Older Adults, Learning and Technology
An Exploration of Tangible Interaction and Multimodal Representation of Information

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Abstract: This paper explores concepts of tangible interaction and multimodal representation of information framed by the theories of universal design for learning (UDL) to enhance learning for older adults. Two participatory user panels were organised to explore the potential of assistive technology and tangible interaction to engage and support older learners. A creative co-design method using a rich user scenario with practical demonstration examples was used. Existing assistive technologies designed for users with visual impairments and a novel design prototype were presented to participants. This design prototype is based on the idea of linking physical fixed learning materials with digital multimodal representations. Feedback on the existing and new interactive tools are presented based on the reactions and ideas of 7 older adult students between the ages of 57 and 76. Participants were not familiar with examples of assistive technology such as screenreaders and magnification, but were interested in exploring new ways to have information represented through multiple modalities for learning.

1 INTRODUCTION

When asked what active ageing means to them, the majority of older adults tend to think in terms of physical health and activity (Bowling 2008; Stenner et al., 2011). The Active Ageing Policy Framework, states that "active ageing is the process of optimizing opportunities for health, participation and security in order to enhance quality of life as people age" (WHO, 2002). Importantly the word "active" has been further clarified by the WHO as referring to "continuing participation in social, economic, cultural, spiritual and civic affairs, not just the ability to be physically active or to participate in the labour force." (WHO, 2002).

There is considerable evidence to show that the various aspects of active ageing are intertwined and that it is important to take a holistic, interdisciplinary approach rather than looking at each aspect in isolation. For example a growing body of literature posits a connection between engagement in education as an adult and associated 'wider' benefits, including health (Schuller and Watson, 2009; Findsen and Formosa, 2011; Field, 2011). As a further recognition of the importance of education, the active ageing policy has recently been revised and enriched with additional pillar of lifelong learning (ILC, 2015).

This is reflected in the rapidly growing participation of older adults in formal and informal learning sectors. According to Cruce and Hillman (2012) higher education institutions have been slow to respond to these demographic changes due to the lack of empirical information regarding the educational preferences of older adults. Furthermore sensory, physical, cognitive impairments associated with the ageing process hinder initial involvement as current higher education learning infrastructures are designed for a younger student population.

1.1 Older Adults, Learning and Technology

Studies have illustrated that older adults generally have positive opinions and attitudes about trying and using new technology (Mitzner et al., 2010). But we must also acknowledge that sensory, physical and cognitive impairments associated with the ageing process can hinder older users' perceptions and experiences when interacting with technology (Zajicek, 2001; Fisk, 2009), especially if no attention has been paid to principles of inclusive

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design (Clarkson, 2003). Heart and Kalderon (2011) highlight that health status is a moderating factor for computer use and digital literacy. Therefore older adults with illness or disability, the cohort who are often the intended beneficiaries of digital technologies, are likely to have the most difficulty using them.

The rapid rate of technical change will always present challenges to new users of all ages. Once a user has learned a new technology, an even newer version often becomes available. Already the definition of digital literacy has evolved in terms of the tools and skills required. For example, technology classes for older adults that are based in a desktop learning environment may not be relevant or necessary for the tasks and end goals of older students. In order to learn to communicate, share files and participate online, it is no longer necessary to understand file structures, software and operating systems that still form a core component of many digital literacy classes. Alternative approaches to digital literacy using touchscreen tablets and mobile phones are arguably more accessible and relevant to older students (Doyle, 2011).

New innovations as part of the Internet of Things and tangible interaction, where interfaces are embedded into everyday objects, will again redefine what it means to be digitally literate. So when we think about older adult learners and technology we need to move beyond providing digital literacy skills alone. Rather we need to think about sustainable strategies where technology can enhance learning and participation. Without taking away from the value of digital literacy perhaps if we shift the focus to how technology can support learning we might end up with digital literacy as a by-product of learning another subject or skill. The flexible use of technology as proposed in Universal Design for Learning could be a more progressive way to consider learning and technology for older adults.

1.2 Universal Design for Learning

Universal Design for Learning (UDL) is a framework for understanding how to create curricula and resources that meet the needs of all learners from the start rather than retrofitting accessible solutions (Rose and Meyer, 2002). UDL is based upon the most widely replicated finding in educational research: learners are highly variable in the way that they perceive and comprehend information Rose and Strangman, 2007). For example, those with sensory disabilities (e.g., blindness or deafness); cognitive disabilities (e.g., dyslexia, dementia); language or cultural differences, require different ways of accessing content.

Universal design for Learning (UDL) proposes "Learning is most effective when it is multimodal - when material is presented in multiple forms. Students benefit from having multiple means of accessing and interacting with material and demonstrating their knowledge through evaluation." (Rose and Strangman, 2007).

(Rose and Meyer, 2002) highlight that the flexible features of digital media offer an ideal foundation for the UDL framework in comparison to traditional fixed materials such as printed textbooks. The ability to provide multiple forms of representation using technology and make information flexible hold great potential for the groups of adult learners that have taken part in this study. Furthermore Lee et al. (2009) investigated the potential beneficial effect of the presentation of multimodal (as opposed to unimodal) sensory feedback on older adults' performance on a touch screen device. Results of this study clearly show that both objective and subjective measures of older users' performance were enhanced by the presentation multimodal feedback.

1.2.1 UDL and Existing Accessibility Features

Accessibility tools such as Voiceover and Apple's built in screen magnifier Zoom have been designed to specifically support users with visual impairments. Such accessibility solutions could potentially give the flexibility to overcome many of the barriers faced by older adult learners due to sensory and cognitive issues experienced. However the potential of features such as screen readers and magnifiers with support older student's learning has not previously been explored.

The multiple forms of representation and expression proposed in universal design for learning can be implemented easily using tools such as Apple's Voiceover to present information visually through text and also through speech. Findings from interviews with older students revealed that most learners were unfamiliar with existing assistive technology even though the majority of participants reported mild to moderate vision impairments (Murphy, 2015). One of the aims of this present study was to introduce assistive technology to older students to explore their perceptions and reactions.

1.2.2 Tangible Interaction and Multimodal Notes Prototype

Older learners have developed strategies and relationships with fixed traditional materials such as printed books, handwritten notes and diagrams and can be reluctant to swap those strategies for new digital tools (Murphy, 2015). A significant number of participants in student interviews reported anxiety with regard to memory loss particularly in the context of formal learning and preparing for exams. Anxiety related to memory and learning is a significant issue as it affects confidence and stress levels which in turn can have a negative effect if any memory impairment is present (Peavy et al, 2009). While participants were positive about the benefits of technology as an information resource and method for organization, they also showed a striking preference for hand written notes during lectures and in preparation for exams. While learners of different ages also benefit from handwritten physical notes they display a higher and more integrated use of mobile devices and laptops for learning on and off campus (Chen, B., deNoyelles, 2013; Gikas and Grant, 2013).

There is great potential in the application of tangible user interface design to explore this design challenge. Recent advances in the design of tangible interface toolkits as part of the maker movement has made embedded computing more accessible. MaKey MaKey is a printed circuit board that can send key presses, mouse clicks, and mouse movements from every day physical objects to a computer (Silver et al., 2012) (see figure 1 and also figure 2, example of banana piano created with MaKey MaKey).

A design possibility with this tangible interaction toolkit is the potential to use physical drawings in lead pencil as a controller. Figure 1 illustrates an example of physical notes as a controller for a detailed interactive presentation with text and video and screen reader. The intention is to link both intelligent digital systems and familiar strategies and physical tools (such as handwritten notes) that older adults rely on for learning.

This multimodal notes design idea is intended to support memory by extending the use of handwritten notes by linking them with more detailed and flexible digital representations. In addition to providing multiple means of representation this use of multimodal tangible interaction for learning also extends to the UDL principle for multiple means of action and expression (National Center on Universal Design for Learning, 2012). This is particularly important for older adults who may have multiple sensory, physical or cognitive age related impairments.

Furthermore by creating familiar controllers through fixed learning materials (such as pen and paper) older learners might be more willing to use existing accessibility tools such as screen readers and magnifiers so that they can process the information through their preferred modality or multiple modalities. The intention is to link both intelligent digital systems and familiar strategies and physical tools (such as handwritten notes) that older adults currently rely on for learning.

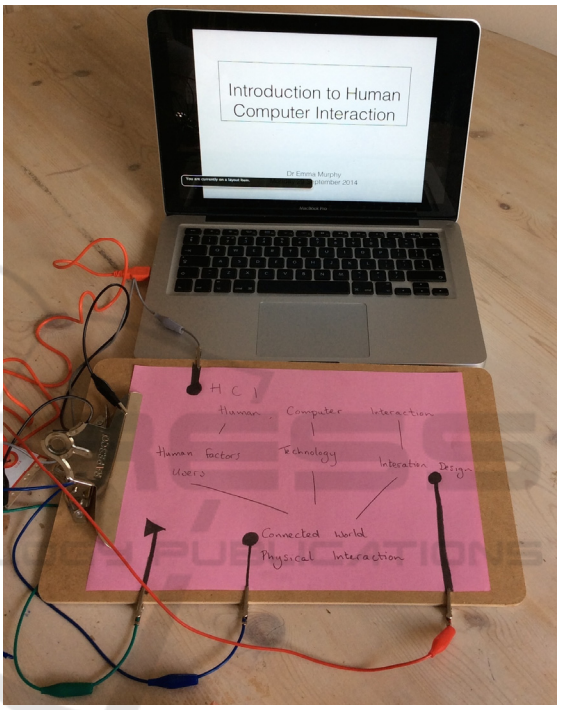

Figure 1: Multimodal Notes Design Prototype.

2 METHODS

2.1 User Panels with Older Students

User panels were organised based on the creative group work format presented in [8]. This method can be summarized as a participatory design method based around a rich use scenario. Lively characters are created at the centre of the scenario to engage users and the scenario is punctuated with interactive elements and demonstrations in the modality that is being designed. In this design method, the purpose of the use scenario is not to cover all possible usages of an application or technology or indeed all possible users. The purpose of the scenario is to

trigger creative design ideas and user reactions while maintaining the discussion on a certain context and user character. Gaps occur at appropriate points in the story, replacing user interface elements where user feedback is required (Pirhonen and Murphy, 2008). The incorporation of tangible interaction design examples built using MaKey MaKey enhances the creative element of this method. Furthermore Rogers et al. successfully demonstrated the benefits of using this toolkit with groups of older adult users as a catalyst for creative and inventive participatory design (Rogers et al., 2014).

2.2 Purpose of the Study

The aim of the user panels with older students was to explore the following areas:

1. To explore older students' reactions to existing accessibility technologies such as screen readers and magnifiers by demonstrating practical examples (Apple Voiceover and Zoom Magnification).
2. To explore participants' reactions to the potential to link fixed learning materials with digital media by presenting the Multimodal Notes Prototype.
3. To explore the next steps for the design of the multimodal notes prototype or other interfaces that use tangible interaction for learning.

2.3 User Panel Participants

7 older students took part in the user panels between the ages of 57 and 76 (AV= 68; SD= 6.7). Three students formed the first panel and four students participated in the second session. Students were asked to complete a short questionnaire to elicit details on age, gender, field of study and age related impairments in hearing, sight, manual dexterity, physical health and cognitive issues (results are presented in table 1).

Students were invited to participate in user panel sessions lasting approximately 90 minutes. Every attempt was made to create an informal relaxed setting to make participants comfortable. Participants were seated around a table and tea/coffee and refreshments were served. Each panel began with informal discussion, an introduction to the study and informed consent. As a warm up exercise and to explore the idea of multimodal interaction users tried out a banana piano made using MaKey Makey (as illustrated in Figure 2). This exercise also aimed to generate a fun creative atmosphere while also introducing the idea of and potential of tangible interaction.

A rich use scenario was created based on findings from interview data with 18 older students (Murphy, 2015). The scenario described a character, studying Philosophy at the age of 68 and had issues with her vision, mild hearing loss, and anxiety about her memory decline. During the scenario there were pauses to demonstrate and discuss technology

Table 1: User panel participant details.

Participant ID	Age	Gender	Type of Study	Self Reported Age Related Impairments
User Panel 1				
Participant 1	74	Female	Recently completed undergraduate degree (currently in informal learning course on campus)	Sight issues, glasses for reading, Mild Memory loss
Participant 2	76	Female	Informal learning on campus	Glasses for Reading
Participant 3	57	Male	1st Year Undergraduate	Mild memory loss
User Panel 2				
Participant 4	64	Female	Informal Learning on campus	Moderate sight issues, wears glasses all the time; hearing, tinnitus an issue in crowds
Participant 5	64	Female	Informal Learning on campus	No reported issues
Participant 6	63	Female	4th Year Undergraduate	Mild Memory Loss and Anxiety
Participant 7	70	Male	1st Year Undergraduate	Moderate hearing loss in one ear; glasses for reading; manual dexterity issues due to arthritis

Figure 2: Photo of music student trying out a "banana piano" created using MaKey MaKey.

examples. The final section of the scenario described the issues related to the relationships between fixed learning materials such as hand written notes and flashcards and the multimodal representations of digital content. The design example used MaKey MaKey to link notes to a multimodal presentation with screen reader and video was presented to the participants. For both sessions the discussion focused the content of the scenario and the older learner character, using open ended questions to focus the discussion.

The following is an extract from the scenario and highlights the way that the technology was demonstrated as part of the scenario:

Molly woke early to the sound of her alarm, today was the last day of lectures before the end of year exams. ……She had begun her Philosophy degree at the age of 68 and was now in her second year of fulltime study……Her eyesight was not what it once was but with her varifocal glasses she generally had no trouble walking around and reading print but screens indoors and outdoors could still be a problem. ….As she had been having trouble reading the notes on her laptop screen, her personal tutor had put her in touch with the technology department who had shown her how to use a screen reader [show example of a screen reader, pass around iPads for participants to try]. Molly was intrigued although she was not sure how she felt about turning on and off the screen reader it seemed complicated. …but she was also very attached to her methods of handwritten notes, translated slowly down to flashcards using shorthand, keywords and diagrams to trigger her memory for longer texts and explanations. What if there was some way of combining the wealth of information on her computer with speech and her familiar handwritten notes? [Demonstrate multimodal notes prototype]

The facilitator read the user scenario pausing at each technology or interaction example to demonstrate and ask participants to interact with the tools for themselves. After each example participants were asked for their feedback and initial reactions to the accessibility tools and multimodal prototype.

2.4 User Panel 1 Main Findings and Quotes

2.4.1 Feedback on Existing Accessibility Tools on the Apple iPad

When participants in the first user panel were shown the screen reader as part of the scenario, they were surprised that the technology existed and had not heard of it previously. The voice speed was set to 50 percent and all participants in the first panel immediately reacted to the speed saying it was too fast to understand. Participant 1 compared the screen reader to audiotapes of written texts which she used extensively when she was studying previously:

"I used them an awful lot…..you could walk the beach and pick up every word" P1

Participants acknowledged that the voice was not as natural as an audio tape but appreciated that it had "an Irish accent" and once it was slowed down felt that they would like to use it.

"*The voice is fine if you can slow it down*" P1
"*Yes I'd find if you are tired you could switch [the screen reader] on….reading is tiring, after reading maybe 100 pages you are just exhausted after it…that [screen reader] would definitely be of benefit to me]"*P3

Participant 3 was very positive about integrating the screen reader into his learning but he did raise one issue regarding language that using the screen reader you may listen more passively and be less likely to stop reading to look up a word or a concept that you were unsure of. However if you could control the screen reader to highlight a word and look it up this would not be an issue.

"*The only thing I would say [with] academic language ..sometimes there's words you'd never heard of and it would be great if you come across a word like that you could double tap…show me dictionary or something like that"* P3

Participants in the first user panel had a very positive reaction to the features on the iPad for low vision users. They particularly liked the Zoom feature that allows users to move a magnified window around the screen like a physical magnifying glass.

Participant 1 liked way method of navigation using the window to move around the screen:

"*This magnifying is brilliant…when you start to use the computer you are very awkward…with that you hold to it…and move right and left….I think for older people that would make all the difference*" P1

All three students felt it was difficult to figure out how to turn on and off accessibility settings. Although there are ways to create shortcuts to turn on and off accessibility features, all 3 participants agreed that they would like a voice command to turn the features on and off. Participant 2 felt that she would not explore the accessibility features in the settings section of the iPad.

"*What does accessibility say to you?....you wouldn't go into any of those buttons [settings menu] unless somebody said to you if you want to make it easier this is what you do*"P2

Participant 1 agreed that she would be hesitant to explore the accessibility functions on an iPad or other device:

"*If there was an "undo" button you might investigate it more…I think with all of these extras you would have to be computer literate to use all of them…you just have to tip a button and the screen changes completely. .and then you have to get it back to the way it was*" P1

2.4.2 Multimodal Notes Prototype

In their reaction to prototype multimodal notes demonstration, participants in the first user panel saw a benefit for this idea for revising for exams. They considered that having the physical controls as part of the written mind map would help to memorise larger amounts of information that you could listen or look at.

"*For older people I think it is great because really all you have is words when you go into an exam and you have to build around it*."P1

"I rely on mind maps..get your keywords down..some way of that interacting with that [computer]" P3

Participant 3 suggested that the combination of physical interaction and multimodal presentation of information might speed up the memory process.

"Rote learning…it still works..I just read it over 4 times…[the multimodal learning tool could be] a way of maybe speeding that process up.." P3

Participant 2 agreed that exploring the information using the mixture of physical presentation, sound and images could benefit your memory.

"You need an icon or a keyword to jog your memory.. bringing it up like this. reinforcing the keywords...even listening to it without having to look at it..is memorizing it for you rather than having to look at it…it's another way" P2

2.5 User Panel 2 Main Findings and Quotes

2.5.1 Feedback on Existing Accessibility Tools on the Apple iPad

Similar to the first user panel, participants were initially struck by the speed of the screen reader:

"*I don't think I could keep up with that…"*P7
*"She speaks very fast!....I don't even know what she is saying it's just garbage!"*P6

After slowing down the screen reader to 20 percent, participant 6 felt that it was not slow enough to understand the article.

"*I'd have to have it slower now….it's academia so the wording is very [important]"* P6

However when the screen reader was set to it's lowest level at 0 percent participant 6 did not like the quality of the voice at the lowest speed.

"She sounds so sad!. .no I'd have to get rid of that voice" P6

Participant 5 appreciated the fact that you could adjust the speed of the speech unlike an audio book.

"*That's very good that you can slow it down to whatever pace you like, that's a plus for it."* P5

For participant 7, the screen reader reminded him of the voice of the GPS system he used in his car and he considered that he would use a screen reader for learning in the same way as an option to not use the screen.

"*I like the sound. .I would compare it to the GPS that I have in the car.. I always like the voice on that means you don't have to look at it…that is what I am*

comparing [the screen reader] with….in the same way I could read the screen but the voice is helpful….It's [the screen reader] actually very good, I wasn't aware of that now" P7

All users agreed voice activation would be their preferred way to turn on and off the screen reader. There was full consensus in the second panel that the screen magnifier was a useful tool

"*They are wonderful [referring to low vision features]"* P6

2.5.2 Multimodal Notes Prototype

The section in the scenario that referred to the character's anxiety regarding memory triggered a lively discussion among participants in the second user panel confirming the relevance of memory and anxiety and how that can affect exam performance. Participant 7 spoke in detail about how he has used mind maps to overcome his memory and confidence issues for learning and revising for exams and he questioned the value of the prototype for exam preparation. He was concerned that having interactive digital material linked to the physical mind map could create a false sense of knowledge which would not be available in an exam.

"*Are you substituting technology for memory?"*P7

However participant 6 recognised the value of the multimodal presentation of information lined to the physical mind map:

"*You know the way there are different forms of learning like there is visual and that...so is that [design prototype] covering all forms of learning [for] your memory"* P6

Participant 5 also agreed that the multimodal presentation would help her to retain information.

In terms of developing this multimodal notes idea, participants questioned the process of organising the information and identified that this was an important missing element in the design of the tool. The group agreed that the information would have to be in a digital format to begin with which could be an issue for certain academic courses. But importantly the organisation of the multimodal material for learning or memorising had to be individualised to the student to suit their need, which would change according to content and circumstance. With regard to linking the digital content to the physical mind map, participants in the second panel considered this a useful idea.

Participant 7 had an interesting observation in that he considered this tool would be more useful for ongoing learning and continuous assessment rather than as a memory enhancing tool for an exam situation as proposed by the first panel. Rather than beginning with the mind map and using it to link to lengthier and interactive content he proposed that you could work the opposite way. In his idea you should begin with the interactive content and reduce it to the more sparse mind map and then use it as a memory tool. For participant 7 the usefulness of the tool would depend on the supporting application that could arrange the various interactive elements including the accessibility tools on the computer/digital device. Participant 6 agreed that this way of working could be beneficial to structuring though and ideas for academic essay writing and continuous learning and assessment.

3 DISCUSSION

In an attempt to create new interactions and designs for older students it is interesting that existing accessibility solutions (such as screen readers and magnifiers) are so underused by a group that could benefit from applications designed to support physical and sensory impairments. None of the participants in the users panels had ever tried a screen reader or magnifier or even heard of related assistive technology. While participants were very interested in trying out the screenreader, certain elements such as the rapid pace do not make it an inclusive tool for older adults. Furthermore the accessibility features on the iPad were considered "hidden" by the older students as they were not aware of them and considered the process of turning features on and off cumbersome. The option to have an obvious "undo" feature for any learning tool was valued by the group. The process of finding the screenreader and magnifier tools on the iPad were not considered straightforward by participants. Furthermore they did not relate to the word "Accessibility" which links to the suite of tools. These are important findings for the designers of assistive technology particularly when they are striving for universal access.

Participants were enthusiastic about the possibilities of using physical handwritten notes to control digital multimodal representations. There was interesting discussion in both panels as to how the prototype could be developed and whether it should be a tool to aid continuous learning or as a memory enhancing tool to help prepare for exams. Participants recognised the need and value of presenting information in different and sometimes

multiple modalities. They felt that this should be controlled by the learner according to their individual learning preference or impairment. From this feedback there is great potential to link existing accessibility features into an inclusive learning tool that focused on multiple representations and interactions with media and information. But also it highlights the relevance of Universal Design for Learning for older students and the importance of providing information through multiple modalities.

The rich use scenario successfully conveyed the wider context of use of how assistive technology tools and the new prototype idea might support a learner. Participants engaged and empathised with the character in the scenario through verbal and nonverbal agreement as the facilitator read the scenario. The section of the scenario regarding memory and learning were particularly relevant to participants' own learning experiences.

While participants tried out the physical controllers using MaKey MaKey they did not build their own controllers or interfaces. This would be interesting to have more of a workshop style to the next panel as proposed in (Rogers et al, 2014). The ideas and feedback generated by both user panels are extremely valuable for the design of the next iteration of the proposed learning tool. The next design panel will have more of a practical creative element to try to explore the area of tangible interaction in more detail.

4 CONCLUSIONS

This interdisciplinary research is an exploration of the potential of UDL and interaction design to create inclusive representations of information to support older adult learners. Previous interviews with older students revealed that learners have strong connections and strategies with traditional fixed learning materials but are also open to trying out new technologies. A prototype multimodal learning tool was created and presented to 2 panels of older students to elicit their feedback and creative ideas for the next iteration of the design. Feedback from the group has revealed that there is potential in linking physical learning strategies and materials to flexible digital representations of information and to existing accessibility solutions. The next stage of this design will continue to involve older students as co-designers to create a software tool and to explore more creative ideas in relation to tangible interaction and learning.

It is also hoped that as this research will highlight the potential of engaging older students with technology to support the wider context of their learning and enable them to overcome barriers due to age related sensory, physical or cognitive impairments. Rather than associating older adults, learning and technology with digital literacy skills alone, this approach focuses on novel ways to engage students in lifelong learning supported by creative and interactive technology.

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