the same item and other people noticing or knowing, it's the 'same trousers'.
- Aesthetics – what it would look like, and look like when wearing?
- Human Factors concerns – e.g. Diabetes, arthritic hands/joints etc.
- Collision detection/falls would it know or protect you?

To date there does not appear to be a TAM or tool that can effectively capture exoskeleton or robotic assistive device acceptance and use, studies such as the one discussed in this paper, could provide the basis for such a tool.

5.1. Research limitations

This paper discusses preliminary findings from a cross section of eight participants involved in a larger study that involved twenty-four older adult participants. Due to the rigour of the process and time constraints, a cross section of the study was analysed to highlight the insights and experiences shared during the interview sessions. In addition, it can be a caution to interview two people together in a conjoint interview setting. There is a risk that one participant may feel less inclined to openly be expressive and commit commentary to the session. However, it can also be an empowering and rich experience where stories can have heightened perspectives shared and discussed collectively.

It was acknowledged that despite the older adult participants being independent, and living in their own homes in the community, that in some instances, 'gatekeepers', i.e. family members may be aware of the research and visits to homes of participants. It was envisaged that should this present as a problem, that there would be an openness and an effort to build trust between the gatekeeper and researcher. During the study, an episode was encountered where the daughter of one of the participants spoke on the phone to enquire more about what would happen during the session. The participant in question lived with her daughter, and family. It was important that everyone was comfortable in this scenario, and the researcher successfully overcame this challenge by building rapport with the daughter and inviting the daughter to feel free to sit in on the session if participant was happy with this. The session was conducted comfortably for all.

6. Conclusions

This study was an endeavour that facilitated freefall contextual enquiry by the researcher with older adult participants. The accommodation and openness shared by the participants revealed intimate share of the world through their eyes. In addition, opportunity presented to see and engage with devices typically associated with ageing, and support by assistive devices, i.e. walking sticks, stair lifts and sleep apnoea mask. These devices have become part of day to day life for some of the participants. Insights such as, the participant with sleep apnoea having to ensure the device is packed as part of holiday luggage to ensure a pleasant and healthy holiday. The methods presented here display rigour and application of work collected and gathered out in the field and driven by real commentary and perceptions by the older adult participants. Older adults have a tacit understanding, and experience of life that is new – ageing happens only once - we are alive until we die. The older adult participants discussed, what can be conceived as 'sensitive' topics such as death, the loss of a partner, the feelings of being a burden. Tasks such as dressing or needing assistance were on occasion empowering but also acknowledged as an aspect of physical decline awareness. The recollection of one participant (aged 81) arriving to an interview carrying a 'dashcam' that they would fit themselves, highlights the embrace of technology, yet conversely another participant preferring the assistance of family, to new technology or technology tasks (i.e. updates on computers, shopping online). This diversity of technology adoption by the older adult participants endorses this study and the potential for support tools development that assist understanding to technology acceptance.

It is clear from the experiences shared by the older adult participants that there are many pleasures, and causes of frustration, or anxiety to the use and acceptance of technology as we age. Likewise, the presence and potential of robots and robotic assistive devices is an area yet to present measurement or acuity by older adults. As an emerging technology, there is a need to enquire and express further the needs requirements of the ageing population and the acceptance and use of these devices in day to day activities and tasks.

The findings of this study require further analysis and build to incorporate the findings of the remaining 16 participants insights. When this work is completed, it will be compared and contrasted separately and collectively to understand and define a hypothesis that directs the build potential of a Technology Acceptance Model that is not currently available, namely an evaluation tool to gauge technology acceptance by older adults to assistive robots, and specifically exoskeletons.

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Appendix 4

Codebook: 'Investigating perceptions to technology acceptance & stigma of wearable robotic assistive devices by older adults.'

4.1 Full Study Codes\\ Phase 1 Codes

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Accessibility - Airports	1	10
Accessibility - Bath	3	6
Accessibility - Bath - Removal	1	2
Accessibility - Bathroom	7	11
Accessibility - Cars	5	16
Accessibility – Computers & screens	6	8
Accessibility - Convenience	2	2
Accessibility - Curtains	1	2
Accessibility - Devices	4	8
Accessibility - Doors	6	13
Accessibility - Equipment	3	5
Accessibility - Footpaths	3	16
Accessibility - Furniture	4	17
Accessibility - Healthcare	1	1
Accessibility - Home	11	26
Accessibility - Hotels	3	4
Accessibility - Lifts	1	1
Accessibility - Packaging	1	4
Accessibility - Pin numbers	1	1
Accessibility - Plugs & Sockets	1	1
Accessibility - Public Spaces	4	23
Accessibility - Public transport	9	19
Accessibility - Screens	2	4
Accessibility - Seating	2	3
Accessibility - Shops	7	10
Accessibility - Signage/wayfinders	1	1

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Accessibility - Stairs	3	22
Accessibility - Trains	1	1
Accidents - Spouse	1	1
Accidents - Accessibility to patient	1	2
Accidents - Car	1	1
Accidents - Causes	3	8
Accidents - Electricity	1	1
Accidents - Home DIY	1	2
Accidents - reminiscence	1	1
Adaptation - ADLs	1	2
Adaptation - Bathroom	1	4
Adaptation - Car	2	4
Adaptation - Furniture	1	2
Adaptation - Home	8	35
Adaptation - Home opt to downsize	1	6
ADLs - Active	4	9
ADLs - Assistance with	12	54
ADLs - Bathing & Showering	6	18
ADLs - Challenge	12	36
ADLs - Collecting	1	6
ADLs - Collecting - Emotion	1	4
ADLs - Collecting - Gathering dust	1	1
ADLs - Cooking	5	9
ADLs - Dancing	7	13
ADLs - Diet & Nutrition	2	5
ADLs - Dressing	13	42

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
appendiADLs - Dressing - Behaviour	2	8
ADLs - Eating	3	4
ADLs - Eating food preference	1	1
ADLs - Exercise	6	8
ADLs - Falling	3	10
ADLs - Gardening	5	13
ADLs - Hobbies	6	10
ADLs - Holidays	9	47
ADLs - Keeping pets	5	24
ADLs - Motivation	2	2
ADLs - Music listening	2	3
ADLs - Pubs	3	10
ADLs - Reading	4	15
ADLs - Receiving gifts	1	1
ADLs - Routines	8	19
ADLs - Social - MEN	1	1
ADLs - Social - Clubs	6	8
ADLs - Social activities	11	17
ADLs - Social outings	6	13
ADLs - Sports Playing	1	10
ADLs - Sports watching	1	10
ADLs - Swimming	1	1
ADLs - Task planning	7	16
ADLs - Television	7	16
ADLs - Television - Preferences	2	12
ADLs - Toileting	10	14
ADLs - Toileting - Incontinence	1	1

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
ADLs - Toileting 2	2	3
ADLs - Vacuuming	2	8
ADLs - Writing	1	1
ADLs and glasses	1	2
Ageing	3	14
Ageing - 'Granny'	4	8
Ageing - Adaptability	4	9
Ageing - Agility	5	12
Ageing - Alone	2	6
Ageing - Anxiety	6	7
Ageing - Appearance	3	8
Ageing - Being careful	4	9
Ageing - being ill	3	3
Ageing - Birthdays	2	2
Ageing - Content	3	6
Ageing - Driving	1	2
Ageing - Empty nesters	1	1
Ageing - Energy levels	6	8
Ageing - Family	4	8
Ageing - Feel young	3	5
Ageing - Feeling exhausted	2	2
Ageing - Feeling the cold	4	7
Ageing - Femininity	5	6
Ageing - Financial Abuse	1	1
Ageing - Good health	1	1
Ageing - Home	1	10
Ageing - Humour	2	3

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Ageing - In place	6	18
Ageing - Intergenerational	4	7
Ageing - Learning	2	5
Ageing - Lonely	3	6
Ageing - Longevity	4	12
Ageing - Manual tasks	1	1
Ageing - Meeting people	3	7
Ageing - Mental changes	1	8
Ageing - Mortality	8	10
Ageing - new adventures	3	3
Ageing - Not getting younger	2	3
Ageing - Nursing Home	2	4
Ageing - Optimism	3	4
Ageing - Physical changes	12	39
Ageing - Policy	1	2
Ageing - preferences	6	9
Ageing - Recovery	1	1
Ageing - Reminiscence	10	27
Ageing - Robots	3	6
Ageing - Seating	2	7
Ageing - Slowing down	4	12
Ageing - Sports Younger	2	5
Ageing - Take care of yourself	1	1
Ageing - Tasks	3	5
Ageing - Vulnerable	1	2
Ageing - Younger generation	2	7
Ageing stigma	2	3

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Assistance	3	4
Assistance - Concentration	1	1
Assistance - No choice	2	2
Assistance - Robots V People	3	3
Assisting people	14	41
Assisting with tasks - Family	7	16
Assistive device - Dependence on	6	9
Assistive device - Phone	1	1
Assistive device - Shopping for	3	9
Assistive devices - ADLs	8	24
Assistive Devices - Autonomy	3	3
Assistive Devices - Benefits	4	8
Assistive Devices - Charging	1	1
Assistive Devices - Charging remembering	1	1
Assistive devices - Dislike	2	3
Assistive Devices - Eating	1	2
Assistive devices - Grants	2	6
Assistive devices - Independence	5	5
Assistive Devices - Inherited	1	1
Assistive devices - Interactions	2	2
Assistive Devices - Learnability	2	5
Assistive devices - Learning aids	3	3
Assistive Devices - Life Cycle	2	4
Assistive Devices - Night time	1	1
Assistive devices - No experience	3	4
Assistive Devices - Perceptions	1	1
Assistive devices - Placement	2	3

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Assistive Devices - Preferences	6	9
Assistive Devices - Reluctance	1	2
Assistive devices - Seat rails etc.	3	18
Assistive Devices - Shower	2	2
Assistive Devices - Temporary	1	4
Assistive Devices - Toilet	1	1
Assistive devices - Trust	2	3
Assistive devices - User adaptations	5	13
Assistive Devices - Wearable	1	3
AT - Reluctance family	1	4
AT - Using or helping someone with	3	6
AT trust	1	2
Banking	2	6
Banking - Accounting	1	4
Banking - ATM	5	13
Banking - Barriers online	3	5
Banking - Behaviour	3	5
Banking - Branch	7	11
Banking - Branch - Accessibility	1	1
Banking - Branch - Automation	3	5
Banking - Card transactions	1	1
Banking - Cards	3	6
Banking - Change	3	7
Banking - Cheques	2	2
Banking - Concerns	1	6
Banking - Direct debits	2	2

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Banking - Easier	1	1
Banking - Family Assistance	2	5
Banking - Interactive	3	3
Banking - Learnability	1	1
Banking - Money Orders	1	1
Banking - NO Card Transactions	1	1
Banking - Online	7	14
Banking - P to P	4	9
Banking - Pin numbers	3	5
Banking - Pleasure	1	2
Banking - Post Office	3	5
Banking - Reminiscence	2	2
Banking - Secure	1	2
Banking - Transfers	1	1
Banking - Trust	6	13
Banking - Usability	6	10
Bathroom	1	2
Battery or Charging	1	1
Being assisted	7	16
Being assisted - Airports	1	2
Being assisted - Anxiety	1	1
Being assisted - Ask more than once	2	3
Being assisted - Benefits	3	5
Being assisted – Couldn't manage without	1	1
Being assisted - Demoralising	1	1
Being assisted - Embarrassment	4	7

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Being Assisted - Family	5	14
Being Assisted - Get used to it	1	1
Being assisted - Happy to ask	8	14
Being Assisted - Hard to accept	2	4
Being Assisted - Hard to ask	1	1
Being Assisted - Holidays	1	1
Being assisted - Home Help	5	13
Being assisted - inconvenience to others	5	10
Being assisted - No attention needed	1	1
Being Assisted - Not wanted	2	3
Being Assisted - Offer of help	2	2
Being Assisted - People v Robots	2	4
Being assisted - Permissions	3	3
Being assisted - Reliance	1	1
Being Assisted - Reluctance	2	2
Being assisted - Robots	13	30
Being Assisted - Shower	1	3
Being Assisted - Thankful	3	4
Being Assisted - Time	1	4
Being assisted - Toileting	3	5
Being assisted - Transport	2	4
Being assisted - Trust	2	2
Being Assisted - Wheelchair	4	5
Broken Bones	2	3
Business - Innovation and change	1	4
Business - Mentoring	1	1

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Business - Operations	1	7
Business - Strategy planning SE	1	11
Buttons - Difficulty with	2	2
Buttons - Ok with	2	2
Car - Adapted	3	8
Car - Automatic	2	2
Car - Autonomous - Perceptions	2	5
Car - Autonomous Robots	2	4
Car - Autonomous TRUST	1	3
Car - Autonomous UE	1	6
Car - Driving	3	3
Car - Ownership	2	2
Car - Parking	2	7
Car - Speed	1	1
Car - Storage	1	1
Car - User control	1	1
Car Park machines	1	3
Car parking - Accessible	1	3
Car parking - App	1	2
Career	13	51
Career - Direction change	4	11
Career - Efficiencies	1	3
Career - Expectations of you	1	3
Career - Illness	1	2
Career - Learning courses	3	4
Career - Money	1	1
Career - Pressure	1	2

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Career - Redundancy	1	1
Career - Reminiscence	3	8
Career - Systems	1	3
Career - Younger colleagues	1	2
Children - Discipline	1	1
Children - Educating	1	7
Children - Play	2	2
Clothing - Abandonment	4	7
Clothing - AD	2	3
Clothing - Age	12	32
Clothing - Age - Choice	1	1
Clothing - Allergies	1	1
Clothing - Body image	1	1
Clothing - Buckles zips	2	3
Clothing - Colour	1	7
Clothing - Colour - Age	7	9
Clothing - Colour - Body form	1	1
Clothing - Colour - Female	12	23
Clothing - Colour - Male	9	30
Clothing - Colour - Mood	1	5
Clothing - Colours - Disliked	1	1
Clothing - Comfort	15	27
Clothing - Conservative	2	3
Clothing - Convenience	4	6
Clothing - Creasing	1	1
Clothing - Death	1	2
Clothing - Discomfort	5	11

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Clothing - Dislikes	3	4
Clothing - Donning - Doffing	11	38
Clothing - Fabric types	2	4
Clothing - Fashionable	6	11
Clothing - Flamboyant	1	5
Clothing - Flight socks	1	1
Clothing - Footwear	18	80
Clothing - Footwear - Support	4	14
Clothing - Footwear - Wide foot	1	10
Clothing - Formal	1	1
Clothing - Formal - Female	6	10
Clothing - Formal - Male	3	6
Clothing - Habits	2	2
Clothing - Influenced	3	5
Clothing - Inter spouse	4	11
Clothing - Jackets Coats	4	5
Clothing - Jumpers	2	2
Clothing - Maintenance	1	1
Clothing - Medical health	5	15
Clothing - Morning Dressing	1	2
Clothing - Online shop	1	2
Clothing - Others opinions	5	9
Clothing - Passion	1	1
Clothing - Personal Shopper	1	5
Clothing - Pockets	2	5
Clothing - Preferences	15	40
Clothing - Price	3	5

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Clothing - Seasonal	14	29
Clothing - Shirts	2	3
Clothing - Shop alone	7	11
Clothing - Shop experience	11	32
Clothing - Shop with Spouse	2	4
Clothing - Shopping for	5	6
Clothing - Shopping trips	3	3
Clothing - Sizing	10	15
Clothing - Skirts or dresses	5	5
Clothing - Sock issues	11	21
Clothing - Sock Types Female	13	36
Clothing - Sock types Male	6	16
Clothing - Specialist	5	9
Clothing - Sports	1	2
Clothing - Static cling	1	2
Clothing - Stylish	4	12
Clothing - Tags irritation	1	2
Clothing - Tops - Female	3	5
Clothing - Trousers	3	9
Clothing - Trousers - Female	11	22
Clothing - Trousers - Male	2	3
Clothing - Trust	3	3
Clothing - Underwear - Female	7	24
Clothing - Underwear - male	1	1
Clothing - User suggestions	2	2
Clothing - Value	2	2
Clothing - Value Opinion	1	3

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Clothing - Value opinion - NO	1	1
Clothing - Velcro	3	3
Clothing - Warmer	6	8
Clothing - Wearability Female	6	13
Clothing - Wearability male	4	5
Clothing - Workwear	2	5
Clothing - Younger	3	5
Clothing - Zippers	1	3
Clothing -Zippers	1	1
Clothing options - Female	4	8
Clothing options - Male	2	4
Clothing options - Size	1	2
Cloud management	1	3
Community - Fitting in	1	3
Community - Neighbours	2	2
Compression stocking- AD	1	6
Compression stocking - Assisted	2	2
Compression stocking - Discomfort	2	2
Compression stocking - Donn Doff	4	12
Compression stocking - Duration	2	5
Compression stocking - Fit	2	4
Compression stocking - Learnability	1	2
Compression stocking - Wearability	4	13
Computer - Sole in group	1	2
Computer - Abandonment	2	2

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Computer - Anxiety	2	5
Computer - Break it	2	3
Computer - Child Friendly	1	5
Computer - Classes	8	14
Computer - Classes - Dissatisfaction	1	3
Computer - Classes - Trust tutors	1	1
Computer - Cost	1	1
Computer – Don't know what you're doing	1	3
Computer – Don't understand them	1	1
Computer - Laptop	5	7
Computer - Lazy	1	1
Computer - Learnability	6	14
Computer - Life ownership	1	2
Computer - Literate	7	9
Computer - Need to know basis	1	1
Computer - No experience	4	6
Computer - Ownership	7	8
Computer - Ownership NO	1	1
Computer - Personal	2	4
Computer - Preferences	3	5
Computer - PU	1	1
Computer - Trust	3	5
Computer - Up to date	1	1
Computer - Usability	7	10
Computer - Use	1	1
Computer tablet	7	11

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Computer tablet - Anxiety	3	4
Computer tablet - Apps	2	9
Computer tablet - Emotional connection	1	1
Computer tablet - ENJ	2	4
Computer tablet - EOU	2	7
Computer tablet - Flexibility	2	3
Computer tablet - Gift	3	3
Computer tablet - Holidays	1	1
Computer tablet - Learnability	4	11
Computer tablet - LPs to stream	1	7
Computer tablet - motivation to learn	2	2
Computer tablet - Music	1	7
Computer Tablet - out and about	1	1
Computer tablet - Preference	3	5
Computer tablet - Screens	2	2
Computer tablet - Transportability	1	1
Computer tablet - Usability	3	16
Computer tablet V PC	3	5
Computer tablet V Phone	2	2
Computer tablets - Error messages	1	1
Computer- Workplace	1	1
Conversations	2	4
Conversations - Avoided	1	1
Cooking - By others	1	1
Cooking - Doesn't Male	1	1

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Cooking - self	1	1
Creating - Education aids	1	2
Crutches	5	18
Crutches - Awkward	3	5
Crutches - Learnability	1	7
Crutches - length of use	1	2
Crutches - Rubber feet	1	2
Crutches - Safety trust	1	4
Crutches - Tasks hands	1	2
Crutches - Usability	1	1
Death	4	9
Death - Anxiety	2	4
Death - Attend funerals	1	1
Death - Causes	3	3
Death - Children	1	5
Death - Coping	5	20
Death - Cremation	1	1
Death - Euthanasia	1	3
Death - Family Discuss	3	5
Death - Friends	1	3
Death - Funeral planning	2	2
Death - Grief	1	2
Death - leave body to science	1	3
Death - new learning post partner	3	5
Death - People	1	1
Death - Self	2	2
Death - Spouse	8	22

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Dependence	6	13
Dependence - Computers learnability	1	1
Dependence - Dressing	1	1
Dependence - Financial Abuse	1	1
Dependence - Mobility	5	9
Driving - AD	3	6
Driving - Anxiety	3	3
Driving - Behaviour	2	4
Driving - Distance	1	3
Driving - Future Options	2	5
Driving - Journey planning	2	4
Driving - Learning	1	5
Driving - Limitations	8	17
Driving - Motorway	2	7
Driving - Night time	4	7
Driving - Restrictions	5	9
Driving - Speed	1	2
Driving - Unlicensed	1	1
Falling	9	14
Falling - Causes	9	26
Falling - Communication	6	16
Falling - Fear	4	6
Falling - Frequency	1	3
Falling - Fright	1	1
Falling - Help	4	11
Falling - Injuries	5	15
Falling - Medical help	3	7

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Falling - Prevention	1	1
Falling - Shock	1	3
Falling - Shower	1	1
Falling - Stairs	2	4
Falling - UX suggestion	3	5
Family	4	7
Family - Being a burden	1	2
Family - Belief in participants	1	5
Family - Carers	6	11
Family - Children	11	70
Family - Children - Disability	1	5
Family - Children - Illness	1	7
Family - Computers	4	11
Family - Conversations	5	5
Family - Coping crisis	1	3
Family - Criticism	2	3
Family - Dependence on	7	17
Family - Dependent on participant	2	3
Family - Distance miles	6	9
Family - Expectations	1	1
Family - Fall-outs	1	1
Family - Financial Abuse	1	1
Family - Focused	1	1
Family - Giving	2	4
Family - Grandchildren	4	10
Family - Hand me downs	2	3
Family - Infantilising	5	15

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Family - Interactions	13	59
Family - Live close by	6	12
Family - Living with	3	9
Family - Odd	1	1
Family - Parenting	2	5
Family - Parents	4	18
Family - Pets	1	1
Family - Reassure	1	1
Family - Recommendations	1	3
Family - Sacrifices	2	4
Family - Siblings	7	29
Family - Size	3	7
Family - Spouse	6	11
Family - Storytelling	2	11
Family - Support	9	41
Family - their criticism	2	2
Family - Trust	5	7
Family - Worried about	1	4
Family - Worry about participant	1	1
Feeling - A burden	5	5
Feeling - Acceptance	6	8
Feeling - Amazed	1	1
Feeling - Annoyed	4	8
Feeling - Anticipation	1	3
Feeling - Anxious	6	6
Feeling - Apologetic	1	1
Feeling - Bad	1	1

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Feeling - bored	1	1
Feeling - Cared about	2	6
Feeling - Caring	1	1
Feeling - Challenged	3	4
Feeling - Cold	4	6
Feeling - Considerate	1	1
Feeling - Delighted	1	2
Feeling - Depressed	1	1
Feeling - Determined	1	1
Feeling - Disapproval	2	3
Feeling - Embarrassed	2	2
Feeling - Empathic	3	5
Feeling - Empowered	1	2
Feeling - Energised	1	3
Feeling - Excited	1	1
Feeling - Exclusion	1	2
Feeling - Fear	6	8
Feeling - Fine	1	1
Feeling - Fright	2	2
Feeling - Frustrated	1	1
Feeling - Fulfilled	1	1
Feeling - Fuming	1	1
Feeling - Gentle	1	1
Feeling - Grand	1	1
Feeling - Grateful	5	7
Feeling - Great	1	1
Feeling - Happy	1	1

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Feeling - Helpful	3	5
Feeling - Hopeful	2	2
Feeling - Humour	2	2
Feeling - In the way	1	1
Feeling - Independent	2	5
Feeling - Intimidated	1	1
Feeling - Jumpy	1	1
Feeling - Kind	1	2
Feeling - Less able	2	2
Feeling - Lonely	2	2
Feeling - Loss	1	1
Feeling - Lost	2	3
Feeling - Loved	1	1
Feeling - Lucky	2	7
Feeling - might as well be dead	1	1
Feeling - Necessary	1	1
Feeling - Negative	1	1
Feeling - Nervous	1	1
Feeling - No energy	1	1
Feeling - No strength	1	1
Feeling - Not in charge	1	1
Feeling - Nuisance	4	6
Feeling - Optimistic	1	1
Feeling - Pissed off	1	1
Feeling - Pleased	2	6
Feeling - Positive	2	2
Feeling - Pro active	1	2

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Feeling - Reassured	2	2
Feeling - Reflective	4	9
Feeling - Reluctant	1	1
Feeling - Resilience	4	11
Feeling - Resourceful	1	2
Feeling - Responsible	1	1
Feeling - Restricted	1	1
Feeling - Sad	2	4
Feeling - Self conscious	2	2
Feeling - Self trust	1	1
Feeling - Selfish	1	1
Feeling - Spiritual	1	2
Feeling - Stress	1	1
Feeling - Thankful	1	1
Feeling - Tired	1	2
Feeling - Trust	1	1
Feeling - Unaware	1	1
Feeling - Uncomfortable	1	1
Feeling - Under obligation	1	1
Feeling - Understanding	1	2
Feeling - Unhappy	1	2
Feeling - Wonder	1	1
Feeling - Worried	5	5
Feeling - Young	1	1
Feeling unwell - Anxiety	1	1
Friendship	3	7
Friendship - Activities	2	4

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Friendship - Influences	1	4
Friendship - Peers	1	1
Friendship - Support	3	7
Glasses - Abandonment	2	3
Glasses - Ageing	3	4
Glasses - Anti glare	1	1
Glasses - Bi Vs Varifocal	3	4
Glasses - Bi- Focal	5	18
Glasses - Contact lenses	1	1
Glasses - Desirability	1	2
Glasses - Dislike	2	7
Glasses - Disposal	1	2
Glasses - Distance	2	5
Glasses - Driving	5	10
Glasses - Emotional attachment	2	3
Glasses - Expense	1	3
Glasses - Fashionable	6	17
Glasses - How many pairs	4	7
Glasses - Issues	1	3
Glasses - Lens	2	7
Glasses - Life stage	3	6
Glasses - Medical card	1	5
Glasses - Off the shelf	1	3
Glasses - Placement	1	2
Glasses - Prescription	2	6
Glasses - Reading	8	18
Glasses - Satisfaction	5	8

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Glasses - Satisfaction with glasses	1	1
Glasses - Sunglasses	2	7
Glasses - Sweat	1	1
Glasses - Television	4	5
Glasses - Trust v contacts	1	1
Glasses - Types	15	36
Glasses – Varifocal	2	4
Glasses - Wearability	12	45
Gym - Outdoors	1	2
Hair - Image	1	2
Hair - Loss	1	4
HC - Alzheimer’s - Memory	1	3
HC - Alzheimer’s - Nursing Home	1	1
HC - Alzheimer’s - Worries	1	3
HC - Alzheimer’s etc.	3	32
HC - Amputation	1	2
HC - Amputation - Leg	1	4
HC - Ankles	1	2
HC - Anxiety	1	1
HC - Arthritis	4	10
HC - Autism - Children	1	2
HC - Back	2	4
HC - Back - Broken	1	1
HC - Back - Pain	1	2
HC - Balance - Hearing	1	3
HC - Bladder	1	1
HC - Bladder - Incontinence	1	1

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
HC - Blood pressure	2	4
HC - Cancer	3	7
HC - Cancer - Diagnosis	2	4
HC - Cancer - Mortality	1	1
HC - Carpal Tunnel Syndrome	1	1
HC - Cholesterol	1	2
HC - Clotting	1	2
HC - Colostomy	1	3
HC - Diabetes	1	1
HC - Dressings	1	1
HC - Drop foot	1	2
HC - DVT	1	1
HC - Eyes	3	4
HC - Eyes - Cataract	2	6
HC - Eyes - Cataract repair	1	1
HC - Eyes - Glaucoma	1	7
HC - Feet	4	14
HC - Feet - Footwear	1	2
HC - Feet - Ligaments	1	1
HC - Feet - Swell	1	3
HC - Feet - Wobbly	2	4
HC - Fingers - Arthritis	1	2
HC - Fingers - Difficulty	2	2
HC - Fingers - Pain	1	3
HC - Gallstones	1	4
HC - Hands - AD	1	5
HC - Hands - arthritis	2	2

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
HC - Hands - grip	1	5
HC - Hands - Wrist	1	4
HC - Head Injury	1	5
HC - Healing	1	2
HC - Heart	3	8
HC - Heart - Angina	1	1
HC - Heart - Hole	1	2
HC - Hereditary conditions	1	1
HC - Hip Replacement	1	6
HC - Hips	3	15
HC - Hysterectomy	1	1
HC - Infection	1	3
HC - Insomnia	1	1
HC - Legs	2	2
HC - Legs - Broken	2	4
HC - Legs - Knees	2	4
HC - Legs - Ligaments	1	1
HC - Legs - Muscles	1	1
HC - Legs - Pain	1	1
HC - Legs - Shorter	1	1
HC - Legs - Weak	3	3
HC - Medication	8	25
HC - Medication - Sleep	1	1
HC - Mental Health	1	2
HC - Muscular Dystrophy	1	2
HC - OT	2	4
HC - Parkinson’s	3	11

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
HC - Parkinson's - Accepting	2	4
HC - Parkinson's - Tremors	1	7
HC - PBC	1	11
HC - Peg Feed - Food transition	1	2
HC - Peg Feed - miss food	1	5
HC - Peg Feeding	1	14
HC - Pelvis - Broken	1	1
HC - Physiotherapy	4	9
HC - Pneumonia	1	1
HC - Posture	1	3
HC - Progressive	1	1
HC - Prostrate	1	3
HC - Shoulders - W&T	1	2
HC - Skin Graft	1	1
HC - Sleep Apnea	1	8
HC - Sleep Apnea - Device	1	12
HC - Stitches	1	1
HC - Stroke	3	6
HC - Stroke - Frustration	1	1
HC - Stroke - Joints	1	1
HC - Stroke - Memory	1	3
HC - Stroke - Multiple	3	5
HC - Stroke - QOL	1	1
HC - Stroke - Rehabilitation	1	1
HC - Stroke - Slow	1	1
HC - Stroke - Taking your time	1	1
HC - Stroke Post changes	1	23

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
HC - Surgery	4	6
HC - Tinnitus	1	4
HC - Ulcers	1	4
HC - Varicose veins	2	3
HC - Weight - Female	1	2
HC - Weight - Male	1	1
HC - Wound	1	2
Healthcare - Gender Doc preference	1	1
Healthcare - Professional communication	4	9
Healthcare Pro - Home Visits	1	3
Healthcare professional - Trust	3	6
Hearing	3	3
Hearing - Ageing	2	3
Hearing - Loss	5	11
Hearing - Loss - affecting others	4	9
Hearing - Loss - Denial Self	2	2
Hearing - Loss - noticed others	2	3
Hearing - Loss - TV	2	7
Hearing - Muffled	2	2
Hearing - Protective aids	1	1
Hearing - Test	1	1
Hearing - Test - Aids	1	1
Hearing aids	8	11
Hearing aids - Abandonment	7	17
Hearing aids - Aesthetics	2	3
Hearing aids - Amplification	1	3

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Hearing aids - Balance	1	3
Hearing aids - Benefits	1	1
Hearing aids - Bloody nuisance	3	3
Hearing aids - Both ears	1	2
Hearing aids - Cost	4	7
Hearing aids - Dissatisfaction	6	27
Hearing aids - Distorted sound	3	7
Hearing aids - Get used to issues	1	2
Hearing aids - Grant	3	8
Hearing aids - Hair washing	1	2
Hearing aids - Hairdressers	1	1
Hearing aids - Layers of talking	5	18
Hearing aids - Life of	3	4
Hearing aids - make no difference	2	2
Hearing aids - Marketing	1	1
Hearing aids - Microphone	1	2
Hearing aids - Older people	1	1
Hearing aids - Over the ear	6	7
Hearing aids - Perceptions	1	4
Hearing aids - Phone	4	8
Hearing aids - Satisfaction	4	4
Hearing aids - Saving for	1	1
Hearing aids - Service system	4	12
Hearing aids - Sharp sounds	3	8
Hearing aids - Shower or bathing	1	1
Hearing aids - Sweat	1	3
Hearing aids - Tailoring	2	8

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Hearing aids - Tele - Headphones	1	7
Hearing aids - Television	4	16
Hearing aids - They don’t work	3	3
Hearing aids - Tinnitus	1	5
Hearing aids - U B	1	4
Hearing aids - UE	3	5
Hearing aids - Uncomfortable	1	1
Hearing aids - Usability	1	1
Hearing aids - Value for money	2	4
Hearing aids - Wearability	8	39
Hearing aids - Whistling	2	6
Hearing aids with glasses	4	10
Home - 'stuff'	1	1
Home - Appliances and devices	3	5
Home - Bed	1	2
Home - Bungalow	2	3
Home - Cleaning - Tasks	2	4
Home - DIY	3	3
Home - Downsizing	1	4
Home - Environment and area	2	17
Home - Fire	1	4
Home - Fireplace	1	2
Home - Maintenance	2	2
Home - Safety	1	3
Home - Security	3	6
Home - Sense of	3	8
Home - Sound	1	2

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Home - Stairs	2	2
Home - Visitors	3	7
Home help - Dependence	2	4
Home help - Don’t qualify	1	1
Home Help - Interference	1	1
Home Help - Private	2	3
Home help - State	1	1
Home help - Tasks	2	3
Home help - Trust	3	4
Home ownership	1	1
Hospital - 'Good' patient	2	3
Hospital - Appointments	3	4
Hospital - Assistive devices	3	6
Hospital - Busy	1	1
Hospital - Communication	2	3
Hospital - Embarrassment	2	3
Hospital - Falling	2	9
Hospital - Home recovery	3	3
Hospital - Needing assistance	2	2
Hospital - Patient gender	1	1
Hospital - Recovery	5	15
Hospital - Staff	2	5
Hospital - Stay	8	21
Hospital - Stay - Children	1	9
Hospital - Surgery	1	1
Hospital - Surgery - Children	1	2
Hospital - Worries	1	3

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Hospital - X-Ray	1	1
Independence	8	13
Independence - Dressing	1	2
Independence - Hate to lose	1	1
Independence - loss of	3	5
Independence - Resilience	3	7
Independence - Shopping	1	1
Internet	5	5
Internet - Browsing	6	16
Internet - Browsing to fix things	1	2
Internet - Calling	3	8
Internet - Connectivity	2	2
Internet - Dongle	1	2
Internet - Downloading	1	4
Internet - Email	4	4
Internet - Enjoyment	3	4
Internet - Good Service	1	2
Internet - Helpful	1	1
Internet - Inconvenience	1	4
Internet - Learnability	1	4
Internet - Perceptions	1	2
Internet - Poor service	1	6
Internet - Skype	3	11
Internet - Social media	6	18
Internet - Social media - Disapproval	2	8
Internet - Streaming	1	1
Interview - Observations	5	7

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Interview - Rapport	9	25
Keeping up with technology	3	4
Learning - Ageing	6	8
Learning - Fear	2	2
Learning - Forgetting skills	2	3
Learning - Frustrated	1	1
Learning - Maintaining competencies	1	7
Learning - Motivators	2	4
Learning - New glasses	1	2
Learning - New skills	4	11
Learning - One to one	2	2
Learning - Persistence	2	3
Learning - Pressure	1	2
Learning - Prompts	1	1
Learning - Support	1	2
Learning - Technology	7	16
Learning - Technology - Fear	1	1
Learning - Technology - no self-belief to learn	2	3
Learning - Visual aids	1	1
Learning - Younger self	2	6
Learning tech - Collaborating	1	1
Learning tech - Family	4	11
Learning tech - from friend	2	2
Learning tech - Motivators	1	2
Learning tech - present and younger	2	2
Learning tech - Too old to learn	1	1

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Life - Experience	3	8
Life - Today Present	1	3
Life Stage - Adaptations	1	1
Life stage - home	2	3
Life Stage - Marriage	4	11
Life Stage - Marriage breakdown	1	2
Life Stage - meeting someone	2	2
Life stage - Planning	4	6
Life Stage - Pregnancy	1	2
Life Stage - Retirement	8	21
Life Stage - Retirement - Choice	1	6
Life stage - Retirement - Relocating	1	2
Life Stage - Seasonal	1	1
Life stage - Teaching	1	1
Life stage - Widowhood	5	12
Life stage - Younger experience	3	14
Lifestyle - Volunteer	4	13
Lifestyle - Volunteer - Motivators	1	1
Living - Alone	9	19
Living - Alone - Falls	1	8
Living - Alone - Lonely	2	4
Living - Alone - Weather	1	1
Living - Alone - Worry	1	2
Living - temp apart from spouse	1	2
Making things	1	2
Medical appts - Pretence	1	1
Memory - Remember pin	1	1

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
numbers		
Mindfulness	1	2
Mobile phone - Accessibility	2	6
Mobile phone - Anxiety	2	3
Mobile phone - Bad manners	2	3
Mobile Phone - Benefits	2	3
Mobile phone - Buttons small	2	2
Mobile Phone - Calls	1	2
Mobile Phone - Charging	1	1
Mobile Phone - Classes	2	7
Mobile phone - Embarrassment	1	1
Mobile phone - Experience	6	8
Mobile phone - Hotspot	1	1
Mobile Phone - Interactive	1	2
Mobile phone - Learnability	2	6
Mobile phone - Leave without	1	4
Mobile phone - Necessary evil	3	3
Mobile phone - No interest	3	3
Mobile phone - Ordinary	6	9
Mobile phone - Ownership	8	9
Mobile Phone - Reassuring	2	4
Mobile Phone - Ringtone	2	2
Mobile Phone - Smart	10	13
Mobile Phone - Talk only	1	1
Mobile Phone - Trust	2	3
Mobile phone - Usability	8	17
Mobile phone - Vibrate	1	2

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Mobility - Difficulty	11	47
Mobility - Incapacitated	2	3
Mobility - Independence	4	6
Mobility - Reduced	14	37
Mobility - Reduced - Acceptance	1	2
Mobility - Reduced - Financial Burden	1	1
Mobility - Reduced - Hide it	1	1
Mobility - Reduced - Optimism	1	1
Mobility - Reduced - Shattering blow	1	1
Mobility Scooter	2	6
Mobility Scooter - PU	5	8
Mobility Scooter - Rental	1	1
Mobility Scooter - Robotic	1	1
Mobility scooter - Styling	1	1
Money - Amount of	2	4
Money - Anxiety	1	2
Money - At Home Saving	1	2
Money - Budgeting	5	11
Money - Cash is King	1	2
Money - Home Safe	1	6
Money - Spending	2	3
Nursing home	3	5
Nursing home - Care	2	4
Nursing Home - Home	3	5
Nursing Home - Institutionalised	1	4
Nursing home - Making friends	1	1

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Nursing Home - Need	1	2
Nursing Home - Oblivious	2	2
Nursing Home - Perceptions	2	3
Nursing Home - Reluctance	2	2
Nursing Home - Service System	1	1
Nursing Home - Spouse	1	1
Nursing Home - Visit	1	3
People - Collaborating	2	2
People - Community - Neighbours	6	14
People - Conversations	2	5
People - Disabilities	1	5
People - Influences	1	1
People - Interactions	10	21
People - Men & Women	1	1
People - Perceptions of participant	5	17
People - To visit	1	2
People - Trust	2	5
Personal - Autonomy	1	3
Personal - Resilience	4	8
Personal alarm	6	8
Personal alarm - Abandonment	3	6
Personal alarm - Accidental trigger	3	6
Personal Alarm - Activate	1	1
Personal alarm - Can't be bothered	1	1
Personal alarm - Disturbing	2	2

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
people		
Personal alarm - Feel like in prison	1	1
Personal Alarm - Forget to use	1	2
Personal alarm - Independence	1	1
Personal Alarm - Influenced use	1	2
Personal alarm - Pendant	4	7
Personal alarm - Placement	3	4
Personal Alarm - PU	1	2
Personal alarm - Reluctance	3	6
Personal alarm - Service system	4	6
Personal alarm - Wearability	5	10
Personal alarm - Worry	1	1
Personal alarm - Wrist	3	4
Personal alarm- Stigma	3	6
Photography	1	1
Physical ability	3	5
Physical Ability - stuck	2	3
Physical Decline - Denial	1	1
Physical Decline - Stephen Hawking	1	1
Physical decline awareness	10	18
Products & Tech	1	8
Products & Tech - Emotion	1	4
Products & Tech - Repurposing	1	3
Prosthesis	3	8
Prosthesis - Abandonment	1	2
Prosthesis - Orthotics	1	2

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Public Transport - Assistance	1	2
Public Transport - Available	3	4
Public Transport - Bus	3	3
Public Transport - Lack of	3	3
Public Transport - Options	3	4
Public transport - Taxis	1	4
QOL	4	5
QOL - Accessibility	4	11
QOL - Adaptability	3	5
QOL - Assistance	4	5
QOL - Convenience	1	7
QOL - Health	7	24
QOL - Limitations	5	15
QOL - Mobility challenge	7	17
QOL - Satisfaction	3	4
QOL - Technology	3	13
RADs - Acceptance	7	11
RADS - Adjustability	1	1
RADs - Anxiety	1	2
RADs - Assistive	5	12
RADs - Cost	2	2
RADS - Don't know	5	9
RADs - Embrace	4	4
RADs - Fear	4	7
RADs - Interactions	2	4
RADs - Learning	2	4
RADs - Mechanical machine	3	4

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
RADs - Mobility enhancement	4	6
RADs - Neural paths	2	8
RADs - Perceptions	15	39
RADs - Personalised. Tailored	2	4
RADs - Prosthesis	3	6
RADs - PU	8	11
RADs - Reluctance	2	4
RADs - Trust	5	10
RADs - User expectations	6	12
RADs - Wearable	3	4
RADs - Wonder	3	3
Robotic Trousers - Adaptability	2	2
Robotic Trousers - Body changes	1	1
Robotic Trousers - Concerns	2	16
Robotic Trousers - Embodied	3	3
Robotic Trousers - Enhance QOL	4	5
Robotic Trousers - Hard to imagine	2	4
Robotic trousers - Mechanical	2	3
Robotic Trousers - Monitoring	1	5
Robotic trousers - Perceptions male	8	23
Robotic trousers - Personalized tailored	2	11
Robotic Trousers - PU	1	7
Robotic trousers - Secondary Conditions	1	2
Robotic Trousers - Service System	2	4

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Robotic trousers - Stigma	3	4
Robotic Trousers - Tailored	2	5
Robotic Trousers - Trust	2	4
Robotic Trousers - Under clothes	2	4
Robotic Trousers - User expectations	4	23
Robots	3	5
Robots - acceptance	10	24
Robots - ADLs - NO	3	7
Robots - ADLs - YES	10	17
Robots - Anxiety	2	5
Robots - Barriers	2	2
Robots - Benefits	4	11
Robots - Commands Instructing	2	6
Robots - Companions	5	5
Robots - Control	3	7
Robots - Convenience	4	5
Robots - Cost	1	1
Robots - Embodied	1	1
Robots - Emotional connection	2	9
Robots - Humanoid	7	16
Robots - Learnability	1	1
Robots - Mechanical	3	3
Robots - Naming	1	3
Robots - Opinion of...	3	9
Robots - People focused	1	3
Robots - Perceived Limitations	1	4
Robots - Perceptions	15	38

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Robots - PU	9	17
Robots - Reliable	1	2
Robots – Re-programme	1	1
Robots - Servicing updating	1	2
Robots - Taking jobs	2	4
Robots - Trust	6	11
Robots - Understanding them	3	4
Robots - Upgrading	1	11
Robots - User Expectations	8	16
Robots - Verbal command	6	15
Security - Car	1	1
Security - Home	2	3
Security - Identity fraud	1	3
Security - Monies	1	2
Security - Personal	3	6
Security - Robot assistance	2	5
Self - 'Being me'	4	7
Self - Accepting Change	3	8
Self - Accepting Help	4	5
Self - Achievements	2	4
Self - Autonomy	4	5
Self - Belief	3	7
Self - Creativity	2	7
Self - Dislikes	1	3
Self - Doctor Trust	1	6
Self - Doctor visit	2	6
Self - Handedness	2	2

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Self - Identity	5	11
Self - Image	10	23
Self - Imposter syndrome	1	2
Self - Learning interest	1	4
Self - Overweight	1	1
Self - Private	1	1
Self - Religious	1	4
Self - Reminiscence	1	1
Self - Spiritual	3	3
Self - Superstitions	2	2
Self - Tacit know	1	1
Self - Taking things for granted	1	1
Self - Worries - Mental capacity	2	9
Self - Worries - Reduced mobility	1	2
Self - Worries - Unnecessary	1	1
Self - Younger	7	23
Self-Aware	6	8
Self-aware - Confidence	4	4
Self-Aware - Fears	3	4
Self-aware - Prevent accidents	1	3
Self-Aware - Self critical	9	18
Self-aware - Technology	1	1
Service Providers	1	4
Service System - Airport support	1	3
Service systems - Anxiety	1	3
Service systems - Barriers	2	5
Service Systems - Healthcare	4	4

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Service Systems - Medical Card	3	15
Service Systems - Online	4	5
Service systems - Options	3	3
Service systems - P to P	2	4
Service systems - Payments	1	1
Service Systems - Phone	2	2
Service Systems - Technology	1	1
Service systems - Transport	1	3
Shopping - Card purchases	2	3
Shopping - Cash preference	1	1
Shopping - Experience	3	4
Shopping - Footwear	2	8
Shopping - Online	4	7
Shopping - Online - not bothered	1	1
Shopping - Preferences	2	3
Shopping - Price	2	3
Shopping - Quality	1	2
Shopping - Sales assistant	1	1
Shopping - Store	1	3
Shopping - Travel Agent	3	10
Shopping - Trust	3	5
Sight - Deterioration	9	27
Sight - Fatigue	1	1
Sight - Fear of loss	1	1
Sight - Testing	6	7
Sight - Testing - Driving	1	1
Sight - testing - Improved	1	2

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Sight - Testing Frequency	6	6
Software - Achievement	1	6
Software - Apps	1	1
Software - competency - Good	2	7
Software - Frustration	1	2
Software - Learnability	3	25
Software - Memorability	1	1
Software - Support	2	15
Software - Up to date	2	2
Spouse	5	16
Spouse - ADL assisting	5	12
Spouse - Death	5	11
Spouse - Differences	1	2
Spouse - Influence	2	9
Spouse - Persona	2	3
Spouse - Separate Interests	1	2
Spouse - Togetherness	4	15
Spouse - worry	4	6
Spouse - Younger Self	2	13
Stair lift - Buying	2	10
Stair lift - Charging	1	1
Stair lift - Long finger	2	4
Stair lift - Noticed	2	6
Stair lift - Satisfaction	1	5
Stair lifts - fit to home	1	2
Stair lifts - Installation	1	6
Stigma - Ageist Self	9	17

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Stigma - Assistive rails or devices	4	7
Stigma - Assumptions	1	1
Stigma - Body	1	1
Stigma - Colour - Clothing	1	4
Stigma - Conforming	3	6
Stigma - Dependence	5	9
Stigma - embarrassment	8	12
Stigma - Familial	4	7
Stigma - Glasses	3	10
Stigma - Hearing aids	1	2
Stigma - Inconvenience to others	4	6
Stigma - Labels	9	21
Stigma - Medical Devices	1	2
Stigma - Pretence	1	1
Stigma - Self perception	12	26
Stigma - Societal	8	17
Stigma - Technology	6	11
Stigma - Too old	3	4
Tablet benefits v phone	1	1
Technology - Anxiety	6	11
Technology - Barriers	13	25
Technology - Benefits	2	7
Technology - Bluetooth	1	3
Technology - Charging it	1	3
Technology - Dislike	4	5
Technology - Downloading	1	1
Technology - Empowerment	2	5

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Technology - Enjoyment	1	2
Technology - Fear	4	6
Technology - Good competency	2	3
Technology - Inherited devices	1	1
Technology - Installation	1	1
Technology - Lazy	1	2
Technology - Learnability	13	24
Technology - Motivation	9	20
Technology - No interest	7	14
Technology - No trust	2	5
Technology - Pressure to learn	1	3
Technology - Screen size	1	1
Technology - Self-belief to learn	3	11
Technology - Support systems	1	1
Technology - Trust	2	2
Technology - Understanding	1	1
Technology - Usability	7	11
Technology - User expectations	3	3
Technology - Verbal command	2	3
Technology- Anxiety	1	1
Telephone - Anxiety	1	1
Telephone - Cost	2	3
Telephone - EOU	2	2
Telephone - Hearing	2	2
Telephone - Landline	6	11
Telephone - Landline & Mobile	2	3
Telephone - Landline v mobile	5	9

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Telephone - Mobile	6	8
Telephone - Placement	2	6
Telephone - Reassuring	1	2
Telephone - Skype	4	10
Telephone - Talking	6	12
Telephone - Usability	4	8
Telephone - Viber	1	1
Telephone - Voicemail	2	3
Texting	7	9
Texting - Abandonment	1	1
Texting - Anxiety	4	9
Texting - Frequency	1	2
Texting - Interactions	1	1
Texting - Learnability	3	5
Texting - not used	1	1
Texting - Predictive text	1	1
Texting - to wrong person	1	1
Too old to learn	1	4
Train - Cost	1	1
Train - Noise	1	2
Travel	4	8
Travel - Agent v Online	1	2
Travel - Agents	2	2
Travel - Book online	1	1
Travel - Events	1	8
Travel - Luggage	1	3
Travel - Mobility challenge	1	4

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Travel - Planning	1	4
Usability - Cons - Home equipment	1	1
UX - Ageing	3	5
UX - Airport	1	2
UX - Behaviour	2	3
UX - Being Assisted	1	1
UX - Career	1	2
UX - Childhood	2	3
UX - Clothing - Hold up stockings	1	1
UX - Colostomy	1	2
UX - Compression Stocking	1	2
UX - Computer tablet	1	1
UX - Crutches	2	3
UX - Doctor	1	1
UX - Donning tights	2	2
UX - Dressing	1	2
UX - Driving	1	5
UX - Glasses	3	4
UX - Golf - Reduced mobility	1	1
UX - Hearing	2	2
UX - Hearing aids	5	13
UX - Holidays	1	1
UX - Home	1	1
UX - Mobility assistance	1	7
UX - Personal Alarm	1	1
UX - Personal safety	1	1
UX - Pockets	1	1

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
UX - RADs	1	1
UX - Reminiscence - Pubs	1	1
UX - Robot upgrade	1	1
UX - Robotic Trousers SS	1	1
UX - Robots	1	2
UX - Screens Usability	1	1
UX - Shopping	1	5
UX - Stair lift	1	6
UX - Stairs	1	1
UX - Stroke Doctor	1	1
UX - Taxi	1	2
UX - Telephone	1	6
UX - Texting	1	1
UX - Toileting - Incontinence	1	1
UX - Train	1	3
UX - Travel Agents	1	1
UX - Walker	1	1
UX - Walking	2	3
UX - Wheelchair	5	18
UX - Wheelchair - Furniture	1	1
Walker or rollator	7	17
Walker or rollator - Child users	1	2
Walker or rollator - Convenience	2	9
Walker or Rollator - Nuisance	1	6
Walker or rollator - Satisfaction	1	2
Walker or Rollator - Trust	1	1
Walking	5	10

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Walking - Benefits	1	3
Walking - Challenge	6	21
Walking - Distance	4	8
Walking - Slowing down	4	6
Walking - Support	1	6
Walking - Surface type	1	3
Walking - Wobbly feet	2	4
Walking Stick - Favourite	1	1
Walking Stick - Hand loop	1	2
Walking stick V Crutch	1	3
Walking stick v Rollator - walker	1	2
Walking sticks	7	14

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Walking sticks - Handier	1	3
Walking sticks - I'd manage	1	2
Walking Sticks - Reassurance	1	5
Wheelchair	9	34
Wheelchair - Blue badge	1	1
Wheelchair - Borrow	1	2
Wheelchair - Child users	1	3
Wheelchair - Comfort	2	6
Wheelchair - Dependence	2	3
Wheelchair - Dislike	1	2
Wheelchair - Frequency of use	2	4
Wheelchair - Helping	8	16

Initial Exploratory Codes	Interviews Coded	Units of Meaning Coded
Wheelchair - Home adaptation	2	3
Wheelchair - Learnability	1	4
Wheelchair - Maneuverability	3	4
Wheelchair - Overweight	1	1
Wheelchair - reluctance to use	5	5
Wheelchair - Restrictions	7	21
Wheelchair - Satisfaction	2	5
Wheelchair - self drive	3	3
Wheelchair passed on	2	3
XXXX TOTALS	19	8208

4.2 Full Study Codes \\ Phase 2 Categories

Category name	Description	Interviews Coded	Units of Meaning Coded
Accessibility	how access experience was expressed though buildings, vehicles, devices, home and healthcare settings.	16	207
Accidents	Causes and types of accidents and people affected, spouse, family members, self.	6	16
Adaptation	How life, ageing and environments change and our adaptation ability to manage or cope with them.	11	55
ADLs	Day to day tasks activities and interactions with people. This category also documents the motivation and personal aspects of engaging daily.	19	512
Ageing	Experiences and perceptions of ageing, life stage events (empty nest) various moods and ability to remain independent (or not)	19	352
Assistance	Options of assistance that were discussed, robots included, considering ADLs (i.e. toileting) also discussed how family members play a part with task assistance.	16	63
Assistive Devices	How we use and apply learning of assistive devices and or technology - wearable, adaptation and perceptions of their use and place in our lives	16	151
AT	Physical capacity to use AT, likewise sentiment expressed towards the use of AT and stigma.	3	12
Banking	Service systems, use of ATMs pin numbers etc., and the in-bank experience discussed in addition to security and management of monies.	11	149
Being Assisted	Due to ageing or mobility or life, participants discussed how they felt and wanted from being assisted, be it from family, friends, members of the public or robots.	18	167
Car	Full experience of access to ownership of a car, including driving and parking experiences shared.	7	51
Career	Life stage progression in relation to career or operating a business, topics such as redundancy, stresses and systems discussed	14	115
Children	Experiences with children, all younger, and sometimes discussed in relation to work roles.	2	10
Clothing	Clothing choice, options such as colour and fit, and items such as zippers, tights, socks etc. discussed.	19	794
Clothing Options	Gender and size-based options and opinion on clothing.	6	14
Community	Experiences shared about being new and fitting into a community, and sense of neighbours/hood.	2	5
Compression Stocking	aspects of wearability, duration of wear, and fit as well as duration of wear discussed.	4	46
Computer	Literacy, learnability, usability as well as abandonment, ownership discussed. In addition, the experience of fear expressed, such as breaking it.	18	116
Computer Tablet	topics such as apps, screen size, discussed, learnability, and how computer tablets that participants owned were sometimes gifts received.	7	104
Conversations	interactions and conversations, places of ease expressed as well as topic avoided.	3	5

Category name	Description	Interviews Coded	Units of Meaning Coded
Cooking	Experience and motivation to cook, for self and others, including discussion topics around male cooking or not.	2	3
Crutches	modular aspects of crutches, such as the rubber feet, including also trust to use, and feeling and experience of use, impact on hands etc.	5	41
Death	as a major life/death event, this topic was discussed openly by most participants and covered aspects of grief, coping with bereavement of spouse. Euthanasia, cremation etc. were raised as items for discussion as well as anxiety about death.	13	91
Dependence	Dependence on others, devices finance, and about reliance on technology discussed here.	13	25
Driving	skill and behaviour of driving experiences as well as limitations, motorway, and night time driving experiences as ageing progresses	15	73
Falling	Injuries, the fright of falling, as well as prevention and causes of… parts of home such as the shower were also discussed in relation to falling.	12	113
Family	the family network is discussed, as well as the functional and sometimes dysfunctional aspects of being in a family.	18	420
Feeling	the numerous expressions and emotions of feelings that were shared by the participants	18	215
Friendship	Relationships with friends and the influence of friendships as well as peers' views.	7	23
Glasses	Service systems to purchase glasses as well as types of glasses, satisfaction with them and how they interfere or not with day to day living.	18	245
Hair	Hair was discussed in relation to hair loss and image, stigma?	2	6
Health Conditions	conditions of health were discussed and expressed from all participants generally about self-conditions but sometimes in relation to family or friends. In addition, weight, broken bones and mental health were raised as conversation topics also.	19	431
Healthcare	Interactions with health care professionals were discussed, topics such as home visits, gender preference etc.	8	19
Hearing	The effect of hearing not performing and how it impacts re QOL, ageing, and relationships or using aids such as headsets or listening to TV.	11	43
Hearing Aids	A lot of topics around hearing aids discussed, cost, service systems, the marketing of them, as well as usability, wearability, layers of sound when talking with one or more persons. UX	13	282
Home	The experience and sent of home, within the context of ageing and how as we age topics such as downsizing and security can become more prominent. Also discussed was affectionate elements and our 'stuff' within the home. Stairs and Bungalows as well as comfort and having visitors.	10	76
Home Help	As we age our ability to have autonomy within our home can change and we sometimes need some help with running or managing out home, discussions were around private help, state funded help or not qualifying for it. In addition, the experience off not wanting the help but acknowledging it. The various tasks that can need assistance, i.e. vacuuming, shopping.	5	17

Category name	Description	Interviews Coded	Units of Meaning Coded
Hospital	Experiences from hospital, such as being an in-patient, or to be a 'good patient'. Sometimes embarrassment was mentioned as well as care and elements of staff and procedures, recovery and the worries experienced while being in hospital.	12	92
Independence	maintaining our independence and how tasks can challenge this sense of independence, i.e. dressing, shopping.	12	29
Internet	Internet experience and connectivity, also apps such as Skype and how they can connect you to family members distances away, varying service level and streaming, the how to experience, tasks such as streaming, downloading and email were topics raised also.	11	107
Interview	Storytelling value aspects of interactions and observations between myself and the participants.	10	32
Learning	The application of learning and aspects that derive pleasure of frustration. How one feels asking for support or help to assist learning and new knowledge, with reflective aspects of younger self and differences learning as an older adult that experience.	12	65
Learning Tech	various persons relied on when learning new technology, family, friends and the motivators that enhance learning the tech. Also discussed here is the sometimes stress relating to keeping up with technology.	8	23
Life	experiences of living and life, as well as the experience of living today as an older adult.	3	11
Life Stage	Stories expressed throughout the life stage, discussions around younger days, pregnancy, marriage, retirement bereavement as a spouse and aspects of planning and adaptation shared also.	12	84
Living Alone	Experiences shared of living alone as a regular way of life as well as the times when you may live alone temporarily, i.e. when partner is in hospital.	12	36
Mobile Phone	All participants had mobile phones, some choosing traditional push buttons or flip top types others had smart phones and conversations were based around some UX as well as interactions, learnability the necessity of them. Features such as sound were discussed with expressions of embarrassment for not hearing the call coming in.	17	115
Mobility Challenge	A prisons mobility dictates their interactions or not with day to day tasks, activities and interactions socially. Discussions were around the challenge's mobility can present to this.	19	99
Mobility Scooter	Perceived Usefulness of this mobility device were discussed, in addition to service option such as renting it, also the aesthetics and advancement of them, such as the capacity to be robotic.	6	17
Money	Money is a requirement to exist, likewise it raises levels of anxiety at times. Reflective discussions on budgeting, saving, spending and the phrase "cash is king' mentioned.	7	30

Category name	Description	Interviews Coded	Units of Meaning Coded
Nursing Home	A lot of discussions on nursing home was based around perceptions (none of the participants lived in one) in this context the conversations were also based on experiences with family members ad their experiences.	6	33
People	Interactions and observations shared by the participants of their interactions with other people between communities, gender etc. How people can influence and have perceptions true or untrue of others.	14	73
Personal	Personal aspects of autonomy and resilience and the coping strategies such as mindfulness when dealing with day to day life and experience.	6	13
Personal Alarm	Personal alarms were not always discussed positively in relation to regular or accepted use. Wearing one or using one and the stigma of same regarding ageing/vulnerability were topics.	7	76
Physical Ability	Day to day activities and physical ability discussions around limitations and self-awareness.	4	8
Physical Decline	the awareness of our decline physically was discussed in relation to self and ageing, reference to Stephen Hawking and his overcoming challenge was discussed during one meeting also.	11	20
Plugs and problems	experience with plugs inserting and removal.	1	1
Products & Technology	Use of products and technology, batteries/charging discussed, as well as repurposing and emotional relationship to same.	1	15
Prosthesis	perceptions, abandonment and use of prosthesis discussed…	4	12
Public Transport	The use and experience of public transport, as well as critical conversation on availability and service options, taxis, buses etc.	10	23
QOL	How our Quality of Life can be influenced and enjoyed or not by topics such as health, accessibility, technology. In addition, mobility challenge limitations and assistance are discussed.	13	106
RADs	RADs were discussed at each session, with fear, reluctance and trust topics of conversation. In addition, the perception of robots as prosthesis or neural path interveners, and some admitting to not knowing what a RAD would be like. Cost is a concern for others. benefits such as mobility enhancement were seen to be valuable.	19	167
Robotic trousers	Lower limb exoskeleton was a term not used during conversations settling more for robotic trousers based on literature reviewing and initial questionnaire discussions with older adult groups. Perceived usefulness and stigma were discussed, as well as perceptions and enhancement/quality of life.	8	126
Robots	Acceptance and assistance with robots in our world as we age, in addition how we expect or perceive communications and commands of robots regarding day to day tasks, ADLs etc.	18	265

Category name	Description	Interviews Coded	Units of Meaning Coded
Self	What makes me, 'me'? various aspects of character, beliefs concerns kept within and sometimes shared, including image, identity and spiritual self.	14	149
Self-Aware	Being self-aware and knowledgeable to express aspects of confidence, fears, technology etc.	14	38
Service Systems	Experience of that various service systems used to enhance experiences in airports, medical, phones etc. Difficulties expressed in relation to people to people, online options and technology discussed.	12	49
Shopping	Shopping was discussed with regards user-journey and experience in various areas such as: card/cash, preferences, quality, items such as footwear, and experience with sales/store assistance.	9	51
Sight	Vision and sight was discussed in the context of testing, deterioration, and the fear of sight loss.	13	45
Software	this was more usability focused conversations and the experiences people have in relation to using software, learning it and apps we interact with.	4	59
Spouse	Relationships were topical and in relation to spousal or partner relationships topics around the togetherness aspect, death, worries about and differences noted.	10	89
Stairlift	purchasing stair-lift and the interactions with installers as well as satisfaction once it has been fitted, I took a spin on a stair lift n participants homes and observed its closeness to the wall when going up on it, if my legs were much longer, it felt almost like a roller coaster rickety, as well as some aspects of learnability and docking it correctly to ensure the battery charges.	3	34
Stigma	experience of stigma was discussed sometimes not stated or recognised as such in relation to self, ageism, body, colour, societal, technology and conforming to others expectations.	18	168
Technology	Fear anxiety about technology and using it, some participants expressed no interest in learning or using it, others discussed how they use it and benefits to using it. Others expressing laziness to learning. Aspects of usability such as screen size, trust, support systems also discussed.	16	175
Telephone	Majority of these discussions related to landline telephones but merged into mobile phone use and usability aspects such as talking, using them as well as the hearing capacity being good or not so good at times. Some participants brought up topics of cost and completion of landline v mobile phone, perception of needing the landline to get the internet….	15	81
Texting	the application of using text and problems sometimes encountered were discussed, challenges learning and remembering how to send and receive texts were some of the topics discussed.	10	30

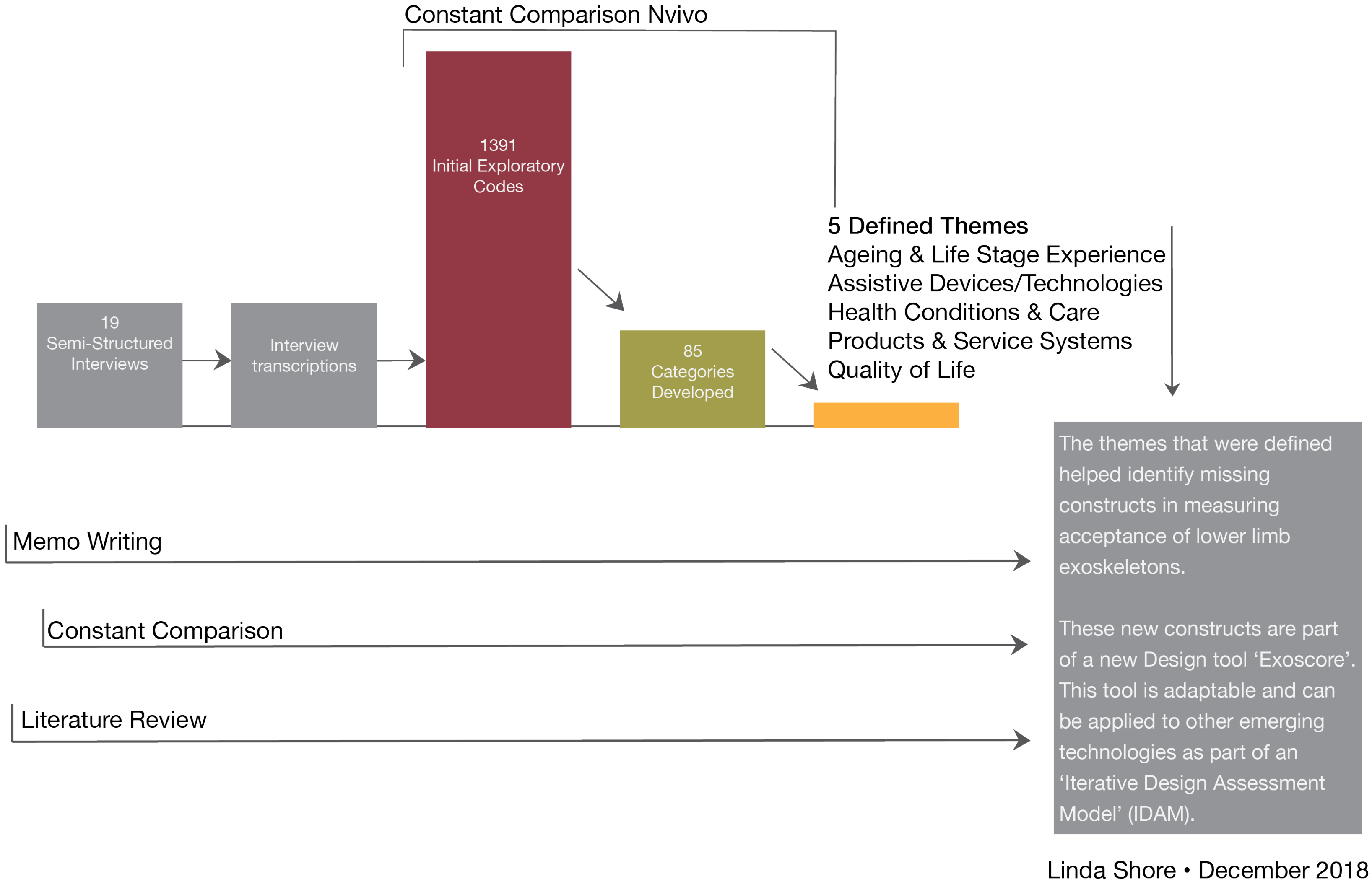
Category name	Description	Interviews Coded	Units of Meaning Coded
Travel	Planning to travel and challenges such as extra luggage re: health conditions, mobility etc, in addition experience of booking whether online or through a travel agent.	5	32
UX	Rich story shares captured in one category but relating to various aspects of ageing and day to day experiences with perceptions and use of products from hearing aids to robots, and services from doctor to travel agents.	12	124
Volunteering	Volunteering stories and requirements of same such as treasury roles or technology applications. Expressions such as "I keep myself busy" documented.	1	1
Lifestyle - Volunteer - Motivators		1	1
Walker or Rollator	using or observing the use and satisfaction or not of walkers and rollators by participant or someone close to them.	8	37
Walking	The activity of walking as we age discussed by the participants in relation to awareness of benefits to exercise but also the awareness of slowing down or ageing aspects such as wobbly feet referenced.	9	61
Walking Sticks	preferences and benefits of using a walking stick, discussions around having a 'favourite' one and the placement of various sticks around the home to assist mobility challenge. Discussed also by a participant the balance of walking stick v rollator, and another, walking stick v crutch.	7	32
Wheelchair	wheelchair ownership and use, sometimes they are 'passed on' from others as needed or borrowed. The experiences were shared mainly of participants who have helped people in wheelchairs, and their experiences including the weight of pushing an adult in a wheelchair and its manoeuvrability, other topics such as overweight, home adaptation and child users were discussed.	16	120
XXX TOTALS		19	8124

4.3 Full Study Codes \\ Phase 3 Themes

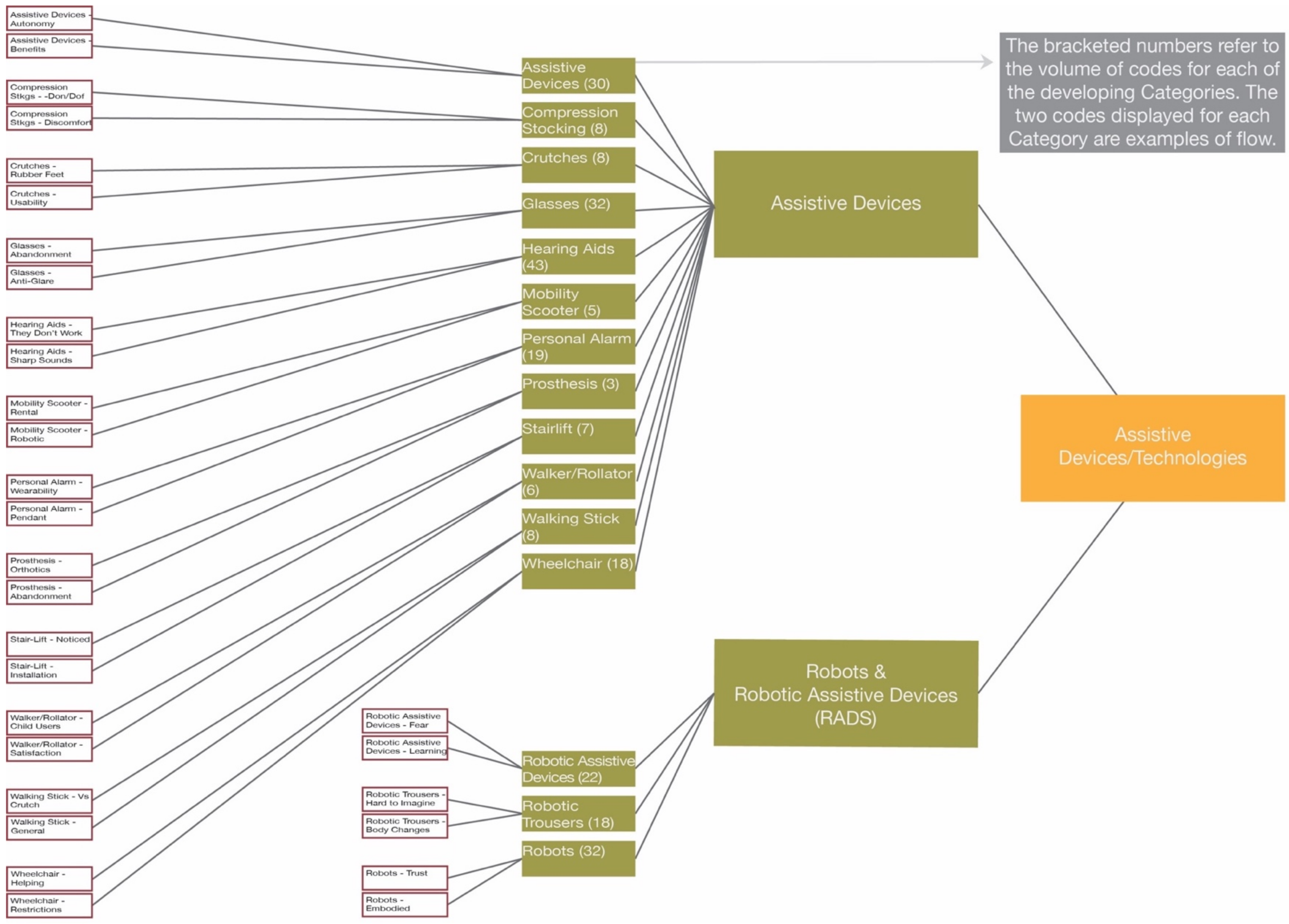
Theme Name	Theme Description	Interviews coded	Units of meaning coded
Ageing and Life stage experiences	How the ageing experience is shared by day to day interactions with others, ability and self-awareness.	19	2039
Assistive Technologies	Existing assistive devices such as wheelchairs, hearing aids are captured here as well as perceptions to the emerging technologies and robotic devices that could be part of the assistive technology assistance in the future.	19	1651
Health Conditions & Care	Many topics were discussed and how health conditions are experiences throughout life, in addition the management and monitoring of these as well as interactions and relationships such as family, health professionals.	19	760
Products & Service Systems	Various product and service system topics discussed and the benefits but likewise challenges of using such as mobile phones, plugs and technology.	19	1106
Quality of Life	How Quality of Life is impacted as a result of day to day activities or experiences, as per ADLs and interactions. Ageing impacts also on our ability to enjoy or have a QOL, physical decline one factor discussed here.	19	2652
***Sessions	General observations and UX stories captured throughout all the sessions.	13	156
XXX TOTALS		19	8364

***documented as reference touchpoints

4.4 Workflow Process to Grounding Theory



4.5 Example of flow from Codes to Categories to Themes



PhD Journey Reflection

Screw the Box

It sometimes feels like life is trying to fit you in box
School is putting you in a box
Your job is putting you in a box
Your insurance company is putting you in a box
Maybe you don't fit in the box
Maybe you don't want to be in this box at all
And, the only way out is a dark road
It's not an easy decision to take
It's not an easy road to walk
But, the feeling of being trapped in a box is just…

So, you enter into the dark
And, it turns out that the dark doesn't hurt
Your eyes adjust and you see
Where the road is leading
It often leads to a point, where you have to take a leap of faith
… or go back to the box
So, you jump
The faith bit is not so much in the leaping…
…it's in the landing
The space between them can feel forever…
But… when you land… and you will…
You learn that landing teaches you to fly

Stig Pryds – Freediver (2019)